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Comparison of a Functional Restoration Program With Active Individual Physical Therapy for Patients With Chronic Low Back Pain: A Randomized Controlled Trial

Ghislaine Roche, MD, Anne Ponthieux, PhD, Elsa Parot-Shinkel, MD, Nathalie Jousset, MD, Luc Bontoux, MD, Valérie Dubus, MD, Dominique Penneau-Fontbonne, MD, PhD, Yves Roquelaure, MD, PhD, Erick Legrand, MD, PhD, Denis Colin, MD, PhD, Isabelle Richard, MD, PhD, Serge Fanello, MD, PhD


Objective: To compare the short-term outcomes of active individual therapy (AIT) with those of a functional restoration program (FRP).

Design: Prospective randomized controlled study.

Setting: Two rehabilitation centers and private ambulatory physiotherapy facilities.

Participants: One hundred thirty-two adults with chronic low back pain. Fifty-one percent of patients on sick leave or out of work (mean duration, 180d in the 2y before treatment).

Interventions: For 5 weeks, FRP (at 25h/wk) or AIT (at 3h/wk).

Main Outcome Measures: Trunk flexibility, back flexor, and extensor endurance (Ito and Sorensen tests), general endurance, pain intensity, Dallas Pain Questionnaire (DPQ) scores, daily activities, anxiety depression, social interest, and work and leisure activities, and self-reported improvement (work ability, resumption of sport and leisure activities).

Results: All outcome measures improved after treatment except endurance in AIT. There was no between-group difference for pain intensity or DPQ daily activities or work and leisure activities scores. Better results were observed in FRP for all other outcome measures. There was a significant effect of treatment and the initial value for the gain of the Sorensen score with a treatment or initial value interaction; a significant effect of treatment and initial value on the gains of Ito, endurance, and DPQ social interest and anxiety depression scores, with no treatment or initial value interaction; and a significant effect of initial value but not treatment for the gains of DPQ daily activities and work and leisure activities scores.

Conclusions: Low-cost ambulatory AIT is effective. The main advantage of FRP is improved endurance. We speculate that this may be linked to better self-reported work ability and more frequent resumption of sports and leisure activities.

Key Words: Low back pain; Physical therapy modalities; Rehabilitation; Randomized clinical trial.

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CHRONIC LOW BACK PAIN (CLBP) is a major public health issue, representing high costs for the health care system. A recent study showed the average overall cost per patient in France to be 15,000 euros, the largest part being indirect costs because of sick-leave payments. In the last 30 years, the social and financial burdens of CLBP have led to the establishment of various multidisciplinary rehabilitation programs. “Back schools” have been developed since the 1970s, offering a combination of patient information and postural training. Patients participated in information sessions focused on basic anatomy and physiology and were trained in various lifting techniques. In the late 1980s, the concept of physical deconditioning was introduced, which led to the development of functional restoration programs. Deconditioning, which denotes a physical and psychologic state induced by inactivity because of low back pain (LBP), is characterized by a loss of spinal mobility, reduction of muscle strength and cardiovascular fitness, frequent anxiety and depression, social isolation, and absence from work. Multidisciplinary functional restoration programs have included intensive training to increase flexibility, force, and endurance as well as psychologic counseling and occupational therapy. In the mid-1990s, attention shifted toward the interactions between the LBP patient and the environment, leading to the development of intervention programs involving the patient’s employer and medical care providers. Such programs have usually included ergonomic intervention and have often been embedded in public health care policies. Although the design of LBP programs has varied over time and across different countries, there is an international consensus regarding the value of active exercise and the idea that the programs should also include formal and informal activities aimed at improving coping strategies (eg, psychologic counseling, group effect, interaction with the work environment).

Most studies consider the main outcome to be return to work and/or the number of days of sick leave taken. This is relevant because sick leave accounts for the main costs. Using this outcome measure, many studies have shown the
effectiveness of LBP programs with a reduction in days of sick leave occurring in the year after the program. Thus, the effectiveness of specific interventions has been quite clearly established in comparison to nonintervention although long-term results are often not studied. These programs have now been implemented in most developed countries. The next step has been the comparison of different programs to improve both the outcome and cost-effectiveness of treatments. Greater cost-effectiveness allows the treatment of a greater number of LBP patients with a given quantity of resources. Various studies have, therefore, compared intensive rehabilitation-based programs, which are mainly derived from functional restoration programs, with less intensive ambulatory-based programs, ranging from programs including 2 or 3 supervised sessions per week,12,22-25 to ones that are exclusively home based.26,27 In a previously reported trial,28 we compared the number of days of sick leave in the year after participation in an intensive program with those after active ambulatory therapy. This study showed that there was a significant reduction in sick leave after ambulatory therapy but a significantly greater reduction after the intensive program, leading to the conclusion that “more intensive” and “more expensive” is better on an individual level, but this is not necessarily feasible for application to a large population. Similar conclusions have also been reached by others.12,13 The results thus far available have not made possible the development of criteria that could help determine which treatment should be applied to which patient to maximize the effectiveness of available resources. They also do not reveal which component of each treatment is essential. The optimal amount of physical reconditioning, psychological counseling, and ergonomic intervention and the specific effects of individual versus group therapy all remain to be established. It, therefore, appears necessary to open the black box of multidisciplinary programs, focusing on selected elementary outcomes such as trunk extensor strength, endurance, and psychological status, and to try to understand which components of treatment influence which outcomes and how the latter are related to the pretreatment status of the patient. Obtaining such data is a necessary preliminary step before directing patients to an array of programs, ranging from less intensive ambulatory-based programs to specialized hospital-based ones.

Therefore, the aim of the present study is to compare the gains in terms of selected physical and psychologic outcomes obtained from 2 LBP programs that differ in the intensity of the physical training and the psychological counseling procedures used. The cross relations between the treatment effect and the initial status of the patient are also analyzed.

METHODS

Population

All patients with CLBP aged 18 to 50 years referred consecutively to a multidisciplinary LBP clinic in a level 1 hospital were eligible for inclusion. A physical medicine and rehabilitation specialist, an occupational medicine specialist, a psychiatrist, and an ergonomist evaluated each patient independently. Each patient underwent a standardized medical examination.

The inclusion criteria were patients aged 18 to 50 years (referred to the multidisciplinary clinic between January 2000 and April 2003) with LBP for at least 3 months and patients on sick leave or at risk of work disability and not in temporary employment. The exclusion criteria were patients with malignant, traumatic, infectious, or inflammatory LBP; patients with acute LBP or sciatica, spondylolisthesis, or cardiac or respiratory insufficiency (diagnosed after exercise stress test on bicycle ergometer); patients with articular or neurologic impair-

ment incompatible with a physical exercise program; patients with psychiatric disorders precluding participation in group therapy; and patients receiving disability pensions or refusing to participate in the study.

This study was approved by the local ethics committee, and written informed consent was obtained from each patient. After inclusion in the study, the patients were randomized into 2 groups and allocated to the active individual therapy program (AIT) or the functional restoration program (FRP). Block randomization was undertaken with an 8-element permutation table established by an independent methodologist.

Treatment

The treatment content of each program was different. The FRP lasted 5 weeks and included 6 hours of treatment a day, 5 days a week in groups of 6 to 8 patients. It was undertaken identically in 2 rehabilitation centers. The AIT lasted 5 weeks and included individual rehabilitation with a private practice physiotherapist for 1 hour 3 times a week and individual exercises to be performed at home for 50 minutes twice a week.

Functional restoration program. The group performed exercises supervised by a physiotherapist who adjusted the exercise intensity to each participant every week. During the first week, patients learned muscular warm-up and stretching techniques, improved their flexibility, and performed cardiopulmonary exercises. During the second week, patients began muscular-strengthening exercises. During the third week, muscular strengthening increased with endurance exercises. Patients performed weightlifting as well as proprioception and coordination exercises. In the fourth and fifth weeks, the intensity of strengthening exercises increased progressively. The endurance training was adapted to each patient’s heart rate and to the exercise stress test performed before the program. Patients performed work simulations during occupational therapy sessions.

Strengthening exercises were performed exclusively with isotonic techniques. Proprioception was developed with static and dynamic destabilization exercises. Walking, running, and cycling developed cardiorespiratory endurance.

Each week patients attended a clinic with the specialist in physical medicine and rehabilitation who was the medical supervisor of the program. They were referred to the psychologist at least once in the first week and for further treatment if requested. Dietary advice was given. The schedule of interventions was standardized for all patients (appendix 1).

Active individual therapy. Each individual session lasted 1 hour and included only active exercises supervised directly by the physiotherapist. All physiotherapists participated in an information session and agreed to apply the program as described. During the first 2 weeks, the program included flexibility training and pain management, stretching, and proprioception exercises. Patients continued these exercises during the third and fourth weeks and started muscular strengthening. The last week focused on functional exercises and endurance training. The program included 50 minutes of individual home exercises 2 days a week (these could include stretching, jogging, and swimming). This part of the program was agreed on by the patient and physiotherapist and depended on the facilities available. It was not standardized. All exercises were isotonic, and no specific equipment was required or provided. At the beginning of the program, patients signed an agreement to follow the prescribed exercises. Patients had to record the duration, type, and number of exercises performed at home.

In both groups, patients were off work during the 5 weeks of treatment. At the beginning (t0) and the end of the treatment (t5), they were assessed in the rehabilitation center by
The table 1: Patients’ Initial Characteristics (t0) (N=132)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>AIT (n=64)</th>
<th>FRP (n=68)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>37.8±6.1</td>
<td>40.8±7.4</td>
<td>NS</td>
</tr>
<tr>
<td>Sex (% men)</td>
<td>62.5</td>
<td>67.65</td>
<td>NS</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>26.2±4.8</td>
<td>25.9±4.0</td>
<td>NS</td>
</tr>
<tr>
<td>Previous depression (%)</td>
<td>17.2</td>
<td>23.5</td>
<td>NS</td>
</tr>
<tr>
<td>LBP associated with work accident or occupational disease (%)</td>
<td>46.9</td>
<td>41.2</td>
<td>NS</td>
</tr>
<tr>
<td>History of spinal surgery (%)</td>
<td>18.8</td>
<td>33.8</td>
<td>.050</td>
</tr>
<tr>
<td>FTF distance (cm)</td>
<td>13.8±12.7</td>
<td>12.6±9.3</td>
<td>NS</td>
</tr>
<tr>
<td>Sorensen test (s)</td>
<td>84.8±53.5</td>
<td>97.7±50.7</td>
<td>NS</td>
</tr>
<tr>
<td>Ito test (s)</td>
<td>65.6±47.8</td>
<td>78.3±50.3</td>
<td>NS</td>
</tr>
<tr>
<td>Endurance (kJ)</td>
<td>57.5±34.2</td>
<td>62.9±37.3</td>
<td>NS</td>
</tr>
<tr>
<td>VAS (cm)</td>
<td>4.5±2.1</td>
<td>4.7±2.1</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ daily activities (%)</td>
<td>51.0</td>
<td>51.8</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ work and leisure (%)</td>
<td>58.0</td>
<td>51.9</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ anxiety and depression (%)</td>
<td>30.9</td>
<td>36.9</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ social comportment (%)</td>
<td>27.4</td>
<td>30.7</td>
<td>NS</td>
</tr>
</tbody>
</table>

Work before treatment: NS

Full time (%)                              37.5  44.1  NS
Part time (%)                             11.0  13.2  NS
On sick leave (%)                         51.6  42.7  NS

NOTE. Values are mean ± standard deviation or percent.
Abbreviation: NS, not significant.
*Comparison between AIT and FRP using the t test or chi-square test.

physiatrists, and the questionnaires were completed. The physical evaluations were performed by physiatrists. The cross-evaluation was performed by private-practice physiatrists for the FRP patients and by physiatrists of the rehabilitation centers for the AIT patients. One training session was provided to reduce evaluator-dependent bias.

Evaluation Criteria

Trunk flexibility was assessed by the fingertip-to-floor (FTF) distance, measured in centimeters.29 Trunk muscle endurance was assessed by the Sorensen test (time of isometric contraction of extensor muscles measured in seconds)30 and the Ito test (time of isometric contraction of flexors muscles also measured in seconds).31 General endurance (in kilojoules) was measured during a cyclo-ergometer test, limited to 85% of maximum cardiac frequency measured during a previous stress test.

The severity of LBP was scored on a 10-cm visual analog scale (VAS), where 0 indicates no pain and 10 the worst possible pain.32,33 The Dallas Pain Questionnaire (DPQ)34,35 was used to assess the impact of pain on quality of life (QOL) and included 4 items scored from 0% to 100%: daily activities, work and leisure activities, anxiety and depression, and social interest.

All items were evaluated at the beginning (t0) and at the end (t5) of treatment. Patients were also asked at the end of treatment whether they believed their physical fitness had improved, whether they had resumed sports activities, and whether they felt able to work.

Statistical Analysis

The statistical analysis was performed with SPSS software.a The t and chi-square tests were performed to test differences between the AIT and FRP groups in terms of the patients’ initial characteristics. The evolution of FTF distance, Sorensen score, Ito score, endurance, VAS, and DPQ scores between t0 and t5 were examined by using a paired t test and the McNemar test.

Changes in Ito, Sorensen, endurance, and the 4 DPQ scores between t0 and t5 were assessed by using analysis of covariance (ANCOVA), with a main-effects model that included their respective values at t0 (t0 Sorensen) as a covariate and treatment effects (AIT or FRP).

The level of significance was defined as .05.

RESULTS

One hundred thirty-two patients (86 men, 46 women) were included. The mean age was 39.8 years (range, 24–50y). Sixty-eight patients were randomized in the FRP group and 64 in the AIT group.

Pretreatment Characteristics

There was no significant difference between the 2 groups (table 1) with regard to sex, age, history of depression, and LBP associated with work accidents. More subjects had undergone surgery in the FRP group.

There was no significant difference across groups regarding days of sick leave in the 2 years before treatment (180±135.1d in AIT vs 185±149.8d in FRP, P=.847). Fifty-one percent of the patients were on sick leave before treatment.

There was no significant difference between the groups in terms of body mass index, physical measures, and QOL scores.

Evolution After Treatment

Some patients did not perform all the tests at t5; 1 patient did not perform the endurance test because of a right tibial fracture. Six patients could not perform the endurance test because of breakdown of the bicycle ergometer. Patients’ flowcharts throughout the study are summarized in figure 1.

Results in the AIT group were higher at t5 than at t0 for each physical test except the endurance test (P = .360). Pain severity on VAS and every score of the DPQ except for the social interest score (P = .068) were significantly lower at t5 than at t0.

In the FRP group, measures were significantly higher at t5 than at t0 for every physical measure and lower for every score of the DPQ. The differences between t0 and t5 were significantly greater in the FRP group than in the AIT group for physical tests and the DPQ anxiety and depression and social interest scores.

Fig 1. Patients’ flowchart through the study.
scores (table 2). There was no significant difference between the 2 treatment groups for the other scores of the DPQ.

The majority of patients considered their physical fitness to be improved in both groups. More patients in the FRP group were taking part in sports or leisure activities ($P<.001$) or felt that they were able to return to work ($P=.003$) at the end of treatment (table 3).

Interaction Among Improvement, Initial Status, and Treatment

The change in Sorensen test score between t0 and t5 correlated significantly with the t0 Sorensen score (ANCOVA, $P<.001$) and treatment (ANCOVA, $P<.001$). The interaction term between the t0 Sorensen score and treatment was also significant (ANCOVA, $P=.001$). There was greater improvement in Sorensen score for patients with lower t0 Sorensen scores and in the FRP group (fig 2A).

Changes between t0 and t5 for Ito and endurance measures and for the DPQ social interest and anxiety and depression scores correlated significantly with their respective values at t0 (ANCOVA, $P=.004$, $P=.017$, $P<.001$, $P<.001$, respectively) and with treatment (ANCOVA, $P<.001$, $P<.001$, $P=.003$, $P=.014$, respectively), but there were no significant interaction terms between their respective values at t0 and treatment. There was greater improvement in outcomes for patients with lower scores at t0 and with FRP (fig 2B).

Changes between t0 and t5 for the DPQ daily activities and work and leisure activities scores correlated significantly with their respective values at t0 (ANCOVA, $P<.001$, $P<.001$) but not with treatment. There was greater improvement in outcomes for patients with lower scores at t0 (fig 2C).

### Table 2: Evolution Between t0 and t5 (N=132)

<table>
<thead>
<tr>
<th>Test</th>
<th>AIT</th>
<th>FRP</th>
<th>$P^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTF distance (cm)</td>
<td>-11.9</td>
<td>-16.3</td>
<td></td>
</tr>
<tr>
<td>Sorensen test (s)</td>
<td>61.2</td>
<td>100.7</td>
<td></td>
</tr>
<tr>
<td>Ito test (s)</td>
<td>71.2</td>
<td>121.3</td>
<td></td>
</tr>
<tr>
<td>Endurance (kJ)</td>
<td>4.2</td>
<td>32.5</td>
<td></td>
</tr>
<tr>
<td>VAS (cm)</td>
<td>-1.5</td>
<td>-1.9</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ daily activities (%)</td>
<td>-17.2</td>
<td>-21.5</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ work and leisure (%)</td>
<td>-19.8</td>
<td>-22.0</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ anxiety and depression (%)</td>
<td>-7.4</td>
<td>-17.6</td>
<td>NS</td>
</tr>
<tr>
<td>DPQ social interaction (%)</td>
<td>-4.1</td>
<td>-13.8</td>
<td>NS</td>
</tr>
</tbody>
</table>

$^*$Comparison between t0 and t5 using paired t test or McNemar test.

$^1$Comparison of difference t5−t0 between AIT and FRP using the t test or chi-square test.

$^P<.05$.

$^P<.01$.

$^P<.001$.

### Table 3: Qualitative Measures at t5 (n=132)

<table>
<thead>
<tr>
<th>Measures</th>
<th>AIT</th>
<th>FRP</th>
<th>$P^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased physical fitness (%)</td>
<td>90.6</td>
<td>97.0</td>
<td>NS</td>
</tr>
<tr>
<td>Resumption of sports and leisure (%)</td>
<td>65.6</td>
<td>94.1</td>
<td>$^*$</td>
</tr>
<tr>
<td>Ability to return to work (%)</td>
<td>78.1</td>
<td>95.5</td>
<td>$^*$</td>
</tr>
<tr>
<td>Return to work (%)</td>
<td>85.7</td>
<td>86.8</td>
<td>NS</td>
</tr>
<tr>
<td>Full time (%)</td>
<td>74.5</td>
<td>74.6</td>
<td>NS</td>
</tr>
<tr>
<td>Same work station (%)</td>
<td>75.5</td>
<td>80.0</td>
<td>NS</td>
</tr>
</tbody>
</table>

$^*$Comparison between AIT and FRP using the chi-square test.

$^1P<.01$.

$^2P<.001$.

### DISCUSSION

The study was a randomized prospective clinical trial with 2 parallel groups and compared an intensive functional restoration program with specific active individual rehabilitation with physiotherapists in private practice by using a protocol in accordance with the international guidelines for active therapy in CLBP. The samples were comparable before treatment in terms of age, sex, socioeconomic and physical characteristics, and QOL indices.

Pain relief was not the main objective in either program. The FRP and the AIT protocols both required the patients to “work through pain”; the main objective was to resume normal activity and return to work. Despite the considerable differences in the intensity of the programs, there was no difference in pain level between the 2 groups at t5. Pain intensity decreased in both groups. This result is comparable with previous results on FRP and on physical exercise that have shown that exercise reduces pain intensity. No subject elected to discontinue participating in the program.

The direct effectiveness of the treatments was assessed by clinical data, physical measures, and the functional and psychosocial consequences of LBP. A comparison of the results between t0 and t5 provided an evaluation of the patients’ improvement with each protocol. The between-group comparison of gains indicated whether one method was more effective than the other. Analysis of the interaction between initial values and treatments may help refer patients for programs.

Physical measures were significantly improved in both treatment groups except for endurance in the AIT group. The improvement was significantly greater in the FRP group for all physical measures except for pain level. The improvements in Sorensen, Ito, and endurance scores were influenced by the levels of these scores at t0 and the treatment; patients with lower scores at t0 showed greater improvement than patients with higher scores, and there was greater improvement with FRP than with AIT. These results suggest that patients with severe physical-deconditioning syndrome should be referred in programs including supervised endurance training.

The strength of trunk muscles has been considered to be a key item of physical deconditioning and muscular strengthening is often the main part of LBP programs. Several techniques and training protocols have been described. Many programs include isokinetic training or isoinertial techniques and the use of specific training machines. The main advantages of these techniques are to provide continuous...
feedback to patients on their performance level and to quantify their progress toward treatment goals. These elements play a role in patients’ tolerance of the exercises and may improve their motivation during treatment. The trunk muscle training in our AIT program was performed exclusively by isotonic techniques; private practice physiotherapists do not usually have isokinetic training machines because they are very expensive. A recent study comparing training on isokinetic devices with standard physiotherapy has shown similar results, and there is currently no evidence of the superiority of any given technique.

The active individual physiotherapy did increase the endurance of isometric back extension, but this gain was significantly lower than with FRP, especially for very weak patients. The decreased endurance of back extensors is thought to be a risk factor for CLBP. If this factor is crucial in the overall result, patients with weak trunk extensors at inclusion could be referred to an intensive program. For patients with higher initial trunk extensor endurance, the gain is lower, and the treatment effect favors the AIT program. This result could indicate that patients with higher scores do not require intensive physical training and can be referred to ambulatory-based programs. For these patients, greater attention to their psychologic status and work environment might be more relevant than intensive physical training.

Most LBP programs include flexibility exercises. In our study, FTF distance was significantly reduced by both treatments. The improvement in flexibility was significantly greater in the FRP, but, although statistically significant, the difference was not of clinical relevance. The aim of such programs is a return to average flexibility, and this result was achieved by performing stretching exercises 3 times a week, with a mean FTF in the AIT program of 1.9cm.

General endurance was improved only in the FRP group. One of the important differences between the 2 treatments was the direct supervision of aerobic exercises (jogging, badminton, swimming) in the FRP program, whereas the patients in the AIT program were only given advice that they should perform such exercise twice a week. This may be related to the higher proportion of patients in the FRP group having resumed leisure and sports activities. It may also have led to a difference in the evolution of the 2 groups, patients with less endurance possibly being more likely to discontinue physical activities after completing the program. This warrants further study, including long-term follow-up of endurance and performance of physical activities. General endurance, combined with trunk muscle endurance, could be used as a criterion for deciding between less and more intensive programs. Peer groups, such as those developed by patients with cardiovascular disease, could also lead to modified ambulatory programs, including supervised group aerobic activities.

Psychosocial status is a major component of LBP-related disability. Psychosocial risk factors can include fear (of pain, of work-related activities, of movement), distress (anxiety or depression), attitudes and beliefs, and relationship factors (eg, conflict or lack of support). The reduction of subjective feelings of disability and of general or emotional distress has been shown to be a key determinant in returning to work. DPQ scores improved with both programs in our study, despite the absence of any specific psychologic treatment in the AIT group. The treatment effect, regardless of the content of the treatment, is probably of major importance for these patients. The improvement in the AIT group could also be explained by the informal support provided by the physiotherapist through his relationship with the patient. Physical exercise has also been shown to have a direct effect on depression.

The improvement in the DPQ daily activities and work and leisure activities scores was significantly higher in the FRP. This was probably related to the higher self-reported ability to resume work and leisure activities in this group. This could be a further argument for the referral of patients with low DPQ scores to intensive programs and/or for the introduction of peer groups in ambulatory programs.

Attitudes and fears toward physical and work activities are also of known importance in the resumption of both work and leisure activities. They can be evaluated by the
Fear-Avoidance Beliefs Questionnaire, and further studies are required to evaluate the treatment effect of this parameter. These conclusions could help shape policies for application to larger populations. Low-cost ambulatory programs are probably sufficient for a high proportion of patients. These ambulatory programs could probably be improved by the participation of patients in peer groups providing psychologic support and motivation for aerobic training at a much lower cost than inclusion in hospital-based rehabilitation programs.

Study Limitations

Limitations of this study include the following. Compliance with both programs should have been assessed. The AIT home-exercise program was easy to follow. It required no specific equipment and was of a duration compatible with other daily activities (50 min). It was tailored to each patient and was agreed on by the physiotherapist who ensured that the patient was able to perform the exercises correctly. We tried to increase motivation and involvement in the program by asking the patient to sign a written agreement and report the actual duration and type of exercises performed.

CONCLUSIONS

Low-cost ambulatory AIT is effective. The main advantage of FRP is improved endurance. We speculate that this may be linked to better self-reported work ability and more frequent resumption of sports and leisure activities.

APPENDIX 1: SCHEDULE OF INTERVENTIONS IN THE FRP

Group interventions (6 to 8 patients):
9:00 AM to 10:00 AM: Warm-up, stretching, and proprioception exercises: walking, running, stretching of trunk and limbs muscles, balance exercises (for dynamic destabilization exercises), and various games.
10:15 AM to 11:15 AM: Strengthening exercises (isotonic training of all major muscular groups).
11:30 AM to 12:30 PM: Aerobic activities (jogging, ball games).
Lunch.
1:30 PM to 2:00 PM: Warm-up, stretching, and proprioception exercises.
2:00 PM to 3:15 PM: Occupational therapy (training in flexibility, endurance and coordination exercises, weight lifting, and work simulation).
3:30 PM to 4:15 PM: Global strengthening exercises and endurance training (jogging, stepping, and cycling exercises).
4:30 PM to 5:00 PM: Balneotherapy (for muscular recovery and proprioception exercises).

Individual interventions: meetings with the physiatrist, the psychologist, and the dietician.

References

24. Mannion AF, Muntener M, Taimela S, Dvorak J. Comparison of three active therapies for chronic low back pain: results of a

Supplier
a. Version 12.0; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

Objective: To examine the effectiveness of a dual-task-based exercise program on walking ability in subjects with chronic stroke.

Design: Single-blind randomized controlled trial.

Setting: General community.

Participants: Twenty-five subjects with chronic stroke who were at least limited community ambulatory subjects (a minimum gait velocity, 58cm/s).

Interventions: Participants were randomized into a control group (n=12) or experimental group (n=13). Subjects in the control group did not receive any rehabilitation training. Subjects in the experimental group underwent a 4-week ball exercise program.

Main Outcome Measures: Gait performance was measured under single task (preferred walking) and tray-carrying task. Gait parameters of interest were walking speed, cadence, stride time, stride length, and temporal symmetry index.

Results: The experimental group showed significant improvement in all selected gait measures except for temporal symmetry index under both task conditions. In the control group, there were no significant changes over the 4-week period for all selected measures. There was a significant difference between groups for all selected gait variables except for temporal symmetry index under both task conditions.

Conclusions: The dual-task-based exercise program is feasible and beneficial for improving walking ability in subjects with chronic stroke.

Key Words: Cerebrovascular accident; Exercise; Rehabilitation; Walking.
understand instructions and follow commands. The exclusion criteria were (1) patient with any comorbidity or disability other than stroke that would preclude gait training, (2) any uncontrolled health condition for which exercise is contraindicated, and (3) any neurologic or orthopedic diseases that might interfere with the study.

Study Protocol

The study protocol was reviewed and approved by the institutional review board. Before data collection, the purposes and procedures were fully explained, and informed consent was obtained from each participant. Thirty-four subjects were identified as potential participants for this study. Seven were excluded because they failed to meet the inclusion criteria (fig 1). Two people did not sign an informed consent form. Twenty-five subjects signed an informed consent form before participating in the study. Participants were randomized to the control group or experimental group by an independent person who picked 1 of the sealed envelopes 30 minutes before the start of the intervention. All subjects were evaluated before the commencement of training (pretraining) and at the end of the 4-week training period (posttraining). Each subject was evaluated individually and tested following a standard protocol. Subjects were tested under the control single-task condition and under the dual-task condition. The 12 subjects in the control group did not receive any rehabilitation training. The remaining 13 subjects in the experimental group received ball exercise training.

Measurements

Subjects were evaluated by a physical therapist who was not involved in the training program and did not know about the subject’s group assignment. For each subject, the gait performance was measured in 2 conditions: (1) preferred walking (single task) and (2) walking carrying a tray with glasses (tray-carrying task). The instructions for each test condition were as follows: (1) “Walk with your comfortable speed right to the end of the walkway” and (2) “Walk with your comfortable speed right to the end of the walkway carrying this tray and glasses in front of you with both hands.” For the tray-carrying task, subjects have to keep the empty glasses (height, 15cm; base diameter, 6cm) on the tray without any dropping otherwise the trial would be considered as failed. The trial order was randomized to compensate for the effects of practice and fatigue. To obtain representative samples, each test condition was repeated 3 times successfully, and the mean of the 3 successful trials was used for further data analysis.

Gait was measured by using GAITRite, an instrumented walkway. The GAITRite system provided temporal (time) and spatial (distance) gait parameters via an electronic walkway connected to the serial port of a personal computer. The standard GAITRite walkway contained 6 sensor pads encapsulated in a roll-up carpet with an active area of 3.66m long and 0.61m wide. The validity and reliability of the GAITRite system has been well established. Subjects were asked to walk at their comfortable speed without an assistive device through a 10-m hallway. The GAITRite walkway was placed in the middle of the 10-m hallway to eliminate the effect of initiating or stopping walking.

The temporospatial parameters recorded were as follows: speed (in cm/s), cadence (in steps/min), stride time (in seconds), stride length (in centimeters), affected single-limb support (percentage of gait cycle), and unaffected single-limb support (percentage of gait cycle). Single-limb support was used only to calculate the temporal symmetry index. The temporal symmetry index was calculated by using the following formula:

unaffected single limb support (% of gait cycle)/affected single limb support (% of gait cycle). 18

Interventions

Subjects in the experimental group participated in 30 minutes of a ball exercise program 3 times a week for 4 weeks. The training program was based on a dual-task concept; subjects walked while manipulating either 1 or 2 balls. The balls used in this study were therapy balls with 45-, 55-, 85-, and 95-cm diameters and a basketball. The training program included (1) walking while holding 1 or 2 balls on both hands, (2) walking

Fig 1. Flow diagram of the study.

Fig 2. The starting position of kicking a basketball.
to match the rhythm of bouncing 1 ball with 1 hand or both hands, (3) walking while holding 1 ball on 1 hand and concurrently bouncing another ball with the other hand, (4) walking in time while kicking a basketball (the basketball was put into a net, and the net was held by the subject) (fig 2), (5) walking while holding 1 ball and concurrently kicking another basketball within a net, (6) walking while bouncing 1 ball and concurrently kicking another basketball within a net, and (7) walking while reciprocally bouncing 1 ball with both hands. Variable practice for the walking condition involved walking forward, walking backward, walking on a circular route, and walking on an S-shaped route. The subject was challenged with increasingly difficult tasks.

### Data Analysis

Information from all subjects was entered into a computerized database and analyzed by using the SPSS statistical package. Descriptive statistics were calculated for the clinical characteristics of each group. To compare the baseline demographic characteristics and the pretraining variables between groups, independent-samples t-tests were used for means and chi-square tests were used for frequencies. To elucidate the effect of training, the differences on all dependent variables between the pre- and posttraining phases within group were analyzed by 1-way multivariate analysis of variance (MANOVA). Difference scores were calculated for each subject by subtracting the pretraining data from the posttraining data. Mean difference scores and the standard deviation (SD) of these changes scores were calculated for each variable. MANOVA was used to determine differences of mean difference scores of each dependent variable between groups. A significance level of .05 was set for all analyses.

### RESULTS

Of the 25 subjects, 12 were randomly allocated to the control group, and the other 13 subjects were randomly allocated to the experimental group. Table 1 indicates the group means and SDs for age and stroke onset and the frequency counts for sex and hemiparetic side. There were no statistically significant differences between groups for age, stroke onset, sex, and hemiparetic side. Additionally, there were no significant differences between the experimental and control group in selected outcome measures before treatment. All subjects successfully completed the study protocol. In the experimental group, the attendance rate was 100% for the 4-week training program. All participants were able to perform the exercises as planned.

The gait performances under the single task and tray-carrying task are shown in table 2 and table 3, respectively. These results show that after the ball exercise training, significant improvement was found in all selected gait variables except for temporal symmetry index under both task conditions. On the contrary, improved gait performance was not shown in the control group. The between-group comparisons also revealed significant differences between the 2 groups for all selected gait variables except for temporal symmetry index under both task conditions.

### DISCUSSION

This is the first published randomized controlled clinical trial study to examine the effectiveness of dual-task–based exercise training on walking ability in subjects with chronic stroke. Our results showed that a 4-week ball exercise program improved walking ability under single- and dual-task conditions in a group of limited community ambulatory (gait velocity between 58 and 80 cm/s) and full community ambulatory subjects (minimum gait velocity, 80 cm/s) with chronic stroke. After the intervention, the walking speed was increased from 85.62 ± 19.85 to 115.35 ± 18.14 cm/s in subjects in the experimental group. It has been reported that a walking speed of 110 to 150 cm/s is considered to be fast enough to function as a pedestrian in most environmental and social contexts. Furthermore, community ambulation is the ability to integrate walking with other tasks in a complex environment. Dual-task gait assessment may prove helpful in identifying those who may have difficulty generalizing gait performance during testing to a complex environment. In the present study, the gait performance under the dual-task condition was also improved after intervention. Therefore, this ball exercise program may help improve community ambulation function.

#### Table 1: Baseline Demographic Characteristics of the Control and Experimental Groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control [n=12]</th>
<th>Experimental [n=13]</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>59.17 ± 11.98</td>
<td>59.46 ± 11.83</td>
<td>.95</td>
</tr>
<tr>
<td>Years poststroke</td>
<td>4.68 ± 7.40</td>
<td>4.08 ± 5.13</td>
<td>.79</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7 (58.33)</td>
<td>7 (53.85)</td>
<td>1.00</td>
</tr>
<tr>
<td>Female</td>
<td>5 (41.67)</td>
<td>6 (46.15)</td>
<td></td>
</tr>
<tr>
<td>Hemisphere side</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>6 (50.00)</td>
<td>10 (76.92)</td>
<td>.16</td>
</tr>
<tr>
<td>Left</td>
<td>6 (50.00)</td>
<td>3 (23.08)</td>
<td></td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD (range) or frequency (percentage).

#### Table 2: Comparison of Single-Task Measures Within Groups and Between Groups

<table>
<thead>
<tr>
<th>Measures</th>
<th>Control [n=12]</th>
<th>Experimental [n=13]</th>
<th>Change Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (cm/s)</td>
<td>92.42 ± 31.19</td>
<td>79.58 ± 15.75</td>
<td>-12.84 ± 21.61</td>
</tr>
<tr>
<td>Cadence (step/min)</td>
<td>104.12 ± 14.42</td>
<td>100.95 ± 8.47</td>
<td>-3.16 ± 10.07</td>
</tr>
<tr>
<td>Stride time (s)</td>
<td>1.21 ± 0.10</td>
<td>1.15 ± 0.14</td>
<td>-0.06 ± 0.08</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>102.07 ± 18.11</td>
<td>105.05 ± 22.53</td>
<td>2.97 ± 12.84</td>
</tr>
<tr>
<td>Temporal symmetry index</td>
<td>1.13 ± 0.18</td>
<td>1.14 ± 0.16</td>
<td>0.04 ± 0.08</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD.
Abbreviation: Post−Pre, posttest−pretest.
*Significance level for within-group comparison.
†Significance level for between-group comparison.
Previous studies have also shown exercise programs that resulted in improvements in the walking ability of stroke subjects who completed a rehabilitation program. Duncan et al. observed an average gain of 25 cm/s after an 8-week, home-based exercise program that was designed to improve strength, balance, and endurance in subjects at an average of 66 days poststroke. Dean et al. found that a 4-week training program on the performance of locomotor-related tasks led to an average gain of 12.6 cm/s in subjects at a mean of 2.3 years poststroke. Furthermore, Ada et al. introduced a concurrent cognitive task and designed a 4-week treadmill and overground walking program. They found that this 4-week treadmill and overground walking program was associated with an average gain of 18 cm/s in subjects with chronic stroke. A greater improvement in walking speed than those found in the previous studies was observed in the current study. An average gain of 29.74 cm/s after a 4-week ball exercise program was found in a group of limited community ambulatory and full community ambulatory subjects poststroke. Thus, the ball exercise program may be an effective exercise program in improving walking ability.

In the present study, we used a gait assessment under dual-task conditions to evaluate walking ability. Because many daily activities involve concurrent motor components, the assessment of dual-task performance may provide a better index of functional daily ability compared with assessment under single motor task conditions. Based on our previous results, the tray-carrying task would be a suitable assessment for subjects with chronic stroke. This assessment is a useful and discriminative tool especially for full community ambulatory subjects. In comparison with our previous results, the mean walking speed under a tray-carrying task after ball exercise training was similar to that of healthy subjects (103.67 cm/s). This finding also showed that the ball exercise program is an effective approach to improve walking ability.

A ball exercise regimen may seem useful in terms of promoting general fitness. The results of the present study showed significant improvement in walking ability after ball exercise. The reasons for the positive finding in this study remain unclear. However, the exercise we used in this study was a task-oriented program. Previous studies performed by using task-oriented intervention have shown significant improvement in locomotor function. In addition, 1 hypothesis is that coordinated muscle activity may be stimulated when working at a high level activity. Furthermore, ball exercise may provide relevant feedback. Subjects were able to achieve a new skill. The ball provides the subject with information from their surroundings, helping the subject to integrate motor tasks in a complex environment. Moreover, ball activities could be an interesting program and could promote patient participation.

As noted, the attendance rate was 100% in the present study for the 4-week exercise program.

It is important to note that community ambulation should include multiple domains. In the present study, walking speed and a dual-task paradigm were measured with respect to community ambulation. Current measures are composed of items that researchers consider to reflect community ambulation, such as walking speed or endurance, functional mobility scales, or self-reported levels of activity. It is important to also consider measures that reflect the broader dimensions of community ambulation.

### Study Limitations

There are several limitations in this study. First, the major limitation of this study was a lack of follow-up. We do not know whether the subjects in the experimental group were able to maintain these changes. However, ball exercise has the potential to encourage exercise habits on a long-term basis. Second, the sample size used in this trial was small, which implies that caution should be exercised when interpreting the results. Third, precaution must be taken in generalizing the results because our results are based on a selected group of participants suffering from chronic stroke with relatively high motor function. Finally, the study was limited to subjects who volunteered, and, therefore, they were a self-selected group of willing and highly motivated people.

### CONCLUSIONS

The results of this study showed that a 4-week ball exercise program was followed by an improvement in the walking ability of a selected group of limited community ambulatory and full community ambulatory subjects with chronic stroke. The high participation rate in the ball exercise program should be considered in developing community-type exercise programs.

### References


Suppliers
a. CIR Systems Inc, 60 Garlor Dr, Haverton, PA 19083.
b. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
The Effect of Hippotherapy on Spasticity and on Mental Well-Being of Persons With Spinal Cord Injury

Helga E. Lechner, MSc, PT, Tanja H. Kakebeeke, PhD, PT, Dörte Hegemann, PT, Michael Baumberger, MD


Objectives: To determine the effect of hippotherapy on spasticity and on mental well-being of persons with spinal cord injury (SCI), and to compare it with the effects of other interventions.

Design: Crossover trial with 4 conditions.

Setting: Swiss paraplegic center.

Participants: A volunteer sample of 12 people with spastic SCI (American Spinal Injury Association grade A or B).

Interventions: Hippotherapy, sitting astride a Bobath roll, and sitting on a stool with rocking seat. Each session lasted 25 minutes and was conducted twice weekly for 4 weeks; the control condition was spasticity measurement without intervention.

Main Outcome Measures: Clinical rating by a blinded examiner of movement-provoked muscle resistance, using the Ashworth Scale; self-rating of spasticity by subjects on a visual analog scale (VAS); and mental well-being evaluated with the self-rated well-being scale Befindlichkeits-Skala of von Zerssen. Assessments were performed immediately after intervention sessions (short-term effect); data from the assessments were analyzed 3 to 4 days after the sessions to calculate the long-term effect.

Results: By analyzing the clinically rated spasticity, only the effect of hippotherapy reached significance compared with the control condition (without intervention); median differences in the Ashworth scores’ sum before and after hippotherapy sessions ranged between −8.0 and +0.5. There was a significant difference between the spasticity-reducing effect of hippotherapy and the other 2 interventions in self-rated spasticity by VAS; median differences of the VAS before and after hippotherapy sessions ranged between −4.6 and +0.05cm. There were no long-term effects on spasticity. Immediate improvements in the subjects’ mental well-being were detected only after hippotherapy (P = 0.048).

Conclusions: Hippotherapy is more efficient than sitting astride position in hip flexion, abduction, and external rotation.

Key Words: Muscle spasticity; Physical therapy modalities; Physiotherapy; Rehabilitation; Spinal cord injuries.

SPASTICITY IS A COMMON sequela of spinal cord injury (SCI). Spasticity is a complex phenomenon that is associated with an upper motor neuron lesion and can be defined as a sensorimotor disorder resulting in an intermittent or continuous involuntary activation of muscles. Decq’s suggested subdivisions of the various components into (1) intrinsic tonic spasticity (eg, increased tone), (2) intrinsic phasic spasticity (eg, clonus), and (3) extrinsic spasticity (eg, flexor reflex). All 3 components can be beneficial or detrimental. On one side, symptoms of spasticity may be helpful with sitting balance or stability during transfers; on the other side, exaggerated spasticity can restrict the functional independence of persons with SCI.

Especially during the early stages of rehabilitation, when spasticity develops and patients are not familiar with it, high muscle tone and suddenly occurring spasms may interfere with the rehabilitation program (eg, training of transfers and dressing or practicing wheelchair skills). In this phase, however, spasticity is only developing and is highly fluctuating. Anti-spastic medication has potentially serious side effects and patients frequently complain of sleepiness, which might interfere with motivation during early rehabilitation. For this reason, many patients and clinicians are on the lookout for conservative measures such as muscle stretching, passive movements, or hydrotherapy to reduce symptoms of spasticity.

Debuse et al reported that many physiotherapists performing hippotherapy shared the opinion that no intervention was as effective in regulating muscle tone as hippotherapy. This therapy has been used for many years in several rehabilitation centers as part of the physiotherapy (PT) program for SCI subjects. Hippotherapy is a PT treatment strategy that uses the rhythmic equine movement to treat mainly persons with neurologic impairments. The horse, at a walking pace, is used as a facilitator, led by a horse master; a specially trained physiotherapist walks beside the horse and is in close contact with the patient. The patient does not actively influence the horse, but is passively influenced by the horse’s movement. Several studies have reported the positive impact of hippotherapy on muscle tone, posture, balance and pain, as well as its psychosomatic influence on patients. Other studies have documented the effect of hippotherapy on spasticity in children with cerebral palsy and in adults with multiple sclerosis. The literature about its effect on spasticity in persons with SCI is scarce, however.

To our knowledge, there has been only 1 study published in which the immediate spasticity reduction in patients with SCI was measured after hippotherapy. According to neurophysiologic standards, this spasticity reduction may be attributed to an inhibiting astride position in hip flexion, abduction, and external rota-
tion, as well as to rhythmic equine movements imposed on a patient’s pelvis and trunk. In the present study, we investigated whether either of these 2 most important elements of hippotherapy (an astride position and rhythmic movements) is as effective in reducing spasticity as hippotherapy. For this purpose, we compared the effects of the 2 following interventions with the effect of hippotherapy: (1) sitting astride a Bobath roll to gain a similar inhibiting position as on a horse’s back (2) sitting on a stool with rocking seat, which implies a rhythmic lateral tilting of the pelvis that provokes a lateral flexion of the trunk similar to when sitting on a walking horse.

A recent study in our laboratory found that passive cycling movements did not change the objectively measured spasticity, but did have a positive effect on the patients’ perceptions about whether their spasticity had changed. It therefore seemed important to assess the extent of a patient’s spasticity and any changes resulting from an intervention through a rating by a clinician (with the Ashworth Scale score), as well as a self-rating by the patient (by visual analog scale [VAS]). Numerous qualitative and quantitative methods have been proposed for measuring spasticity. Resistance to passive movements is 1 symptom of spasticity and can be rated by a clinician with the Ashworth Scale. This scale may provide a valid measure for increased tone but it is not the only available measure of spasticity. VASs have been used for self-assessments of the spasticity, and the importance of including self-reports in spasticity assessments has been emphasized. We aimed to detect short-term and long-term spasticity reduction. The effect on spasticity of the interventions was evaluated clinically by physiotherapists and by the subjects through self-reported VAS.

In addition to its effect on spasticity, hippotherapy may also influence a person’s mental well-being. Contact with a large animal has a profound effect on humans: for instance, a horse may help increase a patient’s confidence and self-esteem through its acceptance of him/her as a rider. To our knowledge, the psychologic effect has not been measured before. It was for this reason that our subjects completed the self-rated well-being scale, the Befindlichkeits-Skala (Bf-S) of von Zerssen. This is a well-known measure in German- and French-speaking countries; its reliability and validity has been evaluated in these 2 languages. It is specific (adjectives on mood states, essentially), current and therefore sensitive (lack of adjectives on the habitual state, on personality traits), and easy to administer and analyze.

The Bf-S evaluates the extent of impairment of the subjective mental well-being. Because of its 2 parallel forms it is applicable for repeated measures to detect changes in mental well-being caused by interventions. It was used in several studies to determine mental well-being of psychiatric patients as well as mentally healthy persons.

Spasticity in persons with SCI has the potential to negatively influence quality of life, to disturb sleep, to impede the rehabilitation efforts of the patient, and may even contribute to a negative self-image. There is evidence that there is a greater prevalence of anxiety and depression in people with SCI than in people in the general population. Moreover, depressive symptoms and impaired subjective mental well-being have been associated both with fewer functional improvements in SCI rehabilitation and with limitations in participation and motivation.

We hypothesized that hippotherapy is a potential intervention with which to improve the mental well-being of persons with SCI.

METHODS

Participants

A volunteer sample of 12 people with motor-complete traumatic SCI (American Spinal Injury Association [ASIA] grade A or B) was recruited to participate in the study. They all met the following inclusion criteria: (1) more than 1 year after onset of SCI, (2) spasticity in the lower extremities (the minimal score defined for the inclusion criteria was that at least 1 of 10 muscle groups had to be scored with 2 on the Ashworth Scale and the Ashworth scores’ sum had to be equal to or greater than 6 in 4 consecutive weekly measurements), (3) sufficient range of motion (ROM) to sit astride a horse and on a Bobath roll, (4) no skin problems or wounds, and (5) no horseback riding (therapeutic or recreational) during the 6 months before the study. All subjects gave their informed consent to participate.

Interventions

Each intervention session was 25 minutes in duration and was performed twice weekly for 4 weeks. In clinical practice, a hippotherapy session lasts 30 minutes. We set the treatment time for all interventions at 25 minutes to provide time for transfers and to ensure that all 3 interventions would be of the same duration.

Intervention H. Intervention H was a hippotherapy treatment, performed according to the concept of Hippotherapy-K (HTK). The therapy horse (Icelandic breed) was led by a trained horse master at walking pace while the subject sat astride the horse on a sheepskin without saddle or stirrups. The subject did not actively influence the horse, but was moved passively by its movement. A physiotherapist with special training in HTK walked beside the horse, controlling and repositioning the subject if necessary. Intervention H was conducted outdoors on a 270m rectangular dirt track or indoors in a riding hall (22×12m), depending on weather conditions.

Intervention R. Intervention R consisted of sitting astride a Bobath roll, a canvassed cylinder made of rubber foam with a diameter of 65cm and a length of 150cm. The subject sat upright with flexed hips and knees, feet on the ground, and hands resting on the thighs (fig 1). The same physiotherapist involved in the hippotherapy intervention helped with transfers and remained with the subject throughout the session. Intervention R was performed in a therapy room beside the horse stables.

Intervention S. Intervention S involved sitting on a rocker board that was integrated into a wood stool with a cushioned seat. The rocking seat was driven by an electrically powered motor; the rotation axis was in the middle of the seat in the sagittal plane. The rhythm of the rocking movement and its amplitude were adjusted to a horse’s walking pace, with a frequency of about 1Hz and amplitude at the subject’s sciatic tuber of about 2 to 3cm (depending on pelvic width). The subject was sitting with 90° hip and knee flexion, ankles in neutral position, feet on the ground or on a block (depending on shank length), and hands resting on a mounting bracket to prevent a fall (fig 2). The same physiotherapist involved in the other 2 interventions helped the subjects with transfers and stayed with them during the session. Intervention S was performed in the same therapy room as intervention R.

Measurements

Spasticity. Spasticity was assessed by a clinical rating using the Ashworth score and by a subject’s self-rating using a VAS, as described in an earlier work.

For the clinical rating the subjects were in a supine position, with knees flexed and lower legs dangling over the edge of a
On 1 limb after the other, the physiotherapist passively performed knee extension and flexion (with extended hip), hip extension and flexion (with knee in flexion), and hip abduction (with extended hip and knee) within the full individual ROM. Each movement from full flexion to full extension or vice-versa, or from full adduction to full abduction, lasted approximately 1 second and was performed 3 consecutive times, with 2 to 3 seconds of rest in the end positions. Thereafter, the examiner rated the perceived resistance against each single passive movement according to Ashworth, from 0 to 4, and added the scores of the 10 different muscle groups (5 each side) to a sum (Ashworth scores’ sum).

For the self-report, subjects were asked to perform a motion sequence (transfer from chair to bed, lying down supine, sitting up on bed) and then to rate the spasticity experienced through the sequence on a 10-cm VAS, ranging from no spasticity to most imaginable spasticity. No further explanations for spasticity were given to the subjects.

Well-being. To assess subjects’ present mental well-being and its change through the interventions, we used the Bf-S of von Zerssen and Koeller.³¹ This measure consists of 2 parallel lists of 28 opposing adjective pairs with which to evaluate mood, motivation, self-esteem, and feeling of vitality. Subjects had to tick on the list given them by the examiner if they felt, for example, “rather happy,” “rather unhappy,” or “neither nor.” The 28 answers were rated on a 3-step scale from 0 to 2 and test scores were subsequently calculated by summing the ratings. This test score consisted of a number between 0 and 56; a higher score represents a more depressed mood and impaired mental well-being. Normative data evaluated by von Zerssen and Koeller³¹ indicate that 95% of mentally healthy men at ages between 20 and 64 years have a score of 28 or lower.

All measurements were taken in the rehabilitation center’s PT department. The physiotherapist involved in the measurements was blinded as to the current intervention. This was possible because of the topology of the study setup and the cooperating subjects, who were instructed not to discuss therapy. There was a post-experimental check by the author (HEL) to ensure that examiners were blinded to the experimental condition.

Study Protocol

The 12 subjects were randomly divided into 3 groups (I, II, III) (fig 3). The protocol began with 4 weeks of weekly measurement sessions, which included the clinical ratings, the subjects’ self-reports of spasticity, and the Bf-S. Each spasticity measurement lasted about 15 minutes and was performed twice, with a 45-minute interval between measurements. The Bf-S was only completed once. These measurement sessions were performed as a control condition to detect any effects on spasticity from the Ashworth Scale and the transfers themselves.

After 4 weeks, each group performed the 3 interventions in a different order. Each intervention period comprised 8 treatments twice weekly for 4 weeks. Before the first session of each week, the subject went to the PT department for a mea}-
surement session (spasticity, well-being), then went in the wheelchair to the hippotherapy terrain (~500 m) for the inter-
vention, and afterward was again measured in the PT depart-
ment. In the week’s second intervention, the subject went only
in the wheelchair to the hippotherapy terrain (spasticity, well-
being), then went in the

One subject withdrew because of health problems unrelated

to the study’s interventions. The remaining 11 subjects had
100% compliance with the interventions; none recorded any
changes in their weekly routine or any health conditions that
might have influenced the study results. The mean age of the 11
subjects was 44 years (range, 27–68 y), mean time postinjury
was 13.1 years (range, 1.5–39.9 y). The sample included 3 men
with tetraplegia and 8 men with paraplegia (table 1). The

We analyzed data from the BF-S by comparing the means of
the before-session test scores with the means of the after-
session test scores of each intervention separately with the
Wilcoxon signed-rank test to detect an immediate effect. We
tested a long-term effect on well-being by calculating a base-
line mental well-being (mean of the first 4 test scores of the
control period) and comparing it with the scores assessed after
each 4-week period of intervention with the Friedman test.
Statistical significance was set at the 5% level. We used SPSS®
for Windows for the statistical analyses.

RESULTS

One subject withdrew because of health problems unrelated
to the study’s interventions. The remaining 11 subjects had
100% compliance with the interventions; none recorded any
changes in their weekly routine or any health conditions that
might have influenced the study results. The mean age of the 11
subjects was 44 years (range, 27–68 y), mean time postinjury
was 13.1 years (range, 1.5–39.9 y). The sample included 3 men
with tetraplegia and 8 men with paraplegia (table 1). The

Short-Term Effects

Spasticity: clinically rated. Analyzing the change in the
clinically rated resistance against passive movements, using
the Ashworth scores’ sum data, there was a significant difference
in the changes caused by the 4 conditions (control and 3
interventions; \( P = .003 \)). Post hoc multiple comparisons de-
tected a significant difference \( (P < .05) \) between the reduction of
Ashworth scores’ sum caused by intervention H in compar-
ison to the change of Ashworth scores’ sum in the control
condition, whereas the reductions caused by the other 2 inter-
ventions did not reach significant differences as compared with
the changes in the control condition (table 2). Effects on mental
well-being could be ana-
lyzed by the BF-S values of 9 subjects—we did not assess
the BF-S of subjects 1 and 2. The baseline mental well-being of
the 9 subjects ranged from 0 to 32.8 (see table 1).

Data Analysis

We calculated the differences in Ashworth scores’ sums and
VAS before and after the pause (during the control period), as
well as before and after the intervention session (during inter-
vention periods). For each subject and for each period we
calculated a median of the differences. All the medians were
grouped and significant differences between intervention peri-
ods and the control period were tested with the Friedman test
and a post hoc multiple comparison test as described by Shel-
don et al.43 Pre and post within-group analyses were tested with
the Wilcoxon signed-rank test to detect a significant immediate
effect on Ashworth scores’ sums and VAS medians.

We tested carryover effects lasting longer than 4 days with
data from each first spasticity measurement by rank methods
for longitudinal data.44

We tested carryover effects lasting longer than 4 days with
data from each first spasticity measurement by rank methods
for longitudinal data.44
Spasticity: self-reported. Analyzing the effect on the self-reported spasticity, using the VAS data, there was again a significant difference between the 4 conditions (P = .043). Post hoc multiple comparisons detected significant differences (P < .05) between the effects on VAS between interventions H and R and between interventions H and S (Table 3).

Pre- and post- within-group analyses showed significant differences between VAS medians before and after each session in the interventions H and R as well as in the control condition (P = .004, P = .014, P = .021, respectively); there was no significant difference between VAS medians before and after each session through intervention S (P = .181).

Well-being. Analyzing the immediate effects of the 3 interventions on subjects’ mental well-being, we found significantly lower scores after intervention H than before (P = .048), which represents an improved mental well-being. There were no significant changes in the Bf-S scores caused by interventions R and S (P = .933, P = .497, respectively).

Long-Term Effects

Spasticity. There was no spasticity-reducing carryover effect that lasted as long as 4 days (from second weekly intervention to the next first weekly visit) and no long-term effect over the 4 weeks of treatment for any of the 3 interventions. This was true for all data, clinically assessed as well as self-reported with VAS.

Well-being. There was no significant difference between baseline mental well-being and the Bf-S scores assessed after each 4-week period of intervention.

DISCUSSION

In this study, we assessed the extent of spasticity reduction for 3 different interventions by both clinical and self-report measures in spastic SCI subjects. There was an immediate reduction of spasticity by hippotherapy, as demonstrated by both the clinical and the self-rating scores. Only the subjects discerned differences between the effects of the 3 interventions.
tions. Neither subjects nor physiotherapists detected long-term effects of the interventions on spasticity. Additionally, we evaluated the effect of the interventions H, R, and S on mental well-being. Temporary improvements in mental well-being were detected only after hippotherapy.

Short-Term Effects

**Spasticity: clinically rated.** The clinically rated data showed a significant difference between the reductions in spasticity by H compared with no intervention. Effects of the 2 other interventions (R, S) did not reach significant levels compared with the control condition. Meregillano\(^{15}\) stressed the importance of sensory input through precise and repetitive movements provided by the horse’s walking motion that are imposed on a subject’s pelvis, lumbar region of the spine, and hip joints. The resultant movement responses in the patient are similar to human movement patterns of the pelvis while walking, including the physiologic rotation movement in the trunk. The concept of Bobath\(^{25}\) emphasizes the importance of the rotation between pelvis and shoulder girdle or vice versa, as well as equilibrium reactions and postural reactions in the dissociation of spastic patterns. Strauss\(^{25}\) attributed the unique spasticity-reducing effect of hippotherapy to this concept. Our data support the finding that neither the inhibiting saddle position nor the rhythmic lateral flexion of the trunk alone is sufficient to compete with hippotherapy in the treatment of patients with SCI. It is the combination of an inhibiting sitting position and rhythmic movements that produces these benefits. Additionally, the horseback movement not only applies a sagittal movement on the patient’s pelvis, as our rocking board did, but also a complex 3-dimensional displacement. Moreover, the warmth of the horseback, the danging of the lower legs following the movement of the pelvis, and the physiotherapist’s controlling of subject’s sitting position, may have an effect on muscle tone.\(^{15,24,25}\) Spasticity is a malfunctioning of spinal circuits caused by an abnormal descending control of spinal pathways and local changes at the spinal level.\(^{46}\) The walking movement of an able-bodied person causes reciprocal inhibition (by spinal circuitries). The alternating rhythmic movement of subjects’ legs and pelvis while sitting on the walking horse may also act as proprioceptive afferent impulses, causing reciprocal inhibition on a spinal level. For this reason, we presume that intervention H has a superior effect on spasticity compared with the other 2 interventions. It is remarkable that we found significant differences between the Ashworth scores’ sum medians before and after each session for all 3 interventions. There was no significant difference, however, between the first and the second Ashworth scores’ sum in the control period. Thus, the testing procedure alone did not significantly reduce resistance against passive movement. We found an immediate spasticity reduction after all 3 interventions, but comparing the magnitude of the effects of the 3 interventions with the effect of the testing procedure alone provides evidence that the benefits of hippotherapy on spasticity cannot be achieved by the other 2 interventions.

**Spasticity: self-reported.** It is noteworthy that subjects rated the effect on spasticity differently than did the physiotherapists. Subjects indicated a significant difference of spasticity reduction between H and R and between H and S, but they did not detect any difference between the effect of the testing procedure alone and the effect of any of the 3 interventions.

Looking at the immediate effects of the interventions H, R, and S on the subjective rating, we found a significant reduction between before and after values in the interventions H and R. There was no detected spasticity reduction through intervention S, however. Interestingly, subjects indicated a significant immediate subjective spasticity reduction through the testing procedure alone.

There may be different reasons for the discrepancy between the rating of the physiotherapist and subjects’ self-ratings. The control period was the beginning of the study for each subject, and using VAS to indicate their spasticity was a new experience for all 11 subjects. They still felt less spasticity during the second motion sequence (transfer from chair to bed, lying down supine, sitting up on bed) that took place 45 minutes after the previous testing procedure. In a previous study,\(^{29}\) only poor-to-moderate correlations between clinically rated and self-rated spasticity were shown, indicating that persons with SCI attributed different sensations (eg, pain) to their self-reported spasticity. This may have also occurred in this study. The clinical rating used incorporates only resistance against passive movements of the lower extremities, whereas the subjects may include high muscle tone or spasms in other body segments (eg, trunk muscles) in the VAS. Additionally, the fact that subjects could not be blinded to the intervention, but the examiners who did the clinical spasticity ratings were blinded, could be another reason for discrepancies.

**Well-being.** Concerning the short-term effect, our hypothesis that hippotherapy improves mental well-being of SCI subjects was corroborated. Although the subjects were given the same attention by a physiotherapist during all 3 interventions, we detected a slight improvement of subjects’ mental well-being immediately only after the hippotherapy. According to Westgren and Levi and the Stockholm Spinal Cord Injury Study,\(^{47}\) problematic spasticity affects—in addition to other components of quality of life—vitality, social function, role function (emotional), and mental health. Consequently, the temporary spasticity reduction and the concurrent improvement in mental well-being through hippotherapy may be related to each other. Additionally, the Bf-S scores may have been influenced by the psychologic effect of the contact with a large animal, as described by Meregillano,\(^{15}\) as well as the fact that subjects were not blinded to the interventions and knew that they were participating in a study to test the effect of hippotherapy (Hawthorne effect). It is therefore not surprising that after hippotherapy there was a temporary improvement in the sense of well-being.

Long-Term Effects

**Spasticity.** In contrast to the short-term effect, we could not detect significant long-term effects by any of the interventions. With our study protocol we were only able to investigate spasticity-reducing effects covering more than 4 days, because the next measurement session was not earlier than 4 days after the last intervention.

Exner et al\(^{14}\) studied the duration of hippotherapy’s effect on spasticity of persons with SCI and found that in more than 20% of subjects spasticity could be reduced by hippotherapy for more than 36 hours, and for more than 24 hours in 33% of the subjects. ROM could be improved in two thirds of subjects with reduced joint movement for as long as 1 week. Hippotherapy sessions were held once a week and the authors stated that holding them more frequently could be beneficial. In the Swiss Paraplegic Centre, where our study was performed, patients usually receive hippotherapy twice a week. Because we wanted to keep our study protocol closely similar to our clinical practice, we did our interventions twice weekly. With this schedule, participants had to drive from home to the rehabilitation center twice weekly. We did not want to burden them with a third visit, therefore the measurements had to be taken on 1 of the 2 visits. Choosing a shorter time interval.
between intervention session and spasticity measurement might have provided information about effect duration. Moreover, the small sample size and the high fluctuation of spasticity made it impossible to study carryover effects. Previous work showed that the highest short-term improvement was observed in patients with severe spasticity. Further research with a larger sample size and with subjects with higher muscle tone is needed to validate long-term effects.

**Well-being.** We did not detect any long-term effects with the BF-S because of the large fluctuation over time in a person’s mental well-being. According to Lienert a test to evaluate the BF-S because of the large fluctuation over time in a person’s mental well-being in an invariant, because the construct implies large variations. The coefficient of stability of the BF-S drops when the interval between measurements is more than 1 or 2 days. A longitudinal analysis of the BF-S scores showed a high variability; any interactions with interventions could therefore not be detected.

**Study Limitations**

One limitation of the study was our inability to double blind it, which is impossible in therapeutic interventions when movement is involved. Another limitation was the fact that not all possible orderings of conditions could be included in the design. The lack of carryover effects from 1 intervention to another showed that this limitation might not have influenced the outcome however.

**CONCLUSIONS**

In this study it was shown that hippotherapy reduces spasticity for a short time and temporarily improves mental well-being in persons with SCI. Sitting astride a Bobath roll (stretching) or on a rocking seat (rhythmic passive movements) did not achieve the same effect. Subjectively, the subjects felt better and less spastic after hippotherapy. With the chosen measures, we could not detect any carryover effects on spasticity or mental well-being. After hippotherapy sessions, our subjects experienced a period of time of less spasticity and an improved sense of well-being. Such time periods could be of help during periods when the interval between measurements is more than 1 or 2 days. A longitudinal analysis of the BF-S scores showed a high variability; any interactions with interventions could therefore not be detected.

**Acknowledgments:** We thank the physiotherapists and the horse masters of the Swiss Paraplegic Centre for their cooperation and assistance with this study. We thank Juerg Huesler, PhD (Institute of Mathematical Statistics, University of Berne, Switzerland), for his support in our statistical analysis.

**References**


Suppliers
a. OBA AG, Auf dem Wolf 20, CH-4002 Basel, Switzerland.
c. Version 13; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
Does the Presence of a Specialized Rehabilitation Unit in a Veterans Affairs Facility Impact Referral for Rehabilitative Care After a Lower-Extremity Amputation?

Barbara E. Bates, MD, Jibby E. Kurichi, MPH, Clifford R. Marshall, MS, Dean Reker, PhD, Greg Maislin, MS, MA, Margaret G. Stineman, MD


Objective: To determine if the presence of specialized rehabilitation units (SRUs) within Veterans Affairs medical centers (VAMCs) influences access to rehabilitation services.

Design: Retrospective cohort analysis.

Setting: Two types of VAMCs: those with and without SRUs.

Participants: Veterans with lower-extremity amputations discharged from VAMCs between October 1, 2002, and September 30, 2003. There were a total of 2375 veterans with amputations; 99% were men; and 60% had transfemoral, 40% had transfibular, and less than 1% had hip disarticulation amputations. Nine hundred sixty-six patients (41%) were seen at a VAMC with an SRU.

Interventions: Not applicable.

Main Outcome Measure: Level of service provided expressed as: no evidence of rehabilitation during the hospitalization, generalized rehabilitation through consultation only, or admission to an SRU.

Results: There were no differences between patients treated at facilities with SRUs and those treated in a facility without SRU beds with respect to age, sex, marital status, source of hospital admission, or level of amputation (all \(P > .05\)). Patients with lower initial FIM instrument scores were more likely to be treated in facilities with SRUs, and to have longer lengths of acute hospitalization (\(P < .01\)). Patients at facilities with an SRU compared with those without an SRU had comparable likelihoods of being seen for an initial rehabilitation consultation (75% vs 74%, \(P = .56\)), but were more likely to be admitted for high-intensity specialty rehabilitation services (26% vs 11%, \(P < .01\)).

Conclusions: Although the majority of patients were seen in consultation, structural differences in service availability among clinically similar populations appear to be causing access disparities to specialized rehabilitation among amputees in the VAMC setting. The implication of these differences with regard to patient outcomes will need to be determined.

Key Words: Amputation; Leg; Rehabilitation; Veterans.

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Amputation of the lower limb can result in permanent impairment and disability, reducing the capacity for productive activities among people of all ages, but especially in the elderly. Lower-limb amputations in the United States can be expected to double from 28,000 to 58,000 per year by 2030 because of the disproportionate shifts in the oldest segments of our population, making cost-effective rehabilitation strategies to help elderly patients achieve independence and home discharge increasingly essential in the upcoming decades.

Rehabilitation immediately after the onset of any new impairment (including lower-extremity amputation) can be provided in a variety of ways that could be considered a continuum ranging from no rehabilitative intervention to high-intensity inpatient rehabilitation services on a specialized unit. Most hospitals have physical and occupational therapists that can be consulted postoperatively to help patients recover their functional abilities after limb loss. In addition to consultative services, some patients may be referred for admission to a specialized inpatient rehabilitation program, to a skilled nursing facility, or for home care or outpatient services only. Despite availability, consultation is not guaranteed, and patients can be discharged from acute care without ever being assessed for rehabilitation services.

There is evidence that, after a traumatic lower-extremity amputation, admission to a specialized inpatient rehabilitation program significantly improves functional and vocational outcomes and reduces bodily pain. Although there is little evidence to date, it is logical to assume that similar benefits would be seen in patients who undergo amputations due to nontraumatic etiologies as well. As Dillingham et al noted in 2 separate studies, few patients are referred to rehabilitation programs, however, with only 9.6% to 16% of patients discharged from acute services to inpatient rehabilitation after dysvascular amputation of a lower limb.

Admission into an inpatient rehabilitation program is dependent on numerous factors, including patient characteristics, referral practices, and the structures and processes within rehabilitation itself. This study is an attempt to determine if variation in structure and processes of care within the Veterans

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Veterans Affairs (VA) health care system influences the rate of admission to a specialized inpatient rehabilitation unit after lower-extremity amputation. Adopting the structure-process-outcome model (Donabedian) developed and applied by Hoenig et al5,6 for stroke rehabilitation, we propose an Amputation Taxonomy of Care with the availability of a specialized rehabilitation unit (SRU), representing the primary structural element studied in our taxonomy.

Based on the Amputation Taxonomy of Care, our study distinguishes among 3 treatment process groups within the rehabilitation continuum: (1) veterans who have no evidence of a rehabilitation assessment while hospitalized, (2) veterans who have evidence of generalized rehabilitation through consultation level services only while hospitalized, and (3) veterans who have evidence of specialized rehabilitation through SRU admission after their amputation surgery. The treatment process is tracked by the entrance into the rehabilitation continuum. This occurs when patients receive an initial consultation intended to address basic access to rehabilitation. If a patient receives consultation level services only, the rehabilitation level is categorized as generalized rehabilitation. These patients, at a minimum, have an initial functional assessment completed and may, or may not, receive therapy services as a result. If the patient is referred for more intensive rehabilitation and is admitted to an SRU, then he/she is assigned to the specialized rehabilitation group (Table 1).

We assumed that the presence of rehabilitation specialists practicing on an SRU within the Veterans Affairs medical center (VAMC) would encourage a cultural shift toward greater awareness of rehabilitation and would drive patients into and through the rehabilitation continuum influencing patterns of patient referral to rehabilitation services. We hypothesized that patients who have surgical amputations in a VAMC that also has an SRU would be more likely to have an initial consultation while still on an acute unit. Among those evaluated by rehabilitation professionals during their surgical hospitalization, we further hypothesized that those treated in facilities with an SRU compared with those without a unit would be more likely admitted for higher intensity rehabilitation to the SRU.

**METHODS**

This study was approved by the University of Pennsylvania Samuel S. Stratton VAMC, and Kansas City VAMC institutional review boards.

**Study Sample**

A total of 2912 surgical amputation admission records to all VAMCs with acute hospital discharge dates between October 1, 2002, and September 30, 2003, were included in this study. Four hundred forty-nine duplicate records were removed, as well as 88 patients who had amputations that involved toes only or who had a record of a previous lower-extremity amputation within the 12 months preceding the index surgical stay, in order to obtain a more homogeneous sample with similar clinical characteristics. The hospitalization at the time of the surgical amputation represented the “index surgical stay.” There were 2375 admissions for transtibial, transfemoral, or hip disarticulation amputations that were captured using International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes 84.10, 84.13 to 84.19, and 84.91, consistent with those used in other studies.

**Table 1: Definitions of Levels and Processes of Rehabilitative Care**

<table>
<thead>
<tr>
<th>Level of Care Terminology*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No evidence of acute rehabilitation</td>
<td>Represents the cohort of patients who have no evidence of hospital-level, generalized consultative, or specialized services associated with their amputation within the first postoperative year.</td>
</tr>
<tr>
<td>Generalized rehabilitation</td>
<td>Represents a cohort of patients who have evidence of at least 1 rehabilitation assessment during their index surgical stay. Therapy services may be provided while the patient is located on an acute med/surgical unit or in a long-term care unit, but there is no evidence of an integrated or coordinated approach to rehabilitation.</td>
</tr>
<tr>
<td>Specialized rehabilitation</td>
<td>Represents a cohort of patients who have evidence of high-intensity, comprehensive rehabilitation during their index surgical stay defined as admission to a specialized rehabilitation unit accredited by the Commission on Accreditation of Rehabilitation Facilities.</td>
</tr>
</tbody>
</table>

*Receipt of an initial rehabilitation assessment: a process involving entry into the rehabilitation continuum, whereby patients receive at least 1 rehabilitation consultant during their hospitalization. Based on this assessment, patients may be admitted to an SRU and thus enter into the specialized rehabilitation cohort. Those who are not admitted to an SRU make up the generalized rehabilitation cohort.
date of first assessment in the FSOD corresponds to the patient’s entry into the rehabilitation continuum. Continuum entry can occur before and/or after the surgical date. For this study, if a veteran had multiple rehabilitation episodes associated with the surgical hospitalization, we applied the first FSOD admission record to obtain initial cognitive and motor functional status.

Creation of Analytic Files for Analysis

Two analytic files were developed, merging data from the PTF, OPC, and FSOD data sources. The first included all 2375 surgical amputation admissions in the study. We used this analytic file to address the likelihood of patients entering the rehabilitation continuum, according to whether or not they had their amputations at VAMCs with an onsite rehabilitation unit. This expressed the likelihood of the patients receiving an initial rehabilitation consultation. The second analytic file represented a subset of patients included in the larger analytic file and was limited to the 1775 patients who were seen by rehabilitation consultants, that is, limited to those patients who entered the rehabilitation continuum. It added additional functional status information from the FSOD, which is collected only for those patients who enter the rehabilitation continuum. We used this data set to address the likelihood of admission to an SRU for patients receiving generalized rehabilitation.

Measures of Patient Case Mix

We compared patient characteristics across the 3 groups. Patient demographics included age, sex, and marital status, defined as married or not married. Location of the patient prior to the surgical hospitalization included 3 categories: extended care, hospital, and home. Levels of amputation were transtibial, transfemoral, and hip disarticulation.

Amputation etiology categories were developed by literature consensus.8-11 The diagnoses were obtained from the PTF inpatient database and were grouped into 11 etiologic categories.8-11 Congenital deformity (1 case) and lower-extremity cancer (0 cases) were not analyzed because of insufficient prevalence. The categories were intended to recognize limb loss as multifactorial. For example, a patient could have both trauma and diabetes mellitus contributing to limb loss. Consequently, patients’ reasons for amputation were not classified into mutually exclusive and exhaustive groups.

Comorbid medical diagnoses were expressed by using 2 separate comorbidity measures: the Elixhauser measure13 and the Charlson/Deyo Index.14-16 The Elixhauser measure was applied as the primary comorbidity measure in this study because it includes a broader array of diagnostic categories (31 conditions) than the more commonly reported Charlson (17 conditions), and it has been shown to more accurately predict mortality.15-17 The Charlson/Deyo Index was also analyzed because it incorporates certain diagnoses not included in the Elixhauser and because certain diagnostic categories are defined by somewhat different lists of ICD-9-CM codes. Our objective was to optimize our adjustment for case-mix differences between the patients with amputations treated in centers with and without onsite SRUs. Contributing etiological conditions such as diabetes mellitus and problems with peripheral circulation were removed from the comorbidity measures because they were already counted as etiologies. Obesity was not analyzed because no case was coded with this condition.

Measure of Structure

We examined how the presence or absence of an SRU onsite within treating VAMCs influenced the rehabilitation services patients received by using the Commission on Accreditation of Rehabilitation Facilities accreditation as criteria to classify centers into those with and without an SRU. The presence versus absence of an SRU was expressed as the primary independent variable after adjusting for patient characteristics and clinical severity.

Measure of Care Process

Acute care utilization. Average medical and surgical LOS, average medical ICU and surgical ICU LOS, and average total LOS were calculated.

Levels of rehabilitation care. As noted previously, we defined 3 levels of service: no evidence of rehabilitation, generalized rehabilitation through consultation only, and specialized rehabilitation evidenced by an SRU admission. Evidence of entry into the rehabilitation continuum was based on the patients’ receipt of at least an initial consultation. Patient cohorts were assigned using information from the 2 analytic files described above. In the first analytic file, evidence of rehabilitation was expressed as a dichotomous variable. No evidence of rehabilitation was defined as the lack of an FSOD record, and receipt of an initial consultation was noted with the presence of FSOD record(s). The specialized and generalized consultation rehabilitation levels were defined in the second analytic file. These levels were expressed as a dichotomous variable characterizing the receipt of higher intensity rehabilitation through SRU admission versus lower-intensity generalized consultation only where there were FSOD records present but no SRU admission.

Statistical Analyses

Descriptive statistics were used to test demographic characteristics of patients who received amputations in VAMCs with and without SRU beds. Chi-square analyses and Student t tests were used to test differences between patients treated at VAMCs with and without designated beds and rehabilitation care process outcomes. A P value of less than .05 was considered statistically significant for all comparisons. In addition to estimating simple proportions, a set of unadjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. OR analyses were designed to investigate 2 questions. The first was the degree to which the presence of rehabilitation with an onsite unit within the VAMC was associated with admission to the continuum. In this analysis, the adjusted OR compared the likelihood of finding evidence of at least an initial rehabilitation consultation among patients in systems with and without onsite SRU beds controlling for case-mix characteristics. In the second analysis incorporating functional status data, the adjusted OR compared the likelihood of receiving higher intensity specialized inpatient rehabilitation versus lower-intensity generalized rehabilitation, comparing patients in systems with and without onsite SRU beds while controlling for case-mix characteristics.

We adjusted the OR for potentially confounding sociodemographic and clinical characteristics. Each of the 2 treatment process-level variables served as dependent variables in multivariable logistic regression models. The primary explanatory variable for these models was the dichotomous VAMC rehabilitation structure-indicator variable (ie, presence or absence of an SRU). Candidate variables for these logistic regression models included age, sex, marital status, source of hospital admission, level of amputation, presence of an SRU, amputation etiological diagnoses, and Elixhauser comorbidities. Model identification began by using 2 domain-specific forward stepwise algorithms in order to identify a parsimonious subset
of variables that sufficiently contained all information in that domain useful for prediction of the outcomes. Variables entered the forward model at \( P \) equal to .25. The first analysis included: age, sex, marital status, source of hospital admission, level of amputation, presence of an SRU, and amputation etiological diagnoses. The second analysis included age, sex, marital status, source of hospital admission, level of amputation, presence of an SRU, and Elixhauser comorbidities. The variables that were significant in these 2 models were then placed in a backward stepwise regression. Variables were removed from the backward model at \( P \) equal to .10. The crude OR calculated from the VAMC rehabilitation structure-indicator variable was compared with the adjusted OR for the same variable. The magnitude of differences between the unadjusted and adjusted OR addressed the degree to which discovered associations between VAMC rehabilitation structure type and the treatment process-level outcomes were confounded by clinical factors. The \( C \) statistic corresponding to the area under the receiver operating characteristic curve was used to assess overall model predictive value. The Hosmer-Lemeshow goodness-of-fit statistic was applied to test fit of the data to the model. Statistical analyses were performed using SAS software. In this study, 98.9% were men, and the average age was 67.3 years. The majority of the amputations were transtibial (59.6%), with 39.8% transfemoral and only 0.7% hip disarticulation.

**RESULTS**

**Analysis of the Larger Population of Amputees**

Descriptive information regarding the total study population and the subsets of veterans treated at facilities with and without an SRU is shown in table 2. Among the 2375 veterans included in this study, 98.9% were men, and the average age was 67.3 years. The majority of the amputations were transtibial (59.6%), with 39.8% transfemoral and only 0.7% hip disarticulation. Twenty-six patients (1.1%) did not have a record of a surgical or medical bed section. Eighteen of those subjects were on a spinal cord injury service, 7 were on extended care, and a single subject was in an SRU at the time of surgical amputation. Problems with peripheral circulation, diabetes mellitus, significant local infection, and skin breakdown were the most common conditions contributing to limb loss among veterans undergoing surgical amputations in VAMCs. Trauma was a relatively infrequent contributing factor, present in just over 10% of amputees at both types of centers.

There were a total of 125 VA facilities, with 31 having a designated SRU. Nine hundred sixty-six (40.7%) patients were treated in a VAMC with an onsite SRU. There were no statistically significant differences between patients who were seen at centers with and without an SRU with respect to age, sex, marital status, source of hospital admission, or level of amputation (table 3). Patients seen at VAMCs with an SRU had longer average total LOS (24.1d vs 19.4d, respectively, \( P < .01 \)) and LOS in medical and surgical bed sections (19.5d vs 16.1d, respectively, \( P < .01 \)) compared with patients seen at facilities without an SRU; however, there was no statistically significant difference in LOS at medical ICU or surgical ICU bed sections.

There were 1775 amputees (74.7% of the total population) admitted to the rehabilitation continuum in the perioperative period as ascertained by the presence of an FSOD record. There was no statistically significant difference in the probability of an amputee receiving an initial rehabilitation consultation according to whether or not the treating facility had an SRU (\( P = .56 \)). The unadjusted OR and adjusted OR estimates were similar: 1.06 (95% CI, 0.88–1.28) and 1.1 (95% CI, 0.90–1.34), respectively. The \( C \) statistic in the multivariable model was .68, and the Hosmer-Lemeshow goodness-of-fit \( P \) value was not significant.

Problems of peripheral circulation were more common among patients treated in VAMCs without an SRU (\( P = .03 \)),

### Table 2: Comparisons of Patient Characteristics and Treatment Process Variables According to the Presence or Absence of an SRU in the Entire Population (\( N = 2375 \))

<table>
<thead>
<tr>
<th>Patients</th>
<th>Total Population</th>
<th>SRU Present</th>
<th>No SRU</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age ± SD (y)</td>
<td>67.3 ± 11.0</td>
<td>67.5 ± 11.2</td>
<td>67.2 ± 10.9</td>
<td>.56</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.82</td>
</tr>
<tr>
<td>Male</td>
<td>2349 (98.9)</td>
<td>956 (99.0)</td>
<td>1393 (98.9)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>26 (1.1)</td>
<td>10 (1.0)</td>
<td>16 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Marital status, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.05</td>
</tr>
<tr>
<td>Married</td>
<td>1100 (46.3)</td>
<td>424 (43.9)</td>
<td>675 (47.9)</td>
<td></td>
</tr>
<tr>
<td>Not married</td>
<td>1275 (53.7)</td>
<td>542 (56.1)</td>
<td>734 (52.1)</td>
<td></td>
</tr>
<tr>
<td>Source of hospital admission, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.52</td>
</tr>
<tr>
<td>Extended care</td>
<td>264 (11.1)</td>
<td>116 (12.0)</td>
<td>148 (10.5)</td>
<td></td>
</tr>
<tr>
<td>Hospital</td>
<td>81 (3.4)</td>
<td>33 (3.4)</td>
<td>48 (3.4)</td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>2029 (86.4)</td>
<td>817 (84.6)</td>
<td>1212 (86.1)</td>
<td></td>
</tr>
<tr>
<td>Level of amputation, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.14</td>
</tr>
<tr>
<td>Transtibial</td>
<td>59.6%</td>
<td>592 (61.3)</td>
<td>823 (68.4)</td>
<td></td>
</tr>
<tr>
<td>Transfemoral</td>
<td>39.8%</td>
<td>365 (37.8)</td>
<td>579 (41.1)</td>
<td></td>
</tr>
<tr>
<td>Hip disarticulation</td>
<td>0.7%</td>
<td>9 (0.9)</td>
<td>7 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Treatment process variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean total LOS ± SD (n = 2349)</td>
<td>21.3 ± 35.7</td>
<td>24.1 ± 50.5</td>
<td>19.4 ± 20.3</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Mean LOS ± SD, medical and surgical (n = 2310)</td>
<td>17.4 ± 16.2</td>
<td>19.5 ± 18.0</td>
<td>16.1 ± 14.8</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Mean LOS ± SD, medical and surgical ICU (n = 954)</td>
<td>8.6 ± 17.0</td>
<td>8.0 ± 12.1</td>
<td>9.2 ± 19.9</td>
<td>.29</td>
</tr>
<tr>
<td>FSOD record, n (%)</td>
<td>1775 (74.7)</td>
<td>728 (75.4)</td>
<td>1047 (74.3)</td>
<td>.56</td>
</tr>
<tr>
<td>Level of rehabilitation received, n (%)</td>
<td>600 (25.3)</td>
<td>238 (24.6)</td>
<td>362 (25.7)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>No evidence of rehabilitation</td>
<td>1361 (57.3)</td>
<td>473 (49.0)</td>
<td>888 (63.0)</td>
<td></td>
</tr>
<tr>
<td>Generalized rehabilitation only</td>
<td>414 (17.4)</td>
<td>256 (26.4)</td>
<td>159 (11.3)</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviation:** SD, standard deviation.
whereas skin breakdown was listed more frequently in amputees seen at centers with an SRU (P=11005.04). There were no other statistically significant differences between the 2 types of facilities according to amputation etiology (data not included and is available on request).

There were also a few differences in comorbid conditions between patients treated at VAMCs with and without an SRU. Only 2 of 27 conditions, paralysis and hypertension with complication, showed prevalence differences across VAMCs with and without onsite rehabilitation beds (P=11021.01, P=11005.04, respectively). According to the Charlson/Deyo Index, only 1 of 16 conditions (mild liver disease) was more likely to be coded present among patients at VAMCs without an SRU (P=11005.02) (results not shown; data is available on request).

Analysis of the Subpopulation Receiving Rehabilitation Services

Similar to the larger sample, there were no significant differences between patients who were seen at centers with and without an SRU, with respect to age, sex, marital status, or source of hospital admission among patients admitted to the rehabilitation continuum (all P>.05) (see table 3). A significantly higher proportion of veterans treated at VAMCs with an SRU were transtibial as opposed to a higher level (P=.04). Patients being treated in facilities with SRUs onsite had more severe physical and cognitive disabilities on rehabilitation admission (both P<.01).

Four hundred fourteen of the 1775 amputees admitted to the rehabilitation continuum for assessment received specialized inpatient rehabilitation. This represents 23% of those who entered the continuum or 17% of the entire amputee population in this study. Admission to an SRU for higher intensity rehabilitation was strongly related to the presence of onsite beds within the same VAMC as the surgical amputation. Among amputees treated in VAMCs with an onsite rehabilitation unit, 35.1% received specialized rehabilitation as contrasted to 15.2% of those whose surgical amputations occurred in VAMCs without an SRU (P=.01). Among those who entered the continuum, the adjusted odds for admission to an SRU was 3.74 (95% CI, 2.92–4.80) times larger if an SRU was present in the same facility in which they received their amputation compared with when no unit was present. The C statistic in this multivariable model was .73, and the Hosmer-Lemeshow goodness-of-fit P value was not significant.

DISCUSSION

Findings failed to support our first hypothesis that patients whose surgical amputations occurred in VAMCs with an onsite SRU would be more likely to be admitted to the rehabilitation continuum. Rehabilitation consultants (physiatrist, rehabilitation nurse, or rehabilitation therapist) saw three quarters of all veterans with lower-extremity amputations regardless of the presence or absence of an SRU. The finding that veterans with amputations of the lower limb(s) were equally likely to be...
evaluated by rehabilitation consultant irrespective of the presence of an SRU in their treating VAMC suggests that access to the rehabilitation continuum is not influenced by the structure of rehabilitation services within the VAMC. These unanticipated findings are a positive outcome of a system-wide quality improvement initiative issued by the Veterans Health Administration to enhance the accountability of rehabilitation services and efficiency of operations across the postacute care continuum. In 2003, as part of the overall quality framework, a rehabilitation performance measure was adopted by the VA’s Office of Quality and Performance. This measure required that a functional assessment be completed on veterans admitted to VA facilities with a new amputation. The intent of this functional assessment was to determine the patients’ need for rehabilitation services. This specific performance measure is likely driving the practice in the VA of initiating rehabilitation consults postamputation, regardless of where the patient is located. The availability of the FSOD provides an opportunity not found in other health care systems to study these types of referral patterns.

Our findings support our second hypothesis that the presence of designated rehabilitation units within the larger medical center influences process and access among veterans with amputations. Among those assessed, veterans who had their surgical amputations at facilities with onsite SRUs were nearly 4 times more likely to have been admitted to higher intensity specialized rehabilitation. This finding was evident when controlling and not controlling for patient and clinical differences. This higher admission rate does not appear strongly related to case mix differences. Indeed, veterans who received amputations in VAMCs without SRUs were clinically quite similar to those who had their surgical amputations at VAMCs with SRUs as confirmed by the remarkably comparable diagnostic mix. The longer medical and surgical bed lengths of hospitalization of amputees treated in VAMCs with onsite rehabilitation beds suggest either that patients were clinically more severe (and the severity was not captured by the variables available) or that they received more complicated procedures that lengthened their stays. Longer total LOSs in facilities with SRUs also reflect the time spent waiting for an available bed on an SRU or the time being treated in the SRU. ICD-9-CM codes provide information about diagnoses but measure degree of severity poorly. Level of amputation, a good approximation of limb ischemia, is also affected by local surgical practices and decision making. It is noteworthy that there was a trend toward more distal amputations at VAMCs with onsite rehabilitation units. Those VAMCs also tend to be larger centers with presumably more specialized and comprehensive acute care services available.

Our results are consistent with others who have found that the availability of postacute care services, such as inpatient rehabilitation, is a more powerful predictor of postacute care use than the availability of rehabilitation services available. Moreover, over the past several years, there has been approximately a 10% decline in specialized rehabilitation admission rates in the private sector. In 2004, less than 8% of patients with amputation of the lower extremity were discharged from SRUs, which is even lower than the rate for VAMCs without onsite SRUs in our study (11%) implying treatment disparities both between the VA and private sectors and within the VA. It is possible that the higher rates of discharge from SRUs in the VA are the result of the VA national performance measures driving the practice of obtaining at least an initial functional assessment of large numbers of veterans with amputations. With that initial assessment, greater numbers of patients may be identified as needing the higher-intensity focus of an inpatient rehabilitation program.

The assessment of rehabilitation potential involves addressing candidacy for various levels of rehabilitation. A transfemoral or transfemoral amputation does not presuppose rehabilitation need. It is rather the manifestations of any number of diagnoses and the combination of these diagnoses in conjunction with environmental factors that drive the need for particular types and intensities of rehabilitation. By requiring, at a minimum, an initial rehabilitation assessment after amputation surgery, the VA is helping to ensure that all veterans with a lower-extremity amputation have at least the opportunity to be evaluated for their ongoing rehabilitation needs. In all likelihood this would lead to provision of therapy services, if not necessarily specialized inpatient rehabilitation care. Specialized rehabilitation treatment has been shown to be effective among stroke patients in terms of process and outcomes. More intensive rehabilitation treatment could be effective in our amputee population; however, future studies are needed to confirm this. Clinical traits that are both statistically and clinically important determinants of rehabilitation need should be used in deciding on the use of expensive resources such as an SRU. Higher rates of SRU use within the VA do not necessarily imply optimal use of services. Availability of rehabilitation services, although strongly predictive of receiving that service, is distinct from the clinically important factors that should be driving the decision-making process. Additional studies are needed to fully understand the benefits of SRUs and to ensure the best possible identification of the patients who would most benefit from that level of care.

Study Limitations

This study has a number of limitations. Only 3 levels of rehabilitative care were addressed. The full rehabilitation continuum encompasses home care and outpatient care, and future studies need to consider referral processes within and through all levels of rehabilitation. Additionally, the study was limited to veterans, and the results may not be applicable to the larger U.S. population. Because this study was not a randomized trial, causality cannot be inferred. Yet the findings make intuitive sense. Moreover, our structure and process variables were global. The presence versus absence of an SRU at the VAMC where amputation occurred implies greater accessibility of high-level rehabilitation services but says nothing about the contents of those services or their influence on patient outcomes. In addition, patients who did not receive inpatient rehabilitation treatment evidenced by an FSOD record from the VA may have sought treatment in the private sector. However, with only VA data available to us, we were unable to compare outcomes between VA and non-VA rehabilitation patients. Further studies with a more comprehensive perspective will be essential to address all the components of services within the rehabilitation continuum with regard to their influence on patient outcomes. Moreover, it will be essential to determine if
lack of easy access to specialized rehabilitation beds is generating similar service disparities in Medicare supported hospitals within the private sector. Without operation of the performance indicator formally addressing the need for rehabilitation services, it would be reasonable to assume that access disparities would be even greater.

CONCLUSIONS

The presence of an SRU within a larger medical center does not impact consultation rates for rehabilitation within the VA, but does affect admission to the specialized unit for veterans with lower-extremity amputations. The structure of rehabilitation services strongly influences the intensity of rehabilitation services received once patients enter the continuum. Future studies of outcome differences across generalized consultation only and specialized rehabilitation services are essential in addressing the implications of these findings. Clinicians need to recognize that the presence or absence of SRUs may influence referral patterns in ways that are not clinically equitable.

Acknowledgment: The opinions and conclusions of the authors are not necessarily those of the sponsoring agencies.

References

Supplier
a. Version 9.1; SAS Institute Inc. 100 SAS Campus Dr, Cary, NC 27513.
Musculoskeletal Disorders in Referrals for Suspected Cervical Radiculopathy

Daniel E. Cannon, BS, Timothy R. Dillingham, MD, Haiyan Miao, MS, Michael T. Andary, MD, Liliana E. Pezzin, PhD


Objectives: To determine (1) the prevalence of selected common musculoskeletal disorders in patients referred for electrodiagnosis when cervical radiculopathy is suspected and (2) whether these findings predict electrodiagnostic study outcome.

Design: Prospective study.

Setting: Electrodiagnostic laboratories in departments of physical medicine and rehabilitation at 5 participating institutions.

Participants: A total of 191 subjects undergoing electrodiagnostic evaluations for upper-limb symptoms when cervical radiculopathy was suspected.

Interventions: Not applicable.

Main Outcome Measures: Prevalence of certain musculoskeletal disorders (myofascial pain, shoulder impingement, lateral epicondylitis, de Quervain’s tenosynovitis) and outcomes of electrodiagnostic testing (normal study, cervical radiculopathy, or another electrodiagnostically confirmed diagnosis).

Results: The total prevalence of musculoskeletal disorders was 42%. The prevalence in those with a normal study was 69%, compared with 29% in those with cervical radiculopathy (P<.001) and 45% in those with another diagnosis (P=.02).

Conclusions: Musculoskeletal disorders are common in patients with suspected cervical radiculopathy. Although the presence of certain musculoskeletal disorders makes having a normal electrodiagnostic evaluation significantly more likely, the high prevalence among both patients with normal studies and those with cervical radiculopathy and other disorders limits the usefulness of this information in precisely predicting study outcome. The presence of musculoskeletal disorders should not preclude electrodiagnostic testing when otherwise indicated.

Key Words: Electrodiagnosis; Musculoskeletal diseases; Radiculopathy; Rehabilitation.

FOR PERSONS WITH NECK and upper-limb symptoms referred to an electrodiagnostic lab, the clinician considers the diagnostic possibilities and structures the study accordingly. Suspected radiculopathy is a common reason patients are referred for electrodiagnostic evaluation.1-3 Cervical radiculopathy is a pathologic condition of the cervical spinal nerve roots. It usually presents with pain in the neck and radiating down the arm and numbness and paraesthesia distally.4 The distribution of symptoms depends on the nerve root(s) affected.5 Likewise, musculoskeletal disorders are common causes of upper-limb symptoms.6,7 and they can be mistaken for radiculopathy.8-10

This study examined the following musculoskeletal disorders of the upper-limb: myofascial pain, shoulder impingement syndrome, de Quervain’s tenosynovitis, and lateral epicondylitis. Although other disorders that mimic radiculopathy could have been considered, these were included because they are common conditions and can be diagnosed based on physical exam findings.

Myofascial pain is characterized by pain in skeletal muscles that originates from trigger points, areas within the muscle that are highly sensitive and reproduce the patient’s symptoms when palpated.11,12 The pattern of symptoms seen could mimic radiculopathy at several levels, depending on the muscles and fascia involved. Shoulder impingement occurs when there is excessive dynamic tendon overuse and inflammation resulting in painful overhead arm movement from compression of these tendinous structures by the coracoacromial arch. Positive shoulder impingement signs are diagnostic for this syndrome. The pain is exacerbated by abducting and internally rotating the glenohumeral joint, which can occur when sleeping with the arm overhead or combing one’s hair.13,14 The presence of symptoms at the shoulder could mimic a C5 radiculopathy, for example. De Quervain’s tenosynovitis is caused by narrowing of the first dorsal compartment of the wrist (containing the abductor pollicis longus and extensor pollicis brevis tendons). It presents with pain on the radial side of the wrist (potentially mimicking a C6 radiculopathy) and impairment of thumb function and is identified through a Finkelstein maneuver.15,16 Lateral epicondylitis (also known as tennis elbow) is characterized by pain at the lateral aspect of the elbow that can radiate into the forearm, similar to the pattern of symptoms one may see with a C6 radiculopathy. The pain is reproduced with palpation of the extensor muscles over the lateral epicondylye.17,18

At present, the prevalence of musculoskeletal disorders in patients referred for electrodiagnostic evaluation is unknown. The purpose of this study was to determine the prevalence of these selected common upper-limb musculoskeletal disorders in patients referred for electrodiagnostic testing. Further, although there are studies examining the predictive ability of physical exam on electrodiagnosis,19-21 in this study the influ-
ence of these specific musculoskeletal disorders on electrodagnostic study outcome prediction was examined.

METHODS

Participants

We conducted a prospective study between May 1996 and May 1998 at the following medical centers that treat diverse patient populations and have high volume physical medicine and rehabilitation (PM&R) electrodagnostic services: The Johns Hopkins University, Baltimore, MD; Ingham Regional Medical Center affiliated with Michigan State University, East Lansing, MI; Madigan Army Medical Center, Tacoma, WA; Womack Army Medical Center, Fort Bragg, NC; and Walter Reed Army Medical Center, Washington, DC. Patients who were referred to the electrodagnostic laboratories in the department of PM&R at one of these medical centers for upper-limb symptoms when cervical radiculopathy was suspected were asked to participate. Subjects participated on a voluntary basis after signing written informed consent. The institutional review committee at each of the participating institutions approved the study protocol.

Data Collection

We implemented standardized procedures and data collection sheets at all participating institutions. Patients completed a questionnaire, which collected detailed information and medical history. A standardized physical examination, performed on all subjects, consisted of the following: (1) a neurologic examination, including manual muscle testing, sensation (vibration and pinprick), and reflex assessments; (2) a musculoskeletal examination; and (3) special tests, such as the Tinel sign and Phalen maneuver. After the questionnaire and physical examination, electrodagnostic evaluations conducted by attending physicians and/or supervised resident physicians were performed for all patients. All co-investigators were certified by the American Board of Electrodagnostic Medicine and were skilled musculoskeletal physicians. Such expertise was sought to ensure that electrodagnostic and physical exam findings across participating centers were consistently interpreted.

We administered a standard set of physical examination tests for all patients to identify the presence of musculoskeletal disorders of interest. Myofascial pain was diagnosed for the purposes of this study if palpation of the neck or shoulder region reproduced symptoms.12,13 Shoulder impingement was deemed present if crossed adduction, forward flexion, or abduction with internal rotation of the shoulder reproduced symptoms.13 Lateral epicondylitis was diagnosed if palpation of the wrist extensor muscles reproduced pain.24 De Quervain’s tenosynovitis was diagnosed if a Finkelstein test was positive.24 Each subject had these specific musculoskeletal examination tests performed as a standardized part of the study along with the neurologic testing described above. Other clinical assessments were done as part of the overall consultation at the discretion of the electrodagnosticians, who used their clinical expertise and experience to guide the course of the exam and make the final diagnostic conclusions.

The standardized electrodagnostic study consisted of at least the following: (1) 1 upper-limb motor nerve conduction study, (2) 1 upper-limb sensory nerve conduction study, and (3) needle electromyography with either monopolar or concentric needles of a standard set of 10 muscles. Additional tests were used to evaluate the suspected condition at the discretion of the physician performing the evaluation. The electrodagnostic conclusions and study outcomes were classified in 3 mutually exclusive categories: (1) normal study, (2) cervical radiculopathy, or (3) other diagnosis established by electrodagnostic testing. A stratified data collection strategy was used to recruit sufficient persons in each category because these proportions in the referral population were different.

Cervical radiculopathy was diagnosed using previously established methods.25 Specifically, cervical radiculopathy was considered present if electromyographic findings (spontaneous activity, increased polyphasias, complex repetitive discharges, or reduced recruitment) were found in 2 or more muscles innervated by the same nerve root but with different peripheral nerves, or if the paraspinal muscles showed spontaneous activity. Other diagnoses included plexopathy, median neuropathy (carpal tunnel syndrome), ulnar neuropathy, radial neuropathy, and polyneuropathy. These conditions were identified using nerve conduction and electromyographic findings by the electrodagnostic consultant. For all analyses, electrodagnostic outcomes—normal study, radiculopathy, or other diagnosis—were then analyzed as they related to the presence of the musculoskeletal disorders of interest.

Data Analysis

We used SASa for Windows to compare the prevalence of musculoskeletal disorders between study groups using chi-square analysis or the Fisher 2-sided exact test. To further examine the influence of musculoskeletal conditions on study outcome, a multivariate analysis was undertaken using Stata.b Age, sex, and duration of symptoms were controlled for to eliminate any potential confounding effect that these variables may have had on the outcome of the analysis. Study outcomes were defined as normal study (reference category), cervical radiculopathy, or other diagnosis.

RESULTS

There were 191 subjects included in the study, with 52% having a radiculopathy, 24% a normal study, and 25% another condition identified through electrodagnosis. The mean age ± standard deviation was 49 ± 16 years and 54% were men. The average duration of symptoms reported by the subjects was 20±34 months. The prevalence of the selected musculoskeletal disorders in the study sample by diagnostic category is shown in table 1. Among those diagnosed with radiculopathy, only 2% were diagnosed based on paraspinal findings alone; the majority had electromyographic findings in 2 or more muscles consistent with the diagnostic criteria.

The total prevalence of the musculoskeletal disorders was 42%. The prevalence in those with a normal study was 69%, compared with 29% in those with cervical radiculopathy (P<.001) and 45% in those with another diagnosis (P=.02). Multivariate analyses revealed that the presence of myofascial pain meant about one fifth the likelihood of having cervical radiculopathy compared with a normal study (P=.002), the presence of shoulder impingement meant about one fifth the likelihood of having cervical radiculopathy compared with a normal study (P=.007), and the presence of myofascial pain meant about one third the likelihood of having another diagnosis compared with a normal study (P=.017), given that other variables in the model were held constant.

DISCUSSION

Musculoskeletal disorders are common in patients suspected of having a cervical radiculopathy. However, within the study sample there were significant differences in the prevalence of musculoskeletal disorders when subjects were grouped accord-
ing to the outcome of their electrodiagnostic studies. Over two thirds of patients (69%) with normal studies had a musculoskeletal disorder diagnosed based on physical exam findings. In comparison, 29% of those with a confirmed cervical radiculopathy ($P<.001$) and 45% of those with other electrodiagnostic diagnoses ($P=.02$) had a musculoskeletal disorder.

Although the presence of a musculoskeletal disorder suggests that a patient will have a normal study, the fairly high prevalence of musculoskeletal disorders in those with a confirmed cervical radiculopathy or another electrodiagnostic condition limits the usefulness of this information in predicting the results of an electrodiagnostic study. A study should not be curtailed solely on the basis of finding a musculoskeletal disorder on physical exam. In patients referred to the electrodiagnostic laboratory it is common to have these separate problems.

Myofascial pain in particular was common among those with a normal study (53%), and significantly more common than in those with a confirmed cervical radiculopathy (17%, $P<.001$) or other electrodiagnostic conclusions (19%, $P<.001$). This result could be an indication of the difficulty in distinguishing between myofascial pain and cervical radiculopathy or other neurologic disorders and the degree to which they mimic each other. The referred pain patterns seen in myofascial pain can be very similar to the dermatomal patterns of the spinal nerve roots. Therefore, it is possible that many patients being referred for electrodiagnostic evaluations actually have myofascial pain, either alone or along with radiculopathy. In such cases, an electrodiagnostic evaluation can help clarify the nature of the problem.

Shoulder impingement had a similar prevalence both in those subjects with a normal study (31%) and those with other electrodiagnostic conclusions (30%), but was significantly less common in those with a cervical radiculopathy (9%, $P<.001$) compared to those with a normal study. This finding may be a reflection of the difficulty in distinguishing pain due to shoulder disorders from referred pain to the shoulder due to cervical radiculopathy, similar to the difficulty in distinguishing between myofascial pain and radiculopathy proposed earlier. Both cases emphasize the importance of electrodiagnostic testing in helping to distinguish between upper-limb musculoskeletal disorders and cervical radiculopathy when evidence is present for both conditions and treatment strategies for the musculoskeletal disorder are not effective. However, electrodiagnostic studies are not advocated for all patients with musculoskeletal disorders. Rather, the clinician should consider the possibility of radiculopathy or other disorders even in the presence of such conditions.

It is possible that there was some level of overcall for these musculoskeletal conditions given the nature of the prospective study and the careful and systematic examination for these conditions. In addition, there are interrater differences in physical examination even for skilled practitioners that could influence our findings. For example, the exact finger pressure used to elicit findings during palpation was not standardized. Further, the study design allowed for some subjectivity in the diagnosis of musculoskeletal conditions, relying on the expertise of the participating examiners. More specific pre-established diagnostic criteria would have made the diagnosis more objective.

Also, it is possible that the musculoskeletal conditions diagnosed were unrelated to the reason prompting the electrodiagnostic referral. Further studies examining the relationship between referral reasons, musculoskeletal disorders present, and electrodiagnostic outcomes would help clarify the clinical significance of this issue. However, whether or not the referral reasons were related to the musculoskeletal and electrodiagnostic conclusions, the main purposes of the study (namely, to determine the prevalence of the musculoskeletal conditions in the referral population and whether they predict the electrodiagnostic conclusions) are unaffected.

Finally, the underlying pain system and peripheral nervous system physiology is quite complex and interrelated. These systems may augment the pain responses and perceptions in persons with radiculopathies or entrapment neuropathies such that physical exam maneuvers are perceived as more painful than they otherwise might be in persons without these conditions.

Neither lateral epicondylitis nor de Quervain’s tenosynovitis showed any significant differences across study groups. However, the prevalence of each of these 2 disorders in the study sample was higher than the prevalence in the general population, as one would expect in a sample of patients being referred for evaluation of upper-limb symptoms.

The multivariate analysis showed that the presence of myofascial pain lowers the probability of finding a cervical radiculopathy or another condition through electrodiagnostic testing, and that the presence of shoulder impingement syndrome makes finding a cervical radiculopathy less likely. These findings provide some indication about the outcome of electrodiagnostic testing in patients diagnosed with these conditions, but not enough to accurately predict the results.

The findings are in line with what was concluded in other studies on the predictive ability of physical exam on electrodiagnostic outcome. Physical exam findings are important and helpful in guiding the course of an electrodiagnostic study, but are not sufficient to predict what the outcome of the study will be. Similarly, the presence of musculoskeletal disorders gives some indication about the outcome of an electrodiagnos-
tic study but does not provide enough information to definitively predict the results of the study.

CONCLUSIONS

Musculoskeletal disorders are common in patients referred for electrodagnostic assessment of cervical radiculopathy. However, the presence of a musculoskeletal problem does not accurately predict who will have a normal electrodagnostic study or an electrodagnostically confirmed cervical radiculopathy with sufficient discriminative ability to curtail the electrodagnostic evaluation. Although there is significantly higher prevalence in those with a normal study compared to those with cervical radiculopathy and other electrodagnostic conclusions, the fairly high prevalence in all groups makes it difficult to predict the outcome of electrodagnostic testing based on the presence of musculoskeletal disorders.

References


Suppliers

a. Version 9.1; SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.
b. Version 9.0; StataCorp, 4905 Lakeway Dr, College Station, TX 77845.

Objective: To measure disability-related stress through the development of the Physical Disability Stress Scale (PDSS) for wheelchair users.

Design: Cross-sectional.

Setting: General community.

Participants: Sample of 119 wheelchair users with an acquired physical disability.

Interventions: Not applicable.

Main Outcome Measures: General Health Questionnaire-28 (GHQ) and the World Health Organization Quality of Life (WHOQOL-BREF) (Australian version).

Results: Factor analysis of PDSS items revealed 4 main factors of disability-related stress: access accounted for 33.7% of the variance, physical for 8.4% of the variance, social for 7.9% of the variance, and burden of care for 7.2% of the variance. Internal consistencies for the 4 factors were within acceptable ranges (α range, .78-.83). Concurrent validity was shown with the PDSS factors predicting 7% to 23% of the variance in GHQ subscales and total score and 12% to 31% of the WHOQOL-BREF subscales. Participants scoring in the GHQ psychiatric group showed significantly higher stress levels on the physical, social, and burden of care factors of the PDSS compared with the GHQ nonpsychiatric group.

Conclusions: The results suggest the PDSS factors are valid measures of disability-related stress with potential for clinical and research applications. Confirmatory factor analyses with larger sample sizes of wheelchair users are required to establish consistency in the measurement of disability-related stress.

Key Words: Psychometrics; Questionnaires; Rehabilitation; Spinal injuries; Stress.

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The current study reports on the development of a scale to measure disability-related stress in relation to wheelchair users who have an acquired physical disability. There are approximately 17 million wheelchair users in the United States, representing 0.6% of the total population. The research that has been conducted worldwide has largely focused on people who have sustained spinal cord injuries (SCIs), post-polio syndrome (PPS), and multiple sclerosis (MS). Research shows that acquiring a physical disability either through disease or injury can result in significant losses or changes in physical functioning, mobility, social relationships, employment, health care, and living environments. There may be considerable emotional and financial stress on the affected person, their family members, and carers.

These levels of stress are important to measure given the contribution of stress on health and quality of life (QOL). Chronic stress, in particular, has been shown to predict higher levels of psychologic distress in both disabled and nondisabled adults and can affect disease progression in conditions such as MS and PPS by exacerbating muscle weakness and fatigue. In addition, some research has shown that areas of disability-related stress may be more stressful than nondisability-related stress in subjects with PPS. Research on SCI shows that time since injury does not appear to moderate psychologic adjustment to disability. Instead, distress has been associated with recent life events, which were appraised as stressful, and, different stressful life events are reported across the lifespan (highlighting the chronic nature of disability-related stress).

For the purpose of this study, “disability-related stress” is defined as the unique stress experienced by wheelchair users who have an acquired physical disability. It is proposed that the development of a valid measure of disability-related stress used in clinical or research settings would provide further insight and awareness into the intensity of the stress experienced by wheelchair users. It would allow pre- and postassessments of individual or group interventions and rehabilitation aiming to decrease stress through greater adjustment to disability factors. On an individual level, high scores on a particular factor(s) may help clinicians to modify therapy to a client’s particular needs or areas of stress.

Through the development of the Coping with Multiple Sclerosis Scale (CMMS), Pakenham found that the greatest psychosocial problems for people with MS were physical (eg, fatigue, sensory, bladder and bowel symptoms), emotional (eg, depression, anger and frustration), instrumental (eg, daily living activities, employment, access), and relationship problems (eg, with family members, partner, and friends). Participants reported multiple main problems, sometimes across categories. Although the CMMS did not aim to measure actual levels of stress, its development was useful in highlighting that people with MS have a range of stressful life factors specific to their condition.

Similarly, Manns and Chad, by using semistructured interviews, found QOL for people with SCI consisted of 9 themes: (1) physical function and independence, (2) accessibility, (3) emotional well-being, (4) stigma, (5) spontaneity, (6) relationships and social function, (7) occupation, (8) finances, and (9) physical well-being. Psychosocial stress and reductions in QOL were found by Manns and Chad to be more prevalent when the subjects identified difficulties or limitations in these

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themes. These studies indicate that very similar avenues of disability-related stress are experienced by wheelchair users regardless of the origin of the disability. In addition, these domains of disability-related stress found by Pakenham and Manns and Chad resonate with the World Health Organization (WHO) International Classification of Functioning, Disability and Health (ICF), which recognizes the impact of the social and physical environment on a person’s functioning.

Currently, there is a paucity of studies that have examined the use of self-report measures to assess levels of disability-related stress in people with acquired physical disabilities. Groomes developed the Stress Appraisal Inventory for Life Situations (SAILS) to measure how people with a physical disability might appraise hypothetically stressful situations that they may or may not have experienced. However, the SAILS was not designed to measure a person’s actual level of disability-related stress. Trendle developed the Life Problems Scale (LPS) by modifying the existing Daily Hassles Scale. The LPS consists of 29 items but is not a pure measure of disability-related stress because only 7 items are disability specific. Last, Bramston and Mioche used a measure of intellectual-disability stress (the Lifestress Inventory) to measure physical-disability stress, finding it was not an optimal measure for people with physical disabilities.

Establishing criterion-related validity of new measures requires concurrent examination of well-established, highly related constructs. We aimed to use well-established measures of self-reported general health and QOL to validate the new Physical Disability Stress Scale (PDSS) measure. This decision was supported by the empirical and theoretical evidence that has shown a strong relationship between the construct of stress and the constructs of health and QOL.

Both acute stress and chronic stress have been found to be predictive of a range of health outcomes. Correlating the PDSS with an established general measure of stress was considered as another possible method of assessing its validity. However, it has been argued that general measures of nondisability stress are largely measuring a construct that is quite independent of disability-related stress and thus any attempt at showing a relation may be a poor indication of the validity of the PDSS.

In summary, there is currently no valid instrument to measure disability-related stress unique to wheelchair users. Given the significant proportion of persons that use wheelchairs as their main form of mobility and the prevalence of supportive research highlighting the relation between stress, physical health, and QOL, the development of such a measure is timely.

The current study was largely exploratory in nature and aimed to use participant’s responses to (1) discover which areas of disability life are most commonly stressful to wheelchair users and (2) to measure the intensity of disability-related stress through the development of the PDSS. The final aim was to test the concurrent validity of the PDSS with the clinically significant and related constructs of self-reported QOL and general health. Specifically, it was predicted that higher levels of disability-related stress would be associated with lower levels of self-reported QOL and poorer health.

METHODS

Participants

Participants responded to advertisements in disability-related newsletters and magazines requesting volunteers to participate in the research project. People were also recruited through local newspapers and radio stations. The final participants were 119 adults who had an acquired physical disability and who required the use of a wheelchair as their main source of mobility.

The average length of wheelchair use ± standard deviation (SD) was 16.18±13.63 years (range, 0.5–72y). Six respondents were excluded from the study because they did not fully meet these criteria. There were 71 men and 48 women, with an average age of 50.5 years (range, 18–82y). There was a diverse range of disability among the participants: 31.9% identified with paraplegia, 23.6% with quadriplegia, 11% with PPS, 8.5% with neurologic disorder, 5.9% with arthritis and pain, and 5.0% with MS. Approximately 39% of participants were single, 34% were married, and 17.6% divorced or separated. Subjects were generally well educated and in full-time or part-time employment or retired. Fifteen percent of the subjects indicated they were unemployed or received the Disability Support Pension.

Procedure

Phase 1: development of the instrument. The common areas of disability-related stress were established through the development of an initial survey in which participants provided written information regarding the top 5 most stressful aspects of having a physical disability. The participants were asked to rank their written statements from 1 to 5 in order of most stressful to least stressful. This information was gathered from the first 25 people to respond to advertisements. The respondents were 13 men and 12 women (age range, 25–72y), with SCI or PPS being the predominant disabilities. These 25 respondents were invited to participate in phase 2 of the study; however, because the questionnaires were anonymous, it is unknown how many of the initial 25 respondents are included in the final sample of 119.

Once the initial surveys were returned, the 2 chief researchers independently read the written responses and generated a list of the common areas of disability stress. The individual lists were then compared and areas of agreement and disagreement examined. This resulted in the generation of a list of the most commonly reported areas of disability-related stress. In particular, time was spent on the wording of domains such that they most accurately captured the information provided.

The written responses from participants were reread by the researchers and 2 volunteer raters from nondisability-based backgrounds. Responses were categorized into the nominated domains. Domains with less than 10 responses were discarded, leaving only those domains that have been mentioned most frequently and thus by most people. The final 5 domains were as follows: (1) access, (2) perceptions and attitudes of others, (3) social and sexual relationships, (4) physical health, and (5) adjustment and loss of independence. Specific items were written for each of these final domains and, when possible, the wording of items was based on specific statements made by participants in their written responses. A colleague with a disability then provided independent feedback to ensure the wording of the items was clear and nonoffensive. Forty items were generated with 7 to 9 items under each domain. The items were then randomized. This process of instrument development is based on recommendations by Jackson and Furnham.

In completing the questionnaire, participants were asked to think about the disability-specific situations mentioned in the items and to indicate how stressful these situations are for them on a scale of 1 to 5 (1, not at all; 2, slightly; 3, moderately; 4, considerably; 5, highly). Participants were also given the option of circling NA (not applicable) for situations they have not experienced. Many investigations in psychologic assessment have focused on rating scales with adjectival descriptions. The main advantage of this format is that it makes sense to the respondent and can therefore be easily completed. Jackson and Furnham recommend that the minimum number of categories
used by raters should be in the region of 5 to 7 because reliability coefficients drop as fewer or greater numbers of categories are used. The final instrument was called the PDSS.

Phase 2: administration of the instruments. The PDSS and other measures were sent via mail to participants. Other measures included the General Health Questionnaire (GHQ-28) and the WHO Quality of Life (WHOQOL-BREF) Australian version. The GHQ-28 is a 28-item, self-administered screening test that assesses severe depression, anxiety and insomnia, social dysfunction, and somatic symptoms. The GHQ-28 can be used to establish presence of psychiatric illness in a population. By using the GHQ total score, respondents may have had physical difficulty completing the longer version. The Australian WHOQOL-BREF contains 26 items that are rated on a 5-point scale. There are 4 domains: physical, psychological, social relationships, and environment domains, and all show good internal consistency and test-retest reliability. For the purposes of this study, this instrument will be referred to as the QOL measure.

Statistical Analysis

Principal components analysis (PCA) was used to explore the factor structure of the PDSS. Multiple regression analyses, multivariate analysis of variance (MANOVA), and analysis of variance were used to assess concurrent validity with self-reported mental health and QOL measures. The SPSS was used to conduct these analyses. Tabachnick and Fidell reported that PCA has “fair” to “good” power with subject numbers between 200 and 300; however, comparative studies involved in instrument development have used smaller sample sizes of around 100. In addition, Guadagnoli and Velicer noted that the required sample size for a factor analysis depends on the size of population correlations and number of factors, with less cases required if there are several high loading marker variables (> .80).

RESULTS

Data Screening and Diagnostics

Before analyses, data were screened for inaccuracies in data entry, missing values, outliers, and the fit between distributions and the assumptions of multivariate analysis. Mean substitution (by series) was used to replace the missing values that were less than 5%. An extreme outlier found on the GHQ variable was deleted after preliminary analyses, which revealed that it affected the statistical significance of some GHQ analyses.

As may be expected in a population that has chronic medical and physical concerns, the GHQ and QOL variables were moderately skewed and shown to be significantly high in positive kurtosis across some subscales. Given the proposed parametric analyses, a series of logarithmic transformations were conducted to normalize the data. Nontransformed data results were compared with transformed data results. No differences in statistical significance or interpretation of the analyses were observed. For this reason, findings from the original data were reported. This also had the benefit of preserving the significance of the clinical distribution. Finally, 2 items were deleted before factor analysis because of the high frequency in which respondents had nominated these items as “not applicable.” Factor analyses were conducted on the remaining 38 items.
Development of the PDSS

Principal components analysis. Before analysis, an inspection of the item correlation matrix revealed a number of significant coefficients. A Kaiser-Meyer-Olkin value of .82 indicated that partial correlations were small. Bartlett’s test of sphericity, sensitive to zero-order correlations in the correlation matrix, reached statistical significance ($\chi^2_{63} = 2311.04, P < .001$). This indicated factorability of the data.

Because it was expected that the factors would be related, a PCA with an oblique rotation (obliminal rotation with Kaiser normalization) was performed. The PCA revealed 9 factors; the first 4 of these closely resembled the factors that had been created in the initial instrument development following phase 1 responses. The last 5 factors consisted of only 2 items in each factor and were considered uninterpretable.

A second PCA was performed to force the extraction of the 5 a priori factors. An oblique rotation was performed (obliminal rotation with Kaiser normalization) to account for the expected correlations between the factors. The first 4 of the resulting factors showed a strong resemblance to the original factors; however, the fifth factor consisted of only 2 items with eigenvalues greater than .4. These items had low internal consistency (α=.18) and were considered uninterpretable. The fifth factor was thus deleted. The remaining 4 factors showed significant correlations ($r$ range, .308-.715; $P<.01$).

Analysis of the 4 factors indicated that a further 14 items met criteria for exclusion from the item set, thus leaving 22 items. Items were excluded if they showed (1) eigenvalues less than .4 or (2) significant loading on more than 1 factor. A total of 18 items were removed from the original 40 items. Deleted items can be obtained from the authors by request. Table 1 shows the factor loadings of the remaining items on their factors. Comrey and Lee suggested that factor loadings in excess of .71 are considered excellent, .63 very good, .55 good, .45 fair, and .32 poor. The first factor, labeled access, accounted for 33.7% of the variance and represented the aspect of physical access and reduced motility (independent and spontaneous movement) in and out of environmental structures. The second factor, labeled physical, accounted for 8.4% of the variance and refers to the stress of reduced bodily movements and functional ability. On a broader level, this factor also refers to the stress of reduced involvement in physical activities and to the decreased ability to individually contribute to group tasks. The third factor, labeled social, accounted for 7.9% of the variance and covers the area of stress that is experienced through social stigma and social interactions with other members of society. This factor also encompasses the stress associated with sexual relationships, friendships, and changes to social activities. Finally, the fourth factor, labeled burden of care, accounted for 7.2% of the variance and relates to the stress and burden of having and managing numerous health care needs and of relying on others to help in health care areas (see appendix 1 for the PDSS and scoring instructions).

Internal consistencies for the 4 factors were within acceptable ranges ($\alpha$ range, .78-.83), indicating homogeneity of the scale. Table 2 outlines the properties and internal consistencies of the PDSS, including floor and ceiling statistics.

Concurrent Validity of the PDSS

A series of multiple regression analyses were conducted to investigate the relation between the PDSS measure and measures of general health and self-reported QOL. It was predicted that higher levels of disability-related stress would be associated with lower levels of QOL and poorer health, and lower levels of disability-related stress would be associated with higher levels of QOL and better health.

The relationship between the PDSS and GHQ. Table 3 summarizes the findings from 5 multiple regression analyses performed by using PDSS factors entered simultaneously as predictors of the 4 GHQ subscales and the GHQ total score. As reported in table 3, 7% to 23% of the GHQ subscales and 17% of the GHQ total score were predicted by scores on the PDSS factors. The burden of care factor was the best predictor of variance on the GHQ total score and on all the GHQ subscales other than the social dysfunction subscale (which was best predicted by physical). Some of the variance in GHQ severe

### Table 2: Internal Consistencies and Other Properties of the PDSS (N=119)

<table>
<thead>
<tr>
<th>PDSS Factors</th>
<th>No. of Items</th>
<th>Minimum (% min)</th>
<th>Maximum (% max)</th>
<th>Mean ± SD</th>
<th>Cronbach $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>4</td>
<td>0 (0)</td>
<td>20 (7.6)</td>
<td>14.95 ± 4.1</td>
<td>.79</td>
</tr>
<tr>
<td>Physical</td>
<td>5</td>
<td>0 (0)</td>
<td>25 (9.2)</td>
<td>18.51 ± 4.8</td>
<td>.82</td>
</tr>
<tr>
<td>Social</td>
<td>7</td>
<td>0 (0)</td>
<td>35 (0)</td>
<td>21.89 ± 6.8</td>
<td>.83</td>
</tr>
<tr>
<td>Burden of care</td>
<td>6</td>
<td>0 (0)</td>
<td>30 (0.8)</td>
<td>18.80 ± 5.0</td>
<td>.78</td>
</tr>
</tbody>
</table>

### Table 3: PDSS Factors as Predictors of the GHQ Subscale (N=119)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Somatic Symptoms</th>
<th>Anxiety and Insomnia</th>
<th>Social Dysfunction</th>
<th>Severe Depression</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDSS</td>
<td>$R^2$</td>
<td>$R^2$</td>
<td>$R^2$</td>
<td>$R^2$</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Access</td>
<td>.07</td>
<td>.15$^*$</td>
<td>.10$^*$</td>
<td>-.05</td>
<td>-.23$^*$</td>
</tr>
<tr>
<td>Physical</td>
<td>-.11</td>
<td>.04</td>
<td>.22$^*$</td>
<td>.28$^*$</td>
<td>.14</td>
</tr>
<tr>
<td>Social</td>
<td>-.01</td>
<td>.07</td>
<td>-.19</td>
<td>.11</td>
<td>.02</td>
</tr>
<tr>
<td>Burden of care</td>
<td>.25$^*$</td>
<td>.32$^*$</td>
<td>.24</td>
<td>.27$^*$</td>
<td>.35$^*$</td>
</tr>
</tbody>
</table>

$^*$ $P<.05$.

$^1$ $P<.01$.

$^2$ $P<.001$. 

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depression was additionally accounted for by the access and physical factors. Classification of participant’s scores on the GHQ into psychiatric or nonpsychiatric “caseness” groups allowed for a comparison across PDSS factors. MANOVA revealed an overall psychiatric group effect (Hotelling $T^2 = 14.14$, $F_{4,114} = 3.98$, $P < .01$). Follow-up univariate analyses indicated that those in the psychiatric group showed significantly higher stress levels in areas of physical, social, and burden of care, whereas those in the nonpsychiatric group showed lower stress scores on these factors (table 4). There were no differences between psychiatric and nonpsychiatric groups on the access factor.

### Table 4: Relation Between PDSS Factors and the Psychiatric and Nonpsychiatric Groups on the GHQ-28 (N=119)

<table>
<thead>
<tr>
<th>PDSS Factors</th>
<th>Group (GHQ-28)</th>
<th>Mean ± SD</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Nonpsychiatric</td>
<td>13.44±4.33</td>
<td>1.66</td>
</tr>
<tr>
<td></td>
<td>Psychiatric</td>
<td>14.49±4.52</td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td>Nonpsychiatric</td>
<td>16.75±5.14</td>
<td>4.80*</td>
</tr>
<tr>
<td></td>
<td>Psychiatric</td>
<td>18.83±5.02</td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>Nonpsychiatric</td>
<td>17.29±7.78</td>
<td>5.04*</td>
</tr>
<tr>
<td></td>
<td>Psychiatric</td>
<td>20.42±7.06</td>
<td></td>
</tr>
<tr>
<td>Burden of care</td>
<td>Nonpsychiatric</td>
<td>16.13±5.17</td>
<td>13.93</td>
</tr>
<tr>
<td></td>
<td>Psychiatric</td>
<td>19.61±4.77</td>
<td></td>
</tr>
</tbody>
</table>

NOTE. Degrees of freedom were 1,116 for all analyses of variance. $^*P < .05$. $^1P < .001$. $^2P < .01$.

The relationship of the PDSS to QOL. Table 5 summarizes the findings from 4 multiple regression analyses performed by using PDSS factors entered simultaneously as predictors of the 4 QOL subscales. As shown, 12% to 31% of the QOL subscales were predicted by scores on the PDSS factors. Specifically, physical accounted for the most variance in QOL physical health, whereas social was the best predictor of QOL social relations. The variance in QOL psychological health was best predicted by burden of care, physical, and access factors. Finally, 12% of the variance in the QOL environment subscale was predicted by the PDSS factors, with a trend for the burden of care factor to be the best predictor.

### Table 5: PDSS Factors as Predictors of the QOL Subscales (N=119)

<table>
<thead>
<tr>
<th>Measure</th>
<th>QOL Physical Health</th>
<th>QOL Psychological Health</th>
<th>QOL Social Relationships</th>
<th>QOL Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r^2$</td>
<td>$\beta$</td>
<td>$r^2$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>Access</td>
<td>.13$^1$</td>
<td>.22$^1$</td>
<td>.23$^*$</td>
<td>.26</td>
</tr>
<tr>
<td>Physical</td>
<td>-.28$^1$</td>
<td>.10</td>
<td>-.31$^1$</td>
<td>-.15</td>
</tr>
<tr>
<td>Social</td>
<td>-.19</td>
<td>-.35$^1$</td>
<td>-.07</td>
<td>-.64$^*</td>
</tr>
</tbody>
</table>

$^*P < .05$. $^1P < .01$. $^2P < .001$. $^4P < .10$ (for trend).

**DISCUSSION**

The aim of the current study was to examine the aspects of disability that are most commonly stressful to wheelchair users and to measure the intensity of disability stress through the development of the PDSS. Overall, the findings indicate that the PDSS is a valid measure of disability-related stress. It has shown a robust factor structure with data providing strong support for internal consistency and concurrent validity of the measure. Specifically, deletion of items that loaded onto more than 1 factor provided factors that were empirically distinct and had factor loadings that were on average “very good” and ranged from “fair” to “excellent.” In addition, factor internal reliabilities were within acceptable ranges indicating homogeneity of each scale. The 4 factors of the PDSS, access, physical, social, and burden of care, represented the most common areas of stress experienced by wheelchair users. The themes of the PDSS factors resonate with the WHO ICF, which highlights the importance of activity, participation, and environmental factors when measuring the impact of disability on a person’s life. The PDSS factors also show support for the themes found by Pakenham and Manns and Chad in their respective studies of coping with psychosocial problems and QOL in people with MS and SCI, respectively.

The validity of the PDSS and its factors was shown through their strong and significant relations with the GHQ and the WHOQOL-BREF measure. Specifically, high physical stress on the PDSS was strongly related to lower QOL in both physical and psychological health areas as well as to severe depression on the GHQ. High social stress on the PDSS was strongly related to lower QOL in social relations, and high burden of care stress showed a strong relation to lower QOL in psychological health. High stress on the burden of care factor was also strongly associated with the GHQ total score and 3 of the 4 GHQ subscales, which showed its overall strong link to general health domains.

In addition, those participants with high stress levels on the physical, social, and burden of care factors were more likely to have symptom levels that placed them in the psychiatric group as measured by the GHQ. Lower stress scores on these PDSS factors were more likely to be in the nonpsychiatric group. These findings support the relation between stress, physical health status, and mental health outcomes in people with physical disabilities.

It was not surprising that the access factor was not a strong predictor of general health and QOL compared with the other more health- and social-related PDSS factors that accounted for more of the variance in GHQ and QOL scores. The unexpected finding, however, was that high stress on the access factor was associated with lower depression scores on the GHQ and higher psychological QOL. Potentially, participants with higher access stress are more active and experience access issues more frequently than less active people but are also less depressed and have a higher QOL associated with this greater activity. Conversely, people with high depression and low QOL may be more withdrawn or avoidant of outside activities and may experience access issues to a much lesser degree.
These findings suggest that the inclusion of a frequency scale may provide further information as to how often a person experiences a particular disability-related stressor. The disadvantage of including a frequency scale is that it increases the length and the completion time of the questionnaire. In addition, previous studies have found significant multicollinearity between intensity and frequency scales resulting in frequency data being excluded from major analyses. The PDSS has potential application in the assessment, treatment planning, and evaluation of treatment for disability-related stress in wheelchair users. Although normative data from this study can be used to inform the patient profiles at assessment, it is more likely that service-specific data will be collected that will inform assessment and treatment planning. A person’s strengths and weaknesses can be identified and treatments tailored to meet these needs. After treatment, the PDSS can be readministered and scores examined. It is recommended that posttreatment instructions specifically state the period of time the questions refer to, which typically would be the duration of treatment (eg, the past 12wk). Test-retest reliability was not assessed in this study.

CONCLUSIONS

Based on a robust factor structure and significant concurrent relationships with important clinically relevant constructs, the PDSS is considered a valid measure of disability-related stress for wheelchair users. Although there were only few findings that were unexpected, these results provided potentially new insight into the relation between stress and disability and may indicate avenues for further research with the PDSS. An important research priority is to examine the PDSS in more heterogeneous samples to assess if the factor structure remains robust. Confirmatory factor analytic studies are warranted. Further research may also additionally examine more specific cognitive and emotional markers to determine their impact on and relation with the PDSS.

APPENDIX 1: PHYSICAL DISABILITY STRESS SCALE AND SCORING INSTRUCTIONS

Physical Disability Stress Scale

Below is a list of situations that are generally found to be stressful/upsetting for people with physical disabilities. Please think about each situation and circle a number 1, 2, 3, 4 or 5 to indicate how stressful/upsetting the situation has generally been for you.

Note: If the situation does not occur for you please circle NA for Not Applicable. If the situation does occur, but is Not At All stressful or upsetting please circle 1.

<table>
<thead>
<tr>
<th>Situation</th>
<th>How stressed/upset did you get?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When you have been unable to travel independently due to inaccessible places</td>
<td>Not at All Slightly Moderately Considerably Highly</td>
</tr>
<tr>
<td>2. When you have not been invited to social activities as much as you used to be</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>3. When you have been carried up or down stairs</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>4. When people have tried to help, but have made things more difficult</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>5. When private issues have been made public to doctors, nurses, family, friends</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>6. When you have used a taxi service</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>7. When your disability has affected your relationships/ friendships</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>8. When you have had to deal with carers or helpers</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>9. When you have not been able to do some activities you used to enjoy</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>10. When others have not recognised your sexual identity or sexual desires</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>11. When you have had to rely on others for help</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>12. When your disability affected the development of intimate or sexual relationships</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>13. When you have had to manage a number of health care needs</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>14. When you have arrived at a place that has stairs, but has no ramps or elevators</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>15. When you have been unable to physically help with manual jobs</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>16. When others have seen you as a person in a wheelchair before they have seen the person you really are</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>17. When you have been unable to physically move the way you used to move</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>18. When your health care needs have required time and energy</td>
<td>1 2 3 4 5 NA</td>
</tr>
<tr>
<td>19. When you felt there was nothing you could do to change things</td>
<td>1 2 3 4 5 NA</td>
</tr>
</tbody>
</table>
APPENDIX 1: PHYSICAL DISABILITY STRESS SCALE AND SCORING INSTRUCTIONS (cont’d)

<table>
<thead>
<tr>
<th>Situation</th>
<th>How stressed/upset did you get?</th>
</tr>
</thead>
<tbody>
<tr>
<td>20. When others have not considered your needs or abilities.</td>
<td>Not at All</td>
</tr>
<tr>
<td>21. When you have been unable to physically help others when they need it</td>
<td>Not at All</td>
</tr>
<tr>
<td>22. When you have been told a place is accessible, but find it isn’t accessible</td>
<td>Not at All</td>
</tr>
</tbody>
</table>

Generally, how well do you feel you manage the day-to-day stressful events of having a physical disability?

Physical Disability Stress Scale: Scoring Instructions

There are 4 subscales and a total score on the Physical Disability Stress Scale. In order to obtain subscale scores simply add the items which are indicated for each subscale (see Table 1). The total score is the sum of all items. Table 1 also provides the range of scores that can be expected from each subscale and from the total score. NA registers a score of zero.

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Items</th>
<th>Range of Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access – 4 Items</td>
<td>1-3-14-22</td>
<td>0–20</td>
</tr>
<tr>
<td>Physical – 5 Items</td>
<td>9-15-17-19-21</td>
<td>0–25</td>
</tr>
<tr>
<td>Social – 7 Items</td>
<td>2-5-6-7-10-12-16</td>
<td>0–35</td>
</tr>
<tr>
<td>Burden of Care – 6 Items</td>
<td>4-8-11-13-18-20</td>
<td>0–30</td>
</tr>
<tr>
<td>Total Score – 22 Items</td>
<td>All items</td>
<td>0–110</td>
</tr>
</tbody>
</table>


References


Supplier

a. Version 10; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
Mobility Assistive Device Utilization in a Prospective Study of Patients With First-Ever Stroke

Jeffrey Jutai, PhD, CPsych, Sherry Coulson, MA, Robert Teasell, MD, Mark Bayley, MD, Jayne Garland, PhD, PT, Nancy Mayo, PhD, PT, Sharon Wood-Dauphinee, PhD, PT


Objective: To estimate the extent to which clinical and functional features of stroke were related to the use of mobility assistive technology devices.

Design: Longitudinal study of quality of life after stroke.

Setting: Hospitals, rehabilitation centers, and universities in Ontario and Quebec.

Participants: Subjects (N=316) with confirmed initial stroke were included in this analysis. Fifty-eight percent of the overall sample were men (n=184). The mean age of this sample at the time of the stroke was 65.3±15.3 years (range, 19–96y). One hundred thirty-five patients received a mobility assistive device poststroke, and 181 did not.

Intervention: Assistive devices for mobility (canes, walkers, wheelchairs).

Main Outcome Measures: Assistive device use and mobility capacity.

Results: Mobility device nonusers were less physically disabled than device users on a variety of measures. Poor physical functioning but good cognition were reliably associated with mobility device use. Use of multiple mobility assistive devices was more often associated with poorer physical functioning than was single device use. For single device users, wheelchair use was predicted by cognition, functional independence, and stroke recovery. Cane users, compared with walker users, had better mobility and were less physically impaired by stroke.

Conclusions: Patients were well matched to device type based on their mobility capacity. The findings of this study suggest that assistive device prescription-outcome relationships in stroke can be effectively and meaningfully modeled.

Key Words: Assistive technology; Rehabilitation; Stroke.

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MOBILITY REFERS TO THE ability to move from 1 place to another and requires both motor function and capacity to move from 1 position to another or 1 place to another. Motor impairment and mobility limitations can impede the ability to perform activities of daily living that require use of the lower limbs. A common sequela of stroke, mobility limitation is often the first function to be addressed in the early stages of physical rehabilitation. Assistive technology devices (ATDs), including aids to mobility such as canes, walkers, and wheelchairs, can be useful to accommodate the limitations in daily activities that result from a disabling condition like stroke. They have the potential to reduce residual disability, delay decline in function, decrease burden of care, and lower health care costs. There is also evidence that ATDs may significantly reduce the requirement for hours of personal care. The importance of ATDs can be expected to increase over time as public policy shifts to earlier community reintegration and places greater emphasis on self-care and care delivered in the home and community.

Seniors with stroke who live at home own a large number of ATDs, averaging almost 16 per person. For those who reside at home after completion of a hospital rehabilitation program, canes, and walkers are frequently used, largely because tolerance for walking (ie, cardiovascular endurance) tends to be significantly reduced. Canes and walkers appear to effectively compensate for decreased postural stability and also to enhance participation in life’s roles, especially if hemiplegia is present.

The published data, although informative about the needs and circumstances of device use, have not yielded valid estimates for how frequently ATDs are prescribed for mobility limitations poststroke. Estimates have come from studies that were not specific to stroke, that did not provide sufficient information on devices used, and that did not systematically and prospectively track device use. As a consequence, we do not have reliable data on the kinds of ATDs typically adopted by people with stroke to reduce mobility limitations, or on how device utilization is related to important clinical features of stroke. It is important to examine whether variations in device strength (ie, the amount of support provided by a device) when used for a particular activity limitation, as in mobility, are predictably associated with the capacity and performance of necessary activities. In this way, we may improve the conceptualization of intervention-outcome relationships in stroke rehabilitation and thereby advance research in this field.

It is logical to assume that the major forms of mobility ATDs, namely, canes, walkers, and wheelchairs, should differ significantly in the degree to which they reduce mobility limitations, but this assumption is not well documented. Understanding the relationship between mobility benefit and ATD use is challenged by the fact that it is not feasible to use laboratory-based measures of walking capacity at the population level. Instead, population-based research relies on self-report ratings of walking difficulty or need for assistance.
This study reports findings from the Canadian Stroke Network study, entitled Understanding Health-Related Quality of Life Post-Stroke. The primary aim of the present study was to estimate the extent to which clinical and functional features of stroke were related to device utilization. We hypothesized that these features are reliably associated with the use of mobility devices.

METHODS

Participating patients were recruited as part of a longitudinal investigation of patients with first-ever stroke. We recruited a total of 678 patients from 3 sites in Ontario and Quebec, and followed up at 3-month intervals for 12 months. The participants had confirmed initial stroke (either ischemic or hemorrhagic). Patients with severe comorbidity that was likely to dominate the pattern of care, or result in serious health decline or death within the study period, (eg, metastatic disease, end-stage renal disease) were excluded from the recruitment process. Patients were required to speak either French or English. Patients admitted consecutively to the participating hospitals, who met the recruitment criteria outlined above, were asked to participate. In this study, we report the results from an analysis of the data from the baseline and first assessments of a year-long study of people with first-ever stroke. First assessments took place approximately 1 month after hospitalization for stroke.

Measurements

Each participant received a comprehensive assessment, with a variety of clinical and functional measures. A registered occupational or physical therapist, not involved in the design of the study or in the treatment of the patients, made the initial baseline evaluation while the person was still hospitalized. Clinical information was obtained from the medical chart. Over the next year, 4 follow-up assessments were made through interviews conducted over the telephone by therapists experienced in interviewing. The scales measured utilized self-report methods of assessment, and therefore interviewing via the telephone was an appropriate data collection method for the follow-up assessments.

Clinical Features of Stroke

The clinical features associated with stroke onset that were examined in this study included stroke severity using the Canadian Neurological Scale (CNS), its mentation and motor function subscales, as well as its total score\(^{21,22}\), primary side of brain lesion; presence of neglect, hemianopia, or loss of equilibrium. These were recorded within 72 hours poststroke and extracted from the medical chart after acute-care hospital admission. Loss of equilibrium was typically assessed by a therapist asked whether a mobility ATD had been acquired since the previous interview, and noted which device the person’s perception of his/her stroke recovery using the recovery visual analog scale (VAS) of the SIS.\(^{25}\) Other than the 3 CNS measures, all measures were scored 0 to 100. For all measures, higher scores are better.

Functional Measures of Stroke

The SIS was developed as a stroke-specific health-related quality of life outcome measure.\(^{25}\) The SIS is a self-administered questionnaire that measures 8 domains, including mobility and strength. The SIS mobility subscale is a composite measure used to examine physical mobility and comprises 9 items. Each item begins with the stem, “In the past 2 weeks, how difficult was it to . . . ,” and is rated on a 5-point scale (1, could not do at all; 2, very difficult; 3, somewhat difficult; 4, a little difficult; 5, not difficult at all). The 9 items were “. . . stay sitting without losing your balance?,” “. . . stay standing without losing your balance?,” “. . . walk without losing your balance?,” “. . . move from a bed to a chair?,” “. . . walk one block?,” “. . . walk fast?,” “. . . climb one flight of stairs?,” “. . . climb several flights of stairs?,” and “. . . get in and out of a car?” The SIS strength subscale asks the respondent to rate the strength of each of the following in the past week: arm, hand, leg, and foot and ankle most affected by their stroke. It is rated on a 5-point scale with 1 being no strength at all and 5 being a lot of strength. The SIS strength subscale was used for descriptive purposes and was not used in the analyses.

We used the PF scale of the SF-36\(^ {27} \) as a measure of mobility capacity because most of its items are associated with mobility (8 of 10 items). Each item begins with the stem, “Does your health now limit you a lot, limit you a little, or not limit you at all in . . .” and is rated on a 3-point scale (1, yes, limited a lot; 2, yes, limited a little; 3, no, not limited at all). The 10 items were “. . . vigorous activities such as running, lifting heavy objects, or participating in vigorous sports?,” “. . . moderate activities, such as vacuum cleaning, bowling or playing golf?” “. . . lifting and carrying groceries?,” “. . . climbing several flights of stairs?,” “. . . climbing one flight of stairs?,” “. . . bending, kneeling, or stooping?,” “. . . walking more than one mile?,” “. . . walking several hundred yards?,” “. . . walking one-hundred yards,” and “. . . bathing or dressing yourself.”

Previous research has found that the SF-36 PF scale is highly correlated with the FIM instrument locomotion items\(^ {8,29} \) and with mobility capacity as assessed directly using items of the Activity Measure for Post-Acute Care (AM-PAC)\(^ {10,33} \) in patients with stroke who are able to use mobility devices.\(^ {29} \) This indicates that the 3 measures assess the same basic construct of mobility. FIM scores were not available for the participants in this study.

In a preliminary study of stroke patients in the United States, scores on the SF-36 PF appeared to more clearly distinguish patients on the basis of the type of device used most often for mobility (cane, walker, or wheelchair) than did FIM locomotion scores, with cane users scoring the lowest, and walker users scoring in between.\(^ {20} \) Thus, we have hypothesized that canes, walkers, and wheelchairs can be ordered meaningfully along a dimension of intervention strength and are predictably associated with mobility capacity as measured using the SF-36 PF scale.

Measurement of Device Use

The mobility devices procured after stroke were canes (ie, single-tip support canes), walkers (mainly standard pickup walkers) and wheelchairs. The primary ATD refers to the device that patients with stroke said was the one they were most dependent on for daily functioning. At each assessment, the interviewer asked whether a mobility ATD had been acquired since the previous interview, and noted which device the patients on the basis of the type of device used most often for mobility (cane, walker, or wheelchair) than did FIM locomotion scores, with cane users scoring the lowest, and walker users scoring in between.\(^ {20} \) Thus, we have hypothesized that canes, walkers, and wheelchairs can be ordered meaningfully along a dimension of intervention strength and are predictably associated with mobility capacity as measured using the SF-36 PF scale.

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participant described as their primary ATD. In the assessment interview, if the patient was using an assistive device, his/her device use status was determined to be either single (had only 1 mobility device at time of assessment) or multiple (had a primary mobility device at assessment plus at least 1 other mobility aid). It is important to note that the wheelchair users in this research were not necessarily wheelchair bound, and were capable of some mobility outside of wheelchair use, either independently or with the assistance of a person or another assistive device.

The study was approved by the ethics committees of the participating rehabilitation hospitals, rehabilitation centers, and universities.

Statistical Analyses

We used chi-square tests to examine the association of various clinical features with use or nonuse, single or multiple device use, and primary device type (cane, walker, or wheelchair). Spearman ρ correlations were used to examine the strength of relationships between functional measures and age. Logistic regression analyses, using clinical and functional variables, were undertaken to try to predict various types of device use. The level of statistical significance was set at P less than .05.

RESULTS

Of 678 patients recruited to the study, 316 had complete scores for all clinical and functional measures at baseline and 1-month interviews that were used for analysis. Participants who were not included in the data analysis were those who received an ATD whose type was not described or was a type other than the 3 mobility devices used in this analysis, those whose stroke was not their first, and for whom the side of lesion was described as either both or missing. Of these participants, 181 did not use or obtain an ATD for the duration of the study period (nonusers) and 135 participants procured a mobility ATD within 1 year after their stroke. Usable data were therefore available for 135 mobility ATD users (43% of total ATDs users recruited) and 181 nonusers (51% of total nonusers recruited) (fig 1). The average time from stroke to first assessment ± standard deviation (SD) for device users was 31.2 ± 9.7 days (range, 12–66d) and 33.8 ± 22.7 (range, 11–76d) for nonusers.

The number of patients in each device category are presented in table 1, along with the demographic variables of sex and age. For each type of device, the table shows the number of patients for whom the device was either their sole device (single) or primary device among more than 1 mobility device (multiple). Fifty-eight percent (n = 184) of the overall sample were men. The mean age of this sample (N = 316) at the time of the stroke was 65.3 ± 15.3 years (range, 19–96y). Nonusers were younger than users, with the mean age being 63.0 ± 15.4 years (range, 19–93y), compared with users whose mean age was 68.5 ± 14.7 years (range, 26–96y). Nearly twice as many canes as other mobility devices were used.

![Fig 1. Flowchart depicting relationship between subject recruitment and usable data.](image)

**Table 1: Numbers of ATD Users and Nonusers at the Time of First Assessment According to Sex and Age**

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Sex, n (%)</th>
<th>Mean Age of Patient ± SD (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>316</td>
<td>65 ± 15</td>
</tr>
<tr>
<td>Nonusers</td>
<td>None</td>
<td>316</td>
</tr>
<tr>
<td>Any</td>
<td>Any</td>
<td>316</td>
</tr>
<tr>
<td>Cane</td>
<td>Single</td>
<td>316</td>
</tr>
<tr>
<td>Multiple*</td>
<td>1 (33.3)</td>
<td>2 (66.7)</td>
</tr>
<tr>
<td>Any</td>
<td>34 (55.7)</td>
<td>67 ± 15</td>
</tr>
<tr>
<td>Walker</td>
<td>Single</td>
<td>24 (77 ± 11)</td>
</tr>
<tr>
<td>Multiple†</td>
<td>9 (47.4)</td>
<td>10 (52.6)</td>
</tr>
<tr>
<td>Any</td>
<td>20 (46.5)</td>
<td>19 (70 ± 12)</td>
</tr>
<tr>
<td>Wheelchair</td>
<td>Single</td>
<td>11 (71 ± 17)</td>
</tr>
<tr>
<td>Multiple‡</td>
<td>11 (55.0)</td>
<td>9 (45.0)</td>
</tr>
<tr>
<td>Any</td>
<td>15 (48.4)</td>
<td>61 (65 ± 16)</td>
</tr>
</tbody>
</table>

*Cane was the primary mobility device. Multiple refers to use of more than 1 device type.
†Walker was the primary mobility device.
‡Wheelchair was the primary mobility device.
Device Use and Device Type

Chi-square analysis revealed that there was a significant relationship between single or multiple device use and type of primary device used (P<.001). Cane users were more likely to be single rather than multiple device users. Users of walkers and wheelchairs were as likely to be single device users as to be multiple device users.

Clinical Features

Table 2 summarizes the demographic characteristics of the sample as well as the clinical and functional measures in relation to various patterns of device use. Overall proportions are presented, as well as comparisons for each of the following: any use versus noneuse; single versus multiple device use; cane or walker use versus the use of a wheelchair; and cane versus walker use. Clinical features examined include the presence of neglect, hemianopia, loss of equilibrium, and the primary side of lesion. Chi-square tests examining the relationship between single or multiple device use, device type, and device nonuse with these clinical features revealed no significant associations. Age was segmented into 2 groups to differentiate between the young-old and the old-old. Chi-square analyses revealed a significant relationship between device use and nonuse with age dichotomized using 75 years as the cutpoint (P<.05); a higher proportion of persons over the age of 75 years used a device. Age was also significantly related to cane and walker use (P<.01), with a higher proportion of walker users being over the age of 75. Sex was found to be significantly associated with device use and nonuse (P<.05). There were equal numbers of men and women in the user group, but more men than women in the nonuser group.

Correlations

Nonparametric correlations (Spearman ρ) examining age, CNS mentation, CNS motor functions, CNS total score, Barthel Index, MMSE, SIS mobility, SIS stroke recovery, VAS, and SF-36 PF were performed for the total sample of users and nonusers (N=316). Age was found to correlate negatively (P<.01) with each of the Barthel Index (ρ=.–18), MMSE (ρ=.–26), SIS mobility subscale (ρ=.–29), SIS stroke recovery VAS (ρ=.–16), and SF-36 PF (ρ=.–27). A strong relationship was found between many of the functional measures used in this analysis, as seen in table 3. For example, SF-36 PF (a measure of mobility capacity) correlated positively (P<.01) with the stroke severity measures of CNS motor functions (ρ=.35) and total score (ρ=.35), stroke recovery (SIS stroke recovery VAS, ρ=.58), functional independence as measured by the Barthel Index (ρ=.66), MMSE cognitive functioning (ρ=.21), as well as the second measure of mobility capacity, the SIS mobility subscale (ρ=.87).

Functional Measures

Table 4 presents the descriptive statistics for functional measures of stroke as a function of device type (cane, walker, wheelchair) and device use (single vs multiple) and noneuse. Mean scores on the Barthel Index, MMSE, SIS mobility subscale, and SIS stroke recovery VAS showed similar patterns regarding device types for multiple device users, with wheelchair users having the lowest scores, followed by walker users, with cane users having the highest scores. This pattern was repeated for single device users, with scores for wheelchair users much lower than scores for cane and walker users, as would be expected from patients who relied on this form of mobility. For example, on the Barthel Index, which measures functional independence in personal care and mobility, single

device cane users (mean, 77.2±20.1; range, 0–100) scored higher than walker users (mean, 68.8±22.3; range, 5–100) and both scored higher than wheelchair users (mean, 40.0±12.6; range, 15–65). The difference between device types were more pronounced for the single device users.

Mean SF-36 PF scores for the primary mobility device types were: cane, 38.4±27.1 (range, 0–90); walker, 24.0±24.1 (range, 0–95); and wheelchair, 5.0±13.4 (range, 0–45). No wheelchair user obtained a score higher than 45. Only 5 walker users scored greater than 45. As the primary mobility ATD, wheelchairs were used exclusively by patients who had poor capacity in mobility. This is in contrast to canes, which, although they were the primary devices mainly for patients with significant mobility limitations, were used by patients who represented a very wide range of mobility.

As a global measure of stroke severity in terms of weakness, the CNS motor function results suggested that wheelchair users were weaker than cane users, who were slightly, but significantly, weaker than walker users. CNS motor function mean scores for primary device type were as follows: cane, 3.7±2.2 (range, 0–6.5); walker, 5.1±1.1 (range, 0–6.5); and wheelchair, 2.2±1.9 (range, 0–6).

Regression Analyses

The clinical and functional variables of side of lesion, mobility capacity (SF-36 PF), stroke severity (CNS mentation, motor function, and total score), stroke recovery and mobility (SIS), functional independence in personal care and mobility (Barthel Index), cognitive impairment (MMSE), and age were entered into logistic regression analyses (forward; likelihood ratio; SPSS) to predict various types of device use. Regression analyses were conducted for each of the following binomial outcome variables: (1) any device use versus no device use, (2) single device use versus multiple device use, (3) cane or walker use versus wheelchair use, and (4) cane use versus walker use. The results are summarized in table 5.

A regression analysis examining device users and nonusers suggested that device use was significantly associated with mobility (SF-36 PF) (odds ratio [OR]=.97; 95% confidence interval [CI], .96–.98), functional independence (Barthel Index) (OR=.96; 95% CI, .95–.98), and cognitive status, as measured by the CNS mentation subscale (OR=1.46; 95% CI, 1.03–2.07) and the MMSE (OR=1.03; 95% CI, 1.01–1.06) (R²=.48; percentage correctly classified, 79.4%). As would be expected, device users were more likely to have less functional independence and lower mobility capacity, therefore requiring mobility devices. Interestingly, users were more likely to have higher levels of cognition.

Multiple device use, as opposed to single device use, was significantly associated with age (OR=.97; 95% CI, .94–.99) and level of mobility (SIS mobility subscale) (OR=.97; 95% CI, .95–.98). The total percentage of study participants correctly classified was 71.9% (R²=.24). Multiple device users were more likely to have lower mobility capacity and to be younger than single device users.

The sole use of a cane or walker compared with the sole use of a wheelchair was significantly associated with level of functional independence (Barthel Index) (OR=.92; 95% CI, .87–.97), cognitive status (CNS mentation subscale) (OR=4.39; 95% CI, 1.13–16.99), and level of stroke impairment (SIS stroke recovery VAS; OR=.95; 95% CI, .91–.99). These variables correctly classified 93.5% of the study participants (R²=.65). Cognitively, wheelchair users were more likely to be significantly higher functioning, but to be more severely impaired by stroke and have less func-
### Table 2: Comparisons Between Coded ATD Use and Clinical and Functional Features of Stroke

<table>
<thead>
<tr>
<th>Features</th>
<th>Overall (N=316)</th>
<th>Any Use (n=135) vs None (n=181)*</th>
<th>Single (n=93) vs Multiple (n=42)</th>
<th>Cane or Walker (n=104) vs Wheelchair (n=31)</th>
<th>Cane (n=61) vs Walker (n=43)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (under 75y)</td>
<td>71.5</td>
<td>64.4 vs 76.8^</td>
<td>60.2 vs 73.8^</td>
<td>62.5 vs 71</td>
<td>73.8 vs 46.5^</td>
</tr>
<tr>
<td>Sex (male)</td>
<td>58.2</td>
<td>51.1 vs 63.5^</td>
<td>51.6 vs 50</td>
<td>51.9 vs 48.4</td>
<td>55.7 vs 46.5</td>
</tr>
<tr>
<td>Clinical measures taken at baseline (in-hospital)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side of lesion (left)</td>
<td>42.4</td>
<td>37 vs 46.4</td>
<td>39.8 vs 31</td>
<td>38.5 vs 32.3</td>
<td>36.1 vs 41.9</td>
</tr>
<tr>
<td>Neglect (present)</td>
<td>11.7</td>
<td>12.6 vs 11</td>
<td>14 vs 9.5</td>
<td>10.6 vs 19.4</td>
<td>16.4 vs 2.3</td>
</tr>
<tr>
<td>Hemianopia (present)</td>
<td>13.3</td>
<td>11.9 vs 14.4</td>
<td>12.9 vs 9.5</td>
<td>10.6 vs 16.1</td>
<td>13.1 vs 7</td>
</tr>
<tr>
<td>Loss of equilibrium (present)</td>
<td>21.5</td>
<td>23.7 vs 19.9</td>
<td>25.8 vs 19</td>
<td>26.9 vs 12.9</td>
<td>27.9 vs 25.6</td>
</tr>
<tr>
<td>Functional measures taken at baseline (in-hospital)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNS mentation</td>
<td>5 (4.5, 5)</td>
<td>5 (4.5, 5) vs 5 (4.3, 5)</td>
<td>4.5 (4.5, 5) vs 5 (4.5, 5)</td>
<td>4.8 (4.5, 5) vs 5 (4.5, 5)</td>
<td>4.5 (4.3, 5) vs 5 (4.5, 5)</td>
</tr>
<tr>
<td>CNS motor functions</td>
<td>4.5 (3, 6)</td>
<td>4 (2, 5.5) vs 5 (4, 6.5)</td>
<td>4 (2.5, 6) vs 3.8 (0.9, 5.5)</td>
<td>4.5 (3, 6) vs 1.5 (0.5, 2.5)</td>
<td>4 (2.3, 6) vs 5 (4, 6)</td>
</tr>
<tr>
<td>CNS total</td>
<td>9.5 (7.5, 10.5)</td>
<td>8.5 (6.5, 10) vs 9.5 (8.1, 11)</td>
<td>9 (7, 10) vs 8.3 (5.5, 9.6)</td>
<td>9.3 (7.6, 10.5) vs 6.5 (5, 7.5)</td>
<td>8.5 (6.5, 10.5) vs 9.5 (9.11)</td>
</tr>
<tr>
<td>Barthel Index</td>
<td>90 (85, 100)</td>
<td>65 (45, 85) vs 100 (85, 100)</td>
<td>75 (52.5, 90) vs 52.5 (38.8, 65)</td>
<td>75 (60, 90) vs 45 (35, 50)</td>
<td>80 (65, 92.5) vs 65 (50, 85)</td>
</tr>
<tr>
<td>Functional measures taken at 1-month poststroke</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>95.5 (86.4, 100)</td>
<td>95.5 (86.4, 100) vs 95.5 (86.4, 100)</td>
<td>95.5 (86.4, 100) vs 90.9 (85.2, 100)</td>
<td>95.5 (86.4, 100) vs 90.9 (77.3, 100)</td>
<td>95.5 (86.4, 100) vs 90.9 (81.8, 100)</td>
</tr>
<tr>
<td>SIS strength subscale</td>
<td>75 (50, 93.8)</td>
<td>50 (37.5, 75) vs 81.3 (62.5, 100)</td>
<td>62.5 (37.5, 81.3) vs 37.5 (25, 59.4)</td>
<td>68.8 (50, 81.3) vs 25 (12.5, 37.5)</td>
<td>68.8 (50, 87.5) vs 59.4 (48.4, 76.6)</td>
</tr>
<tr>
<td>SIS mobility subscale</td>
<td>75 (50, 94.4)</td>
<td>52.8 (25, 75) vs 91.7 (75, 100)</td>
<td>61.1 (34.7, 81.9) vs 34.7 (18.1, 53.5)</td>
<td>61.1 (40.3, 77.8) vs 19.4 (11.1, 30.6)</td>
<td>75 (55.6, 84.7) vs 50 (25, 61.1)</td>
</tr>
<tr>
<td>Stroke recovery VAS</td>
<td>70 (40, 88.6)</td>
<td>50 (30, 75) vs 75 (50, 90)</td>
<td>60 (32.5, 75) vs 47.5 (23.8, 60)</td>
<td>60 (40, 75) vs 30 (10, 50)</td>
<td>65 (41, 77.5) vs 50 (40, 70)</td>
</tr>
<tr>
<td>SF-36 PF</td>
<td>45 (10, 80)</td>
<td>15 (5, 40) vs 70 (45, 90)</td>
<td>30 (5, 50) vs 5 (0, 20)</td>
<td>30 (10, 45) vs 0 (0, 5)</td>
<td>35 (17.5, 5.5) vs 15 (5, 30)</td>
</tr>
</tbody>
</table>

**NOTE.** Values are percentage or mean with (25%, 75% quartiles).

*This includes only those patients who had complete scores on all measures and had side of lesion listed as either left or right. The user group includes only mobility (cane, walker, or wheelchair) device users (user, n=135; nonuser, n=181).

^To interpret the cell results, for example, 60.2% of single device users were aged less than 75 years and 39.8% were aged 75 or greater, compared with 73.8% of multiple device users aged less than 75 and 26.2% aged 75 or higher.

*Chi-square tests determined relationships to be significant (P<.05).
tional independence than cane and walker users, indicating greater mobility disability.

Analysis examining the use of a cane versus a walker as the sole mobility aid indicated that use of a walker was significantly associated with the level of overall weakness as measured by the CNS motor functions subscale (OR = 1.20–2.59) and level of mobility as measured by the SIS mobility subscale (OR = 0.30–0.68). These variables correctly classified 76.8% of study participants. Correlation is significant at the .01 level (2-tailed).

Table 3: Spearman Correlations for the Functional Measures of Stroke and Age for the Study Population (N = 316)

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>CNS Mentation</th>
<th>CNS Motor Functions</th>
<th>CNS Total</th>
<th>Barthel</th>
<th>MMSE</th>
<th>SIS Mobility</th>
<th>SIS SRV</th>
<th>SF-36 PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.00</td>
<td>-0.07</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNS mentation</td>
<td>-0.07</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNS motor functions</td>
<td>-0.02</td>
<td>0.22†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNS total</td>
<td>-0.04</td>
<td>0.49†</td>
<td>0.93†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barthel</td>
<td>-0.18†</td>
<td>0.03</td>
<td>0.38†</td>
<td>0.34†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>-0.26†</td>
<td>0.20†</td>
<td>0.09</td>
<td>0.12†</td>
<td>0.21†</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIS mobility</td>
<td>-0.29†</td>
<td>0.04</td>
<td>0.30†</td>
<td>0.30†</td>
<td>0.68†</td>
<td>0.24†</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIS SRV</td>
<td>-0.16†</td>
<td>0.11</td>
<td>0.32†</td>
<td>0.33†</td>
<td>0.45†</td>
<td>0.23†</td>
<td>0.57†</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>SF-36 PF</td>
<td>-0.27†</td>
<td>0.09</td>
<td>0.35†</td>
<td>0.35†</td>
<td>0.66†</td>
<td>0.21†</td>
<td>0.87†</td>
<td>0.58†</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Abbreviation: SRV, stroke recovery VAS.
*Correlation is significant at the .05 level (2-tailed).
†Correlation is significant at the .01 level (2-tailed).

DISCUSSION

This prospective, longitudinal study of first-ever stroke patients collected comprehensive data about the use of assistive devices for mobility. The findings provide empirical support for a number of reported clinical applications for these devices. Analysis examining the use of a cane versus a walker as the sole mobility aid indicated that use of a walker was significantly associated with the level of overall weakness as measured by the CNS motor functions subscale (OR = 1.20–2.59) and level of mobility as measured by the SIS mobility subscale (OR = 0.30–0.68). These variables correctly classified 76.8% of study participants. Walker users had lower levels of stroke severity in terms of general weakness and lower mobility capacity than cane users.

The use and nonuse of mobility assistive devices in stroke patients is reliably associated with scores on the SF-36 PF scale, Barthel Index, MMSE, and CNS mentation subscale obtained in-hospital and after hospital discharge. However, in predicting single- versus multiple-device use among device users, the SIS mobility scale appears to be a more sensitive substitute for the SF-36 PF among these measures. In predicting which specific device type (cane, walker, or wheelchair) was used, the SIS mobility scale continued to demonstrate sensitivity, this time in combination with measures of stroke severity (CNS).

Though not as pure a measure for the construct of mobility capacity as would be desired, the SF-36 PF provides a relatively cleaner separation of categories of device user and non-user than was obtainable from measures of stroke severity and functional independence, such as the CNS and the Barthel Index. These measures were all correlated with age.

The use of canes and walkers could be predicted on the basis of mobility capacity; however, wheelchair use was not as reliably predicted based on measures of mobility. Other factors, such as stroke severity, loss of balance and postural sway, contribute to the cost of the most basic equipment essential for mobility. The government pays a proportion of a fixed price for each approved device. The kinds of mobility devices covered include selected wheeled walkers, forearm crutches, manual and power wheelchairs, and specialized positioning devices for wheelchairs (ie, seat cushions and back supports). The cost of equipment required for occasional use, used only at school or work, an exercise program, sports, or to replace personal and/or public transportation is not covered. In these provinces, only 1 mobility device per person is funded, which may have influenced the selection of devices by persons with limited financial means.

It is possible that the availability of government funding had a significant influence on the relationships we observed. In the 2 provinces where this study took place, the government contributed to the cost of the most basic equipment essential for mobility. The government pays a proportion of a fixed price for each approved device. The kinds of mobility devices covered include selected wheeled walkers, forearm crutches, manual and power wheelchairs, and specialized positioning devices for wheelchairs (ie, seat cushions and back supports). The cost of equipment required for occasional use, used only at school or work, an exercise program, sports, or to replace personal and/or public transportation is not covered. In these provinces, only 1 mobility device per person is funded, which may have influenced the selection of devices by persons with limited financial means.

Table 4: Mean Outcome Measure Scores as a Function of Device Use, Group, and ATD Type

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Device Use</th>
<th>CNS Mentation</th>
<th>CNS Motor Functions</th>
<th>CNS Total</th>
<th>Barthel</th>
<th>MMSE</th>
<th>SIS Mobility</th>
<th>SIS SRV</th>
<th>SF-36 PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonuser</td>
<td>None</td>
<td>4.4 ± 0.9</td>
<td>4.6 ± 2.0</td>
<td>9.1 ± 2.3</td>
<td>89.4 ± 17.0</td>
<td>89.6 ± 15.6</td>
<td>83.1 ± 21.9</td>
<td>69.6 ± 26.5</td>
<td>63.2 ± 30.0</td>
</tr>
<tr>
<td>User</td>
<td>Total</td>
<td>4.5 ± 0.8</td>
<td>3.7 ± 2.2</td>
<td>8.2 ± 2.5</td>
<td>65.4 ± 23.7</td>
<td>89.7 ± 12.3</td>
<td>50.7 ± 28.2</td>
<td>52.2 ± 26.3</td>
<td>24.9 ± 25.8</td>
</tr>
<tr>
<td>Cane</td>
<td>Single</td>
<td>4.4 ± 0.8</td>
<td>3.7 ± 2.2</td>
<td>8.1 ± 2.7</td>
<td>77.2 ± 20.1</td>
<td>91.8 ± 12.3</td>
<td>68.9 ± 23.2</td>
<td>61.7 ± 22.8</td>
<td>38.4 ± 27.1</td>
</tr>
<tr>
<td></td>
<td>Multiple</td>
<td>4.8 ± 0.3</td>
<td>5.0 ± 1.3</td>
<td>9.8 ± 1.5</td>
<td>71.7 ± 16.1</td>
<td>89.4 ± 5.2</td>
<td>63.0 ± 14.0</td>
<td>46.7 ± 23.1</td>
<td>33.3 ± 7.6</td>
</tr>
<tr>
<td>Walker</td>
<td>Single</td>
<td>4.5 ± 0.9</td>
<td>5.1 ± 1.1</td>
<td>9.5 ± 1.4</td>
<td>68.8 ± 22.3</td>
<td>87.7 ± 14.0</td>
<td>46.4 ± 24.4</td>
<td>53.0 ± 28.2</td>
<td>24.0 ± 24.1</td>
</tr>
<tr>
<td></td>
<td>Multiple</td>
<td>4.5 ± 0.9</td>
<td>4.8 ± 1.8</td>
<td>9.3 ± 2.5</td>
<td>61.6 ± 25.4</td>
<td>89.0 ± 10.1</td>
<td>42.7 ± 19.9</td>
<td>51.5 ± 22.3</td>
<td>18.9 ± 17.8</td>
</tr>
<tr>
<td>Wheelchair</td>
<td>Single</td>
<td>4.7 ± 0.5</td>
<td>2.2 ± 1.9</td>
<td>6.9 ± 1.8</td>
<td>40.0 ± 12.6</td>
<td>81.8 ± 14.9</td>
<td>22.7 ± 23.9</td>
<td>24.1 ± 20.1</td>
<td>5.0 ± 13.4</td>
</tr>
<tr>
<td></td>
<td>Multiple</td>
<td>4.6 ± 0.7</td>
<td>1.5 ± 1.3</td>
<td>6.1 ± 1.6</td>
<td>44.3 ± 11.8</td>
<td>91.4 ± 10.0</td>
<td>24.2 ± 15.6</td>
<td>40.8 ± 27.3</td>
<td>2.3 ± 3.4</td>
</tr>
</tbody>
</table>

Scale range: 0–100

NOTE. Values are mean ± SD.
ables are continuous.)

for a relatively short time (within a month of procurement) and, were using a device at the first assessment had been doing so them rather at a later time in the 1-year study period. Those that been using an ATD at the time of first assessment, procuring performance.

idated for assessing mobility, we acknowledge that they are

ally, the effects observed in this study were not influenced by participants received prior to procuring their devices. Addition-

what types of canes and walkers were used by the participants, Study Limitations

ntensively studied in further research with mobility ATDs.

It is noteworthy that our research participants may not have

are likely to use 1 or more mobility devices from the 3 main categories examined in this study. The use or nonuse of ATDs for mobility, and the types of devices used, are reliably associated with measurements of mobility capacity, functional independence, cognitive status, and stroke severity. Predictably, device nonusers were less physically disabled than device users. Surprisingly, cognitive impairment was reliably associated with device nonuse, independently of physical disability. It is not clear why cognitive status should be so consistently related with the use of what are generally regarded to be simple technologies for assisting mobility. Poor physical functioning but good cognition are clinical features of stroke that are reliably associated with the use of multiple assistive devices for mobility. This finding raises the possibility that some patients might be better able to function with additional devices, but are not getting or using them due to cognitive difficulties.

If applied effectively, ATDs can be an important approach to promoting the functional recovery and long-term health of people with stroke. The findings from this study support the feasibility of effectively and meaningfully modeling ATD intervention-outcome relationships in stroke, and thereby advancing research in the field.

Acknowledgment: We gratefully acknowledge the technical assistance of Naim Ghany, MASc, with the data analysis.

References


Table 5: Best Predictive Models for Each Contrast of Device Use

<table>
<thead>
<tr>
<th>Variable (unit)</th>
<th>OR*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any use (n=135) vs nonuse (n=181)†</td>
<td>1.46</td>
<td>1.03–2.07</td>
</tr>
<tr>
<td>CNS mentation</td>
<td>0.96</td>
<td>0.95–0.98</td>
</tr>
<tr>
<td>Barthel Index</td>
<td>1.03</td>
<td>1.01–1.06</td>
</tr>
<tr>
<td>SF-36 PF</td>
<td>0.97</td>
<td>0.96–0.98</td>
</tr>
<tr>
<td>Single (n=93) vs multiple devices (n=42)‡</td>
<td>0.97</td>
<td>0.94–0.99</td>
</tr>
<tr>
<td>Age</td>
<td>0.97</td>
<td>0.95–0.98</td>
</tr>
<tr>
<td>SIS mobility</td>
<td>0.97</td>
<td>0.95–0.98</td>
</tr>
<tr>
<td>Single device users only:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cane or walker (n=82) vs wheelchair (n=11) use§</td>
<td>4.39</td>
<td>1.13–16.99</td>
</tr>
<tr>
<td>CNS mentation</td>
<td>0.92</td>
<td>0.87–0.97</td>
</tr>
<tr>
<td>Barthel Index</td>
<td>0.95</td>
<td>0.91–0.99</td>
</tr>
<tr>
<td>SIS SRV</td>
<td>1.76</td>
<td>1.20–2.59</td>
</tr>
<tr>
<td>Single device users only:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cane (n=58) vs walker (n=24) use§</td>
<td>1.76</td>
<td>0.95–0.93</td>
</tr>
<tr>
<td>CNS motor functions</td>
<td>0.95</td>
<td>0.93–0.98</td>
</tr>
<tr>
<td>SIS mobility</td>
<td>0.95</td>
<td>0.93–0.98</td>
</tr>
</tbody>
</table>

*The change in the odds of a unit change. (The independent variables are continuous.)
†R²=.48; % correctly classified, 79.4%; χ²=140.45, P<.001.
‡R²=.42; % correctly classified, 71.9%; χ²=75.0, P=.001.
§R²=.65; % correctly classified, 93.5%; χ²=37.93, P<.001.
¶R²=.38; % correctly classified, 76.8%; χ²=25.21, P=.001.


Supplier
a. Version 15.0; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

Objective: To determine the efficacy of acupuncture in the treatment of chronic musculoskeletal shoulder pain in subjects with spinal cord injury (SCI). The treatment of chronic musculoskeletal shoulder pain in SCI has been a focus of investigations. A Cochrane review of clinical trials that evaluated the effectiveness of acupuncture in adults with shoulder pain reported that there may be short-term benefits with respect to shoulder pain and function.

Methods: A single-blind, randomized controlled trial using a similar design is warranted. The lack of a separate group to control for nonspecific treatment factors. Because acupuncture treatments are moderately invasive, somewhat time consuming, and administered by an enthusiastic and empathetic therapist, they have the potential to function as a strong placebo.

Results: Shoulder pain decreased significantly over time in both the acupuncture and the sham acupuncture groups (P = .005), with decreases of 66% and 43%, respectively. There was no significant difference between the 2 groups (P = .364). There was, however, a medium effect size associated with the acupuncture treatment.

Conclusions: There appears to be an analgesic effect or a powerful placebo effect associated with both acupuncture and sham acupuncture. There was a medium treatment effect associated with the acupuncture, which suggests that it may be superior to sham acupuncture. This observation, along with the limited power, indicates that a larger, more definitive randomized controlled trial using a similar design is warranted.

Key Words: Acupuncture therapy; Rehabilitation; Shoulder pain; Spinal cord injuries.

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area through advertisements and letters. To be eligible, they had to be between 18 and 70 years of age, have had no experience with acupuncture, have had chronic musculoskeletal shoulder pain (defined as a history of musculoskeletal* shoulder pain for more than 3 months and that physical examination found to be localized to the subacromial space and/or to the regional muscles of shoulder complex), were at least 1 year post-SCI, and used a manual wheelchair as their primary means of mobility (>40h/wk). Subjects were excluded if they were pregnant or had a medical condition that would interfere with the study or the interpretation of the study’s results. All participants provided written informed consent, in accordance with procedures approved by the appropriate institutional review board.

**Procedures**

**Screening.** All participants underwent a screening history and a focused physical exam of the neck and shoulders that included a series of provocative tests specific for shoulder pain. Each participant’s neurologic level of injury was based on the International Standards for Neurological and Functional Classification of Spinal Cord Injury. The physician who performed the exams was blinded to treatment group assignments.

**Intervention.** The study consisted of 3 consecutive 5-week periods: (1) a no-treatment baseline period; (2) a treatment period; and (3) a follow-up period.

**Baseline period.** After the baseline period, participants were randomly assigned to either the acupuncture group or the sham acupuncture group through a stratified block randomization based on neurologic level of injury, to ensure equal distribution between treatment groups. All participants and the principal investigator were blinded as to group assignment. In an effort to maintain the blind, participants were asked to not discuss details about their treatment experience with other participants or the principal investigator.

**Treatment period.** Both groups received 10 treatments over a period of 5 weeks (range, 5–8wk). Treatments were given in an outpatient medical setting in a clinical research center by 2 licensed acupuncturist (PK, LB) trained in traditional Chinese medicine–style acupuncture. The 2 had more than 20 years of clinical experience, including experience in using the treatment protocol. Treatments consisted of either acupuncture or sham acupuncture.

**Acupuncture.** We used a hybrid version of a completely individualized acupuncture needle treatment and a standardized acupuncture needle treatment to accommodate the differences between participants and changes in symptoms during the treatment period, while still providing some consistency in the treatment. This protocol, described elsewhere, is briefly summarized here. Before each treatment, up to 6 local points and 2 distal points were chosen per painful shoulder (fig 1A), according to the distribution of shoulder pain or tenderness on palpation in individual participants. Points were chosen from a list of points (appendix 1) believed to relieve shoulder or upper-limb pain and were based on traditional Chinese medicine methods. Also needed were any ashi points ("ouch" points; local points of tenderness or sensitivity that do not correspond to classical acupuncture points) in the shoulder region (range, 1–4 points per treatment). During the treatment, stainless steel, pre-sterilized disposable acupuncture needles

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*Spinal Cord Injury Pain Task Force of the International Association of the Study of Pain classification: nociceptive (tier I), musculoskeletal (tier II), secondary overuse syndromes (tier III).*

---

**Fig 1.** (A) An example of 6 local and 2 distal acupoints used for the treatment of chronic musculoskeletal shoulder pain in subjects with SCI (illustration by Jody Banks). (B) Needle acupuncture involves the insertion of fine needles into specific points on the body called acupoints.
were inserted into the skin to a depth of 1 to 3 cm and were manually stimulated to acquire DeQi (ie, the arrival of the Qi sensation; often described as a feeling of heaviness, soreness, or numbness) (fig 1B). Once the needles were inserted, the acupuncturist left and the participant sat quietly with the needles in place for 20 minutes, with manual stimulation repeated once by the acupuncturist during this period.

Sham acupuncture. We used an invasive sham acupuncture technique consisting of shallow needling with no manipulation (ie, minimal acupuncture) at sites located at least 1 cun (1 Chinese anatomic inch) away from established meridian points and extra points,3,29 so as not to influence the superficial flow of Qi within the meridians. A total of 8 points was needled per painful shoulder: 6 local points and 2 distal points (appendix 2). During the sham treatment, the needles were tapped in with the insertion tube only to the most superficial depth, so that the needles stayed upright in the skin. DeQi and manual stimulation of the needles were avoided. Once the needles were inserted, the acupuncturist left and the participant sat quietly with the needles in place for 20 minutes, with sham manual stimulation performed once by the acupuncturist during this time. During sham stimulation, the acupuncturist gently held the needle and pretended to twirl or stimulate each needle. Again, DeQi was avoided.

No auxiliary techniques (eg, moxibustion, cupping, use of Chinese herbs), lifestyle advice, additional medications, or therapeutic exercises were prescribed during the treatment period. Participants were instructed to continue their usual daily activities and were permitted to continue taking previously prescribed medications as needed; they were, however, asked to document pain medication use in their weekly diaries.

Follow-up period. Subjects were followed for 5 weeks after completing the treatment. While they received no further treatment, they were asked to continue recording their pain medication use, activity level, and shoulder pain intensity.

Outcome Measures
We used an intake questionnaire based on that developed by Curtis et al38 to collect weekly demographic data and medical history and to assess the intensity of shoulder pain experienced while subjects performed activities of daily living (ADLs). A weekly self-report questionnaire was used to collect information on activity level, analgesic intake, and to assess the intensity of shoulder pain.

Wheelchair User’s Shoulder Pain Index. Shoulder pain intensity was assessed weekly with the Wheelchair User’s Shoulder Pain Index (WUSPI),30 a 15-item, self-report instrument that measures shoulder pain intensity in wheelchair users in their various ADLs. The WUSPI is a valid and reliable disease-specific measure of pain intensity and is sensitive to treatments that have an impact on shoulder pain intensity.28,38

Numeric rating scale. Shoulder pain intensity was also assessed weekly with a numeric rating scale (NRS). Subjects were asked to rate their average pain on an 11-point scale (ie, 0–10), anchored at the ends by “no pain” and “worst pain ever experienced.” An 11-point NRS measure of pain intensity permits comparison across clinical trials of chronic pain treatment and is recommended as a core outcome measure for chronic pain clinical trials.30

Data Analysis
Efficacy analyses were performed on the intent-to-treat (ITT) population, which consisted of all randomized participants who received at least 1 acupuncture or sham acupuncture treatment. The primary efficacy variable was end-point WUSPI scores and the NRS end-point average pain intensity score was the secondary efficacy measure. A multivariate analysis of variance (MANOVA) was used to evaluate differences in WUSPI and NRS scores across the 3 time points (baseline, post-treatment, follow-up). Because baseline pain scores differed in both treatment groups, we also used post hoc analyses of covariance (ANCOVA) to evaluate the changes in WUSPI and NRS scores from baseline to post-treatment only. Baseline, post-treatment, and follow-up scores were the WUSPI and NRS scores reported in the last week of each period. The WUSPI was scored according to the methods described by Curtis et al.38,41 The percentages of patients obtaining 30% or more reductions in pain intensity NRS from baseline were also analyzed using the Wilcoxon rank-sum test. The rejection of 30% or more in the pain intensity NRS represents a “clini-

RESULTS

Figure 2 summarizes the flow of participants through the study. Overall, 23 manual wheelchair—using subjects (18 men, 5 women; mean age ± standard deviation [SD], 39.9 ± 10.3 y; range, 21–65 y) with chronic SCI (8 with tetraplegia, 15 with paraplegia; average duration of injury, 11.9 ± 9.3 y; range, 1.25–30 y) met inclusion and exclusion criteria and were enrolled in the study. Six participants (3 men, 3 women; 2 with tetraplegia, 4 with paraplegia; 4 with previous shoulder pain) were randomized to acupuncture groups (Wilks λ = .866, F2,11 = 7.932, P = .005, partial η2 = .531). Although the decrease in shoulder pain appeared greater in the acupuncture group than the sham acupuncture group (66% vs 43%, respectively), overall, there was no significant difference between the 2 groups (Wilks λ = .866, F2,11 = 1.087, P = .364, partial η2 = .134). The acupuncture group had a higher mean baseline score (starting point), which, although not statistically different from that of the sham group (P = .299), could have affected the results. Therefore, to assess
ANCOVA with the change in WUSPI scores from baseline to post-treatment as a dependent variable after adjusting for baseline scores. The findings with the ANCOVA were similar to the overall MANOVA in that there was a significant change (decrease) from baseline within each group (acupuncture, \( P = .000 \); sham acupuncture, \( P = .001 \)), but no difference between groups in the amount of change (\( P = .386 \)). The differences in amount of change between groups were not statistically significant; however, acupuncture appeared to produce a longer lasting reduction in pain, based on change from baseline to long-term follow-up.

**Table 1: Participant Demographics in Acupuncture and Sham Acupuncture Groups**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Acupuncture (n=8)</th>
<th>Sham (n=9)</th>
<th>Total (N=17)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>36.0±10.0</td>
<td>41.1±12.1</td>
<td>38.7±11.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Sex (female/male)</td>
<td>1/7</td>
<td>1/8</td>
<td>2/15</td>
<td>0.9</td>
</tr>
<tr>
<td>SCI diagnosis (tetraplegia/paraplegia)</td>
<td>3/5</td>
<td>3/6</td>
<td>6/11</td>
<td>0.9</td>
</tr>
<tr>
<td>Duration of SCI (y)</td>
<td>9.3±10.5</td>
<td>13.1±7.7</td>
<td>11.3±9.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Shoulder pain: dominant side</td>
<td>1/8</td>
<td>1/9</td>
<td>2/17</td>
<td>0.9</td>
</tr>
<tr>
<td>Shoulder pain: nondominant side</td>
<td>1/8</td>
<td>2/9</td>
<td>3/17</td>
<td>0.6</td>
</tr>
<tr>
<td>Shoulder pain: bilateral</td>
<td>6/8</td>
<td>6/9</td>
<td>12/17</td>
<td>0.7</td>
</tr>
<tr>
<td>Performance corrected WUSPI score (0–150)</td>
<td>52.1±29.1</td>
<td>37.1±28.0</td>
<td>44.1±28.7</td>
<td>0.3</td>
</tr>
<tr>
<td>NRS: average</td>
<td>5.3±2.1</td>
<td>4.5±2.6</td>
<td>4.9±2.3</td>
<td>0.6</td>
</tr>
<tr>
<td>NRS: worst</td>
<td>7.1±2.5</td>
<td>6.3±2.7</td>
<td>6.7±2.5</td>
<td>0.6</td>
</tr>
<tr>
<td>NRS: least</td>
<td>2.8±1.7</td>
<td>1.8±1.8</td>
<td>2.3±1.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Wheelchair transfers per day</td>
<td>10.6±7.1</td>
<td>7.9±6.2</td>
<td>9.3±6.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Work/school (h/wk)</td>
<td>18.0±19.9</td>
<td>9.5±12.0</td>
<td>13.8±16.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Driving (h/wk)</td>
<td>6.0±6.7</td>
<td>7.5±8.7</td>
<td>6.8±7.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Chores (h/wk)</td>
<td>5.4±3.0</td>
<td>8.8±7.6</td>
<td>7.1±5.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Personal care (h/wk)</td>
<td>7.9±3.0</td>
<td>7.8±3.2</td>
<td>7.8±3.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Social/recreational (h/wk)</td>
<td>26.4±16.4</td>
<td>26.8±17.4</td>
<td>26.5±16.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Sports/fitness (h/wk)</td>
<td>3.1±2.0</td>
<td>12.1±16.9</td>
<td>7.6±12.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Fig 2. CONSORT flow diagram illustrating the route taken by participants entering the study.** *Medical complication unrelated to study protocol.*

Pain Intensity: Numeric Rating Scores

Table 3 shows the means and SDs of the pain intensity NRS scores. There were similar findings with the NRS; however, there was a larger treatment effect size for the acupuncture group than was seen with the WUSPI. Once again, the MANOVA revealed a significant effect for time (Wilks \( \Lambda = .501 \), \( F_{2,13} = 6.470 \), \( P = .011 \), partial \( \eta^2 = .499 \)), but not for treatment group by time (Wilks \( \Lambda = .794 \), \( F_{2,13} = 1.690 \), \( P = .223 \), partial \( \eta^2 = .206 \)). Although the ANCOVA showed a significant change from baseline for the acupuncture group (\( P = .003 \)) and a nonsignificant change for the sham group (\( P = .284 \)), the difference in change between groups was still not significant (\( P = .107 \)). Similarly for the long-term follow-up, the differences in amount of change between groups were not statistically significant, although acupuncture appeared to produce a longer lasting reduction in pain, based on change from baseline to long-term follow-up. Figure 3 shows the proportion of subjects in each treatment group that achieved a “clinically meaningful”\(^{42,43}\) reduction in pain intensity NRS (eg, ≥30%). On completion of treatment, 75% (6/8) of participants in the acupuncture group had 30% or more pain score reductions, while only 25% (2/8) of participants in the sham acupuncture group reported similar reductions. By the end of the follow-up period, 75% (6/8) of participants in the acupuncture group had 30% or more reductions in their pain score, while 50% (4/8) of participants who received sham acupuncture reported similar reductions. These differences were not statistically significant (\( P = .13 \), \( P = .61 \), respectively).

**Table 3** shows the means and SDs of the pain intensity NRS scores.
Activity Level, Analgesic Intake, and Other Therapies

Confounding variables that may have influenced mean shoulder pain intensity, such as activity level (number of wheelchair transfers a day, hours spent per week at work and/or at school, driving, doing household chores, personal care, social/recreational activities, and fitness-related activities), analgesic intake, or other therapies did not change significantly in either group (P > .05).

DISCUSSION

Our study is the first randomized, double blind (evaluator, participant), placebo (invasive, sham) controlled trial to evaluate the efficacy of acupuncture for chronic musculoskeletal shoulder pain in subjects with SCI. We found a significant decrease in shoulder pain intensity with acupuncture; however, this change did not differ significantly from the decrease with sham acupuncture. Because pain relief did not differ significantly between the 2 groups, our results may be interpreted in 2 ways. One, acupuncture is no more effective than sham acupuncture in reducing chronic shoulder pain (ie, point location does not make a difference). An equally plausible interpretation, however, is that acupuncture at both specific and nonspecific anatomic sites can relieve pain.45,46 We saw a medium to large effect associated with the acupuncture treatment, indicating that it was superior to sham acupuncture in relieving shoulder pain. Because our sample size was small and SDs were large, however, our study lacked adequate power to detect the differences between acupuncture (ie, needling at acupoints) and sham acupuncture (ie, needling at nonacupoints), thus increasing the risk of a false-negative conclusion (type II error).

Indeed, an interesting finding was the strong response (43%) to our sham acupuncture control intervention. Response rates to inert placebo controls are reported to be around 30%.47 As stated earlier, however, penetration of the skin with acupuncture needles, even light needling at nonacupoints, is not inert. Noxious stimulus to the skin during sham acupuncture may result in endorphin release through neurophysiologic mechanisms called diffuse noxious inhibitory control (DNIC).27,31,32

It has been suggested that DNIC has a relatively minor role in acupuncture analgesia and that other systems, mediated by serotonin and noradrenaline, and changes in the autonomic nervous system, are more important.48 There is evidence that chronic pain is mediated not only through neurotransmitters, but also through the autonomic nervous system.49 These different mechanisms may explain the mixed picture seen in sham acupuncture-controlled trials for chronic pain and in our results. Sham acupuncture will have some effect through DNIC and will, therefore, provide a greater effect than that typically expected from placebo alone. Real acupuncture will utilize the endorphin system, but will also evoke a putative autonomic response and local trigger-point action to produce additional effects and, therefore, an increased clinical response in comparison with sham acupuncture.30

A limitation of our study could be our choice of the control group. There are, unfortunately, no established rules for systematically choosing the most appropriate controls in acupuncture randomized controlled trials (RCTs). The World Health Organization currently recommends the following possible control groups: (1) no treatment; (2) standard therapy; (3) mock transcutaneous electric nerve stimulation; (4) real acupuncture (at alternative sites); and (5) sham acupuncture. Unfortunately, “no treatment” and “standard therapy” (ie, physical therapy) do not control for placebo (or nocebo) effects or for nonspecific responses to needling. Furthermore, physical therapy is a generically vague term used to describe several modalities, none of which have been proven to be more effective than placebo for chronic shoulder pain. One of the challenges in clinical trials of acupuncture is identifying a suitable control with a psychologic impact similar to needle acupuncture, yet has minimal or no physiologic activity.48 Various sham acupuncture controls have been described and include: (1) “placebo needles”; (2) superficial needling (minimal acupuncture); and (3) needling at nonacupuncture points.31 We chose to use superficial needling at nonacupuncture points on the shoulder as our control intervention. Although nonacupoints on the shoulder might be too close to highly effective acupuncture points,48 we were concerned that needling at points located elsewhere on the body would not be as convincing as those on the shoulder. Overall, we believe our sham acupuncture intervention was an effective control because the majority of participants believed they had received acupuncture, regardless of group assignment. The ones who guessed correctly that they were receiving sham acupuncture said they did so only because their shoulder pain did not seem to have improved by the end of the treatment. Other controlled trials have reported success using nonpenetrating (“placebo”) needles composed of a needle (either real or blunted) in a guide tube or retractable handle that is attached to the skin with double-sided adhesive tape that masks the skin (ie, a form of noninvasive sham acupuncture).30-32 We were concerned that the use of these more technologically sophisticated techniques would require substantial deviations from the usual practices of our acupuncturists.35,36

Also noteworthy in our results were the clinically relevant reductions of pain after acupuncture treatment. A reduction in pain of at least 30% represents a clinically important improvement in chronic pain intensity on an 11-point NRS regardless of baseline pain intensity,42 and has been recommended as a core outcome measure in clinical trials of chronic pain.48 In our study, 75% of the subjects in the acupuncture group reported a clinically meaningful reduction in pain immediately after the 10 treatments and at the 5-week follow-up, compared with 25% and 50% in the sham acupuncture group, respectively. Because of limitations in sample size, however, these differences were not statistically significant.

### Table 2: Mean Performance-Corrected WUSP Scores in Acupuncture and Sham Acupuncture Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretreatment (t1)</th>
<th>Post-Treatment (t2)</th>
<th>Follow-Up (t3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acupuncture (n=8)</td>
<td>52.1±29.1</td>
<td>17.7±14.5</td>
<td>16.1±16.3</td>
</tr>
<tr>
<td>Sham acupuncture (n=9)</td>
<td>37.1±28.0</td>
<td>21.0±18.0</td>
<td>20.7±24.6</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD. Wilks $\lambda$ (time) = .469, $F_{2,14} = 7.932$, $P = .005$, partial $\eta^2 = .331$. Wilks $\lambda$ (time by treatment group) = .866, $F_{2,14} = 1.087$, $P = .364$, partial $\eta^2 = .134$.

### Table 3: Mean Pain Intensity NRS Scores in Acupuncture and Sham Acupuncture Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretreatment (t1)</th>
<th>Post-Treatment (t2)</th>
<th>Follow-Up (t3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acupuncture (n=8)</td>
<td>5.0±2.1</td>
<td>2.5±2.1</td>
<td>2.9±2.2</td>
</tr>
<tr>
<td>Sham acupuncture (n=8)*</td>
<td>4.3±2.4</td>
<td>3.6±2.6</td>
<td>3.4±3.1</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD. Wilks $\lambda$ (time) = .501, $F_{2,13} = 6.470$, $P = .011$, partial $\eta^2 = .499$. Wilks $\lambda$ (time by treatment group) = .794, $F_{2,13} = 1.890$, $P = .223$, partial $\eta^2 = .206$.

*One person did not complete the NRS.
The results of our study are similar to those of a previous single-subject clinical trial that assessed the efficacy of acupuncture for chronic musculoskeletal shoulder pain in 9 manual wheelchair-using subjects with SCI. In that study, shoulder pain intensity (WUSPI scores) decreased 53.4% after 10 acupuncture treatments and was maintained through the 5-week follow-up period. To our knowledge, that study was the first RCT of acupuncture for chronic shoulder pain. Finally, although our study lacked adequate power, it identified version has recently been adapted for use with SCI subclinical trials in non-SCI populations and a modified version has been adapted for use with SCI subjects while causing minimal adverse effects. Therefore, rather than reject a potentially effective therapy because of its methodologic shortcomings, we recommend further research into its efficacy through larger, multicenter, clinical trials.

CONCLUSIONS

We observed a significant decrease in shoulder pain intensity with acupuncture treatment; however, this change did not differ significantly from that resulting from sham acupuncture. There appears to be an analgesic effect or a powerful placebo effect associated with both acupuncture and sham acupuncture. There was a medium to large effect associated with the acupuncture treatment, suggesting that it may be superior to sham acupuncture in relieving shoulder pain in subjects with SCI. Our sample size limited the study’s power to detect significant differences between the groups, increasing the risk of a type II error. Therefore, our results should be interpreted cautiously. A larger, more definitive RCT with a similar design is feasible and warranted.

APPENDIX 1: ACUPUNCTURE POINTS USED FOR TREATMENT

Local points (chosen according to shoulder pain symptoms)

LI 14 Binao GB 21 Jianjing SI 14 Jianwaishu
LI 15 Jianyu SI 9 Jianzhen SI 15 Jianzhong
LI 16 Jugu SI 10 Naoshu LU 1 Zhongfu
SJ 13 Naohui SI 11 Tianzong LU 2 Yunmen
SJ 14 Jianliao SI 12 Bingfeng PC 2 Tianquan
SJ 15 Tianliao SI 13 Quyuan

Distal points (chosen according to local points used)

LI 2 Erjian LI 18 Neck-Futu DU 14 Dazhui
LI 4 Hegu SJ 3 Zhongzhui GB 20 Fengchi
LI 10 Shousanli SI 6 Yanglao BL 10 Tianzhu
LI 11 Quchi LU 3 Tianfu BL 11 Dashu

Abbreviations: BL, urinary bladder; DU, Du Mai or governing vessel; GB, gallbladder; LI, large intestine; LU, lung; PC, pericardium; SI, small intestine; SJ, Sanjiao or triple energizer/burner.
APPENDIX 2: CONTROL POINTS (C) USED FOR SHAM ACUPUNCTURE TREATMENTS

Local points
C1 Located on the anterior aspect of deltoid; 1 cun* lateral to M-UE-48 (Jiannecking), which is midway between LI 15 (Jianyu) and top of anterior axillary fold.
C2 Located in the middle of the deltoid muscle, 1 cun proximal to N-UE-14 (Naoshang), which is located in the center of the triangle formed by connecting LI 15 (Jianyu), SJ 14 (Jianliao), and N-UE-14 (Naoshang).
C3 Located on the supraspinatus muscle; anterior and inferior to the acromion, 1 cun proximal to LI 15 (Jianyu) and 1 cun inferior to LI 16 (Jugu).
C4 Located posterior and inferior to the acromion; 1 cun inferior to SJ 14 (Jianliao) and 1 cun medial to SJ meridian.
C5 Located on the scapula on the line midway between SI 9 (Jianshen) and SI 10 (Naoshu).
C6 Located on the line midway between GB 21 (Jianjing) and the acromion.

Distal points
C7 Located on the dorsal aspect of the forearm; 1 cun lateral to LI 10 (Shousanli), approximately midway between LI 10 and the radius.
C8 Located on the dorsal aspect of the hand, midway between LI 4 (Hegu) and LI 5 (Yangxi) and 1 cun lateral to LI meridian, above the first metacarpal bone.

Abbreviations: see appendix 1.

*Chinese anatomical inch.

References


Suppliers
a. DBC-10 spring handle (0.20/H11003 40mm); Lhasa Medical Supplies, 234 Libbey Pkwy, Weymouth, MA 02189.
b. Version 14; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
c. Version 91; SAS Institute, 100 SAS Campus Dr, Cary, NC 27513.
Cognitive Impairment in Patients With Traumatic Brain Injury and Obstructive Sleep Apnea

Mark C. Wilde, PsyD, Richard J. Castriotta, MD, Jenny M. Lai, MD, Strahl Atanasov, MD, Brent E. Masel, MD, Samuel T. Kuna, MD


Objective: To examine the impact of comorbid obstructive sleep apnea (OSA) on the cognitive functioning of traumatic brain injury (TBI) patients.

Design: A case-control study. Neuropsychologic test performances of TBI patients with OSA were compared with those who did not have OSA. The diagnosis of OSA was based on standard criteria using nocturnal polysomnography.

Setting: Three academic medical centers with level I trauma centers, accredited sleep disorders centers, and rehabilitation medicine programs.

Participants: Thirty-five TBI patients who were part of a project that assessed the effect of sleep disorders in a larger sample of consecutively recruited TBI patients. There were 19 patients with TBI and OSA. They were compared with 16 TBI patients without OSA who were comparable in terms of age, education, severity of injury (when available), time postinjury, and Glasgow Coma Scale scores (when available).

Interventions: Not applicable.

Main Outcome Measures: The Psychomotor Vigilance Test, Rey Complex Figure Test, Rey Auditory Verbal Learning Test, digit span test from the Wechsler Memory Scale–Revised, and finger-tapping test.

Results: The TBI patients with OSA performed significantly worse than the non-sleep disordered TBI patients on verbal and visual delayed-recall measures. The groups performed comparably on motor, visual construction, and attention tests. The TBI patients with OSA made more attention lapses (reaction times ≥500ms), but showed comparable fastest and slowest reaction times on a measure of sustained attention.

Conclusions: OSA is associated with more impairment of sustained attention and memory in TBI patients. It is possible that early identification and treatment of OSA may improve cognitive, and thus potentially functional, outcomes of TBI patients with this disease.

Key Words: Brain injuries; Hypersomnia; Neuropsychology; Rehabilitation; Sleep apnea; obstructive; Sleep disorders; Trauma.

There is an apparent increased incidence of obstructive sleep apnea (OSA) and other sleep disorders in traumatic brain injury (TBI) patients.1-5 A wide range of cognitive deficits, most commonly involving vigilance, attention, arousal, memory, and executive functions, have been associated with OSA.6 Additionally, continuous positive airway pressure (CPAP), the first line treatment for OSA, has been associated with improvements in some cognitive functions in some placebo-controlled trials with patients who have OSA.5,6

Conversely, it is well established that significant cognitive impairment is associated with TBI, and that the degree of cognitive impairment is associated with the severity of the injury.7,8 More specifically, deficits in information-processing speed, attention, memory, and executive function are commonly reported.9 TBI patients with a mild level of injury severity (Glasgow Coma Scale [GCS] score of 13–15 and an negative computed tomography [CT] scan of the brain) generally have a complete recovery, while those with more severe injuries have less complete recoveries and may be left with some degree of disability.7,9,10 Rehabilitation appears to benefit people with significant TBI.11 It is likely, however, that other comorbid disorders contribute to less optimal cognitive outcomes in this patient population.

Although sleep disorders appear to be common in TBI, the literature is sparse concerning their potential impact on the TBI patient’s cognitive functioning and outcome.12 Masel et al3 found no significant differences between sleepy and nonsleepy TBI subjects on measures of intellectual functioning, attention, memory, or executive function. Our goal in this study was to evaluate the degree to which the cognitive functioning of TBI patients is associated with the comorbid OSA. We hypothesized that TBI patients with OSA would show more impaired memory and attention than would those without OSA.

METHODS

Participants

The analysis reported herein was based on 35 TBI patients who were participating in a multicenter study of the relation between sleep disorders and TBI. Subjects who were more than 18 years old and at least 3 months post-TBI were prospectively recruited from rehabilitation services at 3 academic medical centers: Memorial Hermann Hospital, Houston, TX, Tertiary Learning Center, Galveston, TX, and Philadelphia Veterans Administration Medical Center, Philadelphia, PA. The study was approved by the committees for the protection of human subjects or the institutional review boards of all partici-
ipating institutions. Eighty-seven TBI patients underwent the initial nocturnal polysomnography (NPSG). Forty-six patients (53%) had no sleep disorder. The other sleep-disorder diagnoses included post-traumatic hypersomnia, periodic limb movements during sleep, and narcolepsy.

The 19 patients who were diagnosed with OSA were compared with 16 patients who had no sleep disorders, as confirmed by NPSG and the Multiple Sleep Latency Test (MSLT). Because of our small sample size, it was impossible to match the groups so that they would be equivalent in age, education, time postinjury, and injury severity variables. Thus, we attempted to equate the groups by eliminating control patients by age and time postinjury until the groups were as similar as possible in the characteristics listed above.

All patients had a diagnosis of TBI that was based on a history of positive loss of consciousness and all were at least 3 months postinjury. We made every effort to collect injury severity data on all patients, but this was not possible in all cases.

When the relevant data were available, we classified TBI severity by considering both emergency department GCS and computed tomography (CT) scan findings according to traditional criteria. Patients were classified as having a severe injury if their GCS was less than 9, irrespective of their CT scan findings. Patients were classified as having a moderate injury if they had a GCS of 9 to 12, again irrespective of CT findings, or if they had a GCS of 13 to 15 and a positive CT scan. Patients were classified as having a moderate-to-severe injury if they had a positive CT scan but there was no GCS score available with which to make a finer characterization. Patients were classified as having a mild TBI if their GCS was 13 to 15 and the CT scan was negative.

Sleep Disorder Diagnosis

All patients underwent a history and physical examination and NPSG. An Epworth Sleepiness Scale questionnaire was completed on each subject on the night of the polysomnography. Nocturnal polysomnograms were performed in sleep laboratories in each center. Using standard techniques, a computer data acquisition and analysis system recorded the following signals: electroencephalogram (EEG) (C3A2, C4A1, O1A2, O2A1), bilateral electrooculograms, submental and bilateral anterior tibialis electromyogram, thoracic and abdominal excursion by piezocrystals, oral and nasal airflow by thermistor O1A2, O2A1), bilateral electrocorticogram, submental and bilateral electrocardiogram signals were recorded during the naps: EEG (C3A2, C4A1, O1A2, O2A1), bilateral electrooculograms, submental and bilateral electrocardiogram. Aurine sample was collected for analysis for possible opiates, benzodiazepines, cannabinoids, amphetamines, or adrenergic drugs.

Obstructive apnea was defined by cessation of breathing lasting 10 seconds or longer and accompanied by continuous respiratory effort. Hypopnea was defined as more than 50% decreases in airflow for 10 seconds or longer, with 4% or more oxygen desaturation by pulse oximetry and/or electroencephalographic arousal.

The diagnosis of OSA was made if there were 5 or more apneas per hour of sleep and/or 10 or more apneas plus hypopneas per hour of sleep. Rapid eye movement (REM)-related OSA was defined as 5 or more apneas per hour of REM sleep and/or 10 or more apneas plus hypopneas per hour of REM sleep, with less than 5 apneas per hour of total sleep and less than 10 apneas plus hypopneas per hour of total sleep.

Table 1 shows the sleep data for each group.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Non-OSA</th>
<th>OSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>Total sleep (h)</td>
<td>6.29±1.36</td>
<td>5.54±1.43</td>
</tr>
<tr>
<td>Sleep efficiency*</td>
<td>79.32±11.55</td>
<td>68.81±18.95</td>
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<tr>
<td>Percent stage 1*</td>
<td>9.05±7.61</td>
<td>17.42±13.61</td>
</tr>
<tr>
<td>Percent stage 2*</td>
<td>70.09±12.34</td>
<td>62.02±14.62</td>
</tr>
<tr>
<td>Percent stage 3 and 4*</td>
<td>2.75±4.21</td>
<td>3.85±7.60</td>
</tr>
<tr>
<td>Percent REM sleep*</td>
<td>16.34±8.79</td>
<td>17.55±10.17</td>
</tr>
<tr>
<td>Apnea Hypopnea Index*</td>
<td>4.49±5.53</td>
<td>26.83±19.30</td>
</tr>
<tr>
<td>MSLT score*</td>
<td>5.06±3.04</td>
<td>11.19±5.23</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± standard deviation (SD) or as indicated.
*Total sleep time/total study time.
†Percentage of total sleep time that is stage 1 sleep.
‡Percentage of total sleep time that is stage 2 sleep.
§The number of apnea and hypopnea events per hour of sleep.
¶The average latency across attempts to fall asleep over the course of 5 MSLT naps.

Measures

Each patient underwent a brief neuropsychologic evaluation. The measures used are described below.

Psychomotor Vigilance Test. Sustained attention was evaluated with the Psychomotor Vigilance Test (PVT). The PVT was chosen because it is sensitive to the effects of sleepiness on cognitive functioning, as well as cognitive deficits associated with OSA and its treatment. The PVT is administered via a small, handheld computerized device with a 3-digit millisecond light-emitting diode counter and display window. Patients undergo a 10-minute trial in which they press a response button when they see a number counting up from 0. Once the response button is pressed, the counter stops and feedback is given on the subjects’ reaction times for a 15-second interval. The amount of time between stimulus presentations varies between minimum and maximum interstimulus intervals of 2000 and 10,000ms. Performances are recorded in the PVT device and downloaded into a database after the testing bout. We selected the average of the fastest 10% of reaction times, the average of the slowest 10% reaction times, and the number of lapses (reaction times ≥500ms) from the PVT for this analysis because these variables are sensitive to sustained attention under conditions of sleep deprivation and in sleep disorders. Normally, the PVT is given in several testing bouts across time. Because of time constraints, each patient in this study was exposed to the PVT once.

Wechsler Memory Scale–Revised digit span test. The patients underwent the digit span test from the Wechsler Memory Scale–Revised. On this test, subjects are asked to repeat numbers of increasing length forward after the examiner speaks them. They are then administered another condition in which they repeat another series of numbers of increasing length backward. The patient receives 1 point for each series correctly.
repeated. The maximum score for each trial is 12. We examined each trial independently for the purposes of this analysis.

**Rey Complex Figure Test.** On the Rey Complex Figure Test (RCFT), a well-known test of visual constructional skill and visual memory, patients are asked to copy a complex geometric figure and then draw it from memory 30 minutes later without warning. The maximum score for the RCFT is 36 for both the immediate and delayed recall trials. In this study, there was no immediate recall trial.

**Rey Auditory Verbal Learning Test.** The Rey Auditory Verbal Learning Test (RAVLT) is a well-known measure of verbal learning and recall in which a subject is read a list of 15 words and asked to recall them after the examiner finishes reading the list. Subjects are given 5 learning trials. They are then read a new 15-word list and are again asked to recall the words after the examiner finishes reading the list. Subjects are exposed to the second list once, after which they are asked to recall as many words as he/she can from the first list. After a 30-minute delay, subjects are again asked to recall the words from the first list; they subsequently participate in a recognition trial in which he/she determines whether the word he/she heard was in the first list. The following measures from the RAVLT were used for this study: (1) total recall over the 5 learning trials; (2) short delay recall (the number of words recalled from the first list after exposure to the second); (3) long delay recall (the number of words recalled after a 30-minute delay); and (4) the Rey percent retained (the percent of words recalled on trial 7 that were also recalled on the last learning trial, allowing for repeated. The maximum score for each trial is 12. We examined each trial independently for the purposes of this analysis.

**Table 2: Demographic Data for the TBI Patients With and Without OSA**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Non-OSA</th>
<th>OSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12 (75)</td>
<td>17 (90)</td>
</tr>
<tr>
<td>Female</td>
<td>4 (25)</td>
<td>2 (10)</td>
</tr>
<tr>
<td>Race</td>
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<td></td>
</tr>
<tr>
<td>White</td>
<td>13 (81)</td>
<td>13 (68)</td>
</tr>
<tr>
<td>African American</td>
<td>2 (12)</td>
<td>3 (16)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1 (6)</td>
<td>3 (16)</td>
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<tr>
<td>Cause of injury</td>
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<td></td>
</tr>
<tr>
<td>Assault</td>
<td>1 (6)</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Auto/vehicle</td>
<td>12 (76)</td>
<td>10 (53)</td>
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<tr>
<td>Construction</td>
<td>1 (6)</td>
<td>0 (0)</td>
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<tr>
<td>Fall</td>
<td>1 (6)</td>
<td>4 (21)</td>
</tr>
<tr>
<td>Hit by falling object</td>
<td>1 (6)</td>
<td>4 (21)</td>
</tr>
<tr>
<td>CT scan findings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>8 (50)</td>
<td>16 (53)</td>
</tr>
<tr>
<td>Negative</td>
<td>1 (6)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Positive</td>
<td>7 (44)</td>
<td>9 (47)</td>
</tr>
<tr>
<td>Brain injury severity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>8 (50)</td>
<td>10 (53)</td>
</tr>
<tr>
<td>Moderate</td>
<td>2 (12)</td>
<td>3 (16)</td>
</tr>
<tr>
<td>Moderate/severe</td>
<td>3 (19)</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Severe</td>
<td>3 (19)</td>
<td>5 (26)</td>
</tr>
</tbody>
</table>

**NOTE.** Values are n (%).

**Table 3: Demographic and Test Performance Data for TBI Patients With and Without OSA**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Non-OSA</th>
<th>OSA</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)*</td>
<td>47.25±9.26</td>
<td>51.37±14.96</td>
<td>.32</td>
</tr>
<tr>
<td>Education (y)*</td>
<td>13.50±2.19</td>
<td>12.95±3.31</td>
<td>.16</td>
</tr>
<tr>
<td>Time post (mo)*</td>
<td>77.08±122.50</td>
<td>124.72±181.75</td>
<td>.30</td>
</tr>
<tr>
<td>Digit span forward*</td>
<td>8.80±2.34</td>
<td>7.28±2.40</td>
<td>.31</td>
</tr>
<tr>
<td>Digit span backward*</td>
<td>5.81±2.88</td>
<td>5.53±2.32</td>
<td>.11</td>
</tr>
<tr>
<td>Finger tapping (dominant)*</td>
<td>41.58±10.22</td>
<td>40.02±11.36</td>
<td>.14</td>
</tr>
<tr>
<td>Finger tapping (nondominant)*</td>
<td>39.08±8.06</td>
<td>36.48±6.98</td>
<td>.34</td>
</tr>
<tr>
<td>RAVLT list A total*</td>
<td>38.13±11.38</td>
<td>33.00±9.59</td>
<td>.49</td>
</tr>
<tr>
<td>RAVLT short delay*</td>
<td>7.75±2.62</td>
<td>4.95±3.36</td>
<td>.93</td>
</tr>
<tr>
<td>RAVLT long delay*</td>
<td>6.81±3.10</td>
<td>4.47±2.99</td>
<td>.77</td>
</tr>
<tr>
<td>RAVLT % retained*</td>
<td>71.68±27.57</td>
<td>49.98±25.42</td>
<td>.82</td>
</tr>
<tr>
<td>Rey figure copy*</td>
<td>33.03±2.83</td>
<td>32.74±3.59</td>
<td>.09</td>
</tr>
<tr>
<td>Rey figure delay*</td>
<td>17.75±5.86</td>
<td>13.08±7.34</td>
<td>.70</td>
</tr>
<tr>
<td>PVT lapses†</td>
<td>2.44±2.90</td>
<td>10.00±11.33</td>
<td>.90</td>
</tr>
<tr>
<td>PVT fastest 10% RT†</td>
<td>220.67±21.99</td>
<td>171.79±267.01</td>
<td>.26</td>
</tr>
<tr>
<td>PVT slowest 10% RT†</td>
<td>508.68±208.51</td>
<td>998.11±1396.12</td>
<td>.50</td>
</tr>
</tbody>
</table>

**NOTE.** Values are mean ± SD. Abbreviation: RT, reaction times. †n for Non-OSA group is 16; n for OSA group is 19.

**RESULTS**

Tables 2 and 3 present the demographic and neuropsychologic data for the 2 groups. On average, the patients were studied 94.3±152.1 months postinjury. As expected, there were no significant group differences for age, education, injury severity, time postinjury, or ethnicity.

Patients performed comparably on the dominant-hand FTT ($t_{35} = 42, P = .68$), nondominant-hand FTT ($t_{35} = 1.02, P = .31$), the digit span test forward ($t_{35} = 91, P = .37$) and backward ($t_{35} = 32, P = .75$), the copy administration of the RCFT ($t_{35} = .26, P = .79$), and the total recall from the RAVLT list A total ($t_{35} = 1.45, P = .16$). The OSA and TBI patients, however, performed significantly worse on memory recall measures, including: RCFT delayed recall ($t_{35} = 2.05, P = .048$), RAVLT short delay free recall ($t_{35} = 2.71, P = .01$), RAVLT long delay free recall ($t_{35} = 2.27, P = .03$), and the RAVLT percent retention ($t_{35} = 2.42, P = .02$). The TBI patients with OSA made a greater number of PVT lapses ($t_{35} = 2.59, P = .01$). The average of the 10% of slowest ($t_{35} = 1.49, P = .14$), and the average of the 10% of fastest response times ($t_{35} = 7.54, P = .44$), were similar between the 2 groups. The effect sizes associated with all of the statistically significant group differences were moderate-to-large by Cohen’s criteria (see table 2).

Because TBI severity is a significant predictor of cognitive outcome, the fact that data on severity of injury were missing for some patients is a weakness of this study. To address this, the analysis was repeated on a subset of 21 patients whose...
injury severity was known. The groups were equated for age, education, and time postinjury, using the same method used in the previous analysis. There were 9 and 12 patients with and without OSA, respectively. Table 4 shows the data from this study, including means, standard deviations, and effect sizes. There were no differences between the groups on age, education, and time postinjury, using the same method used in the previous analysis. There were 9 and 12 patients with and without OSA, respectively. Table 4 shows the data from this study, including means, standard deviations, and effect sizes. There were no differences between the groups on age, education, time postinjury, sex, severity of injury, or race. Analysis of cognitive variables with this small subsample with complete data on injury severity did not significantly change the findings.

**DISCUSSION**

OSA appears to be associated with additional decreased sustained attention and impaired memory function in TBI patients. We compared a group of TBI patients with OSA with a group of TBI patients without a sleep disorder. Both groups were equated on relevant demographic and injury-related variables to the best possible degree, given the limitations in our data. TBI patients with OSA performed significantly worse on measures of delayed recall and retention of verbal and visual information and had more attention lapses on a vigilance task. Because cognitive deficits appear to be associated with functional outcome and employment, this increased level of cognitive impairment may have an impact on functional outcome if OSA is not recognized and treated.25-30 To our knowledge, this is the first study that has compared the cognitive functioning of TBI patients with and without OSA and the first to find a possible link between increased cognitive impairment and OSA in TBI patients.

At present, however, these findings are only correlational and thereby do not imply causality. Furthermore, this study lacked complete data on acute indices of injury severity, such as GCS and brain CT findings, for the entire sample. Thus, we are unable to confirm whether both groups were indeed equivalent in terms of severity and it could be argued that it is possible that our findings resulted from heretofore unrecognized differences in injury severity between the 2 groups. When we repeated the analysis with a smaller group of patients with known severity data, the results did not change significantly. Many studies have shown memory dysfunction in otherwise healthy patients with OSA.6 Thus, it is not surprising that we found greater memory impairment in TBI patients with OSA. This analysis, however, is preliminary and a study with a larger sample of well-characterized TBI patients is needed.

**Study Limitations**

The small sample size could be considered a significant weakness of this study. While we would agree that a study with a larger sample size would be optimal, the effect sizes for the significant differences we found ranged from medium to large. This increases our confidence in the differences with a small sample size. In fact, more statistically significant differences would have likely emerged with a larger sample size.

### CONCLUSIONS

Our findings are intriguing in that they point to a possible avenue for improving the functional and cognitive outcomes of these patients. Thus, our data would suggest that the early identification and treatment of comorbid OSA could potentially have a meaningful impact on the functional recovery of these patients if they are able to comply with CPAP treatment. This finding needs to be authenticated with a more carefully characterized sample of patients. Additionally, further research is needed into cognitive deficits in OSA and TBI and their impact on day-to-day functioning.

#### Table 4: Demographic and Test Performance Data for Subsample of TBI Patients With Known Severity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Non-OSA</th>
<th>OSA</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)*</td>
<td>40.08±13.23</td>
<td>49.67±19.68</td>
<td>-0.25</td>
</tr>
<tr>
<td>Education (y)*</td>
<td>13.00±1.95</td>
<td>13.78±4.18</td>
<td>-0.59</td>
</tr>
<tr>
<td>Time post (mo)*</td>
<td>10.58±16.79</td>
<td>19.22±26.60</td>
<td>-0.07</td>
</tr>
<tr>
<td>Digit span forward*</td>
<td>7.33±2.61</td>
<td>7.00±2.12</td>
<td>0.14</td>
</tr>
<tr>
<td>Digit span backward*</td>
<td>6.33±2.77</td>
<td>5.56±2.24</td>
<td>0.30</td>
</tr>
<tr>
<td>Finger tapping (dominant)*</td>
<td>40.66±10.67</td>
<td>40.09±10.14</td>
<td>0.05</td>
</tr>
<tr>
<td>Finger tapping (nondominant)*</td>
<td>38.42±13.20</td>
<td>36.71±6.93</td>
<td>0.16</td>
</tr>
<tr>
<td>RAVLT list A total*</td>
<td>39.08±9.35</td>
<td>35.11±6.75</td>
<td>0.48</td>
</tr>
<tr>
<td>RAVLT short delay*</td>
<td>7.42±2.35</td>
<td>4.67±3.67</td>
<td>0.92</td>
</tr>
<tr>
<td>RAVLT long delay*</td>
<td>6.50±2.54</td>
<td>4.22±3.11</td>
<td>0.82</td>
</tr>
<tr>
<td>RAVLT % retained*</td>
<td>65.21±22.60</td>
<td>42.84±26.44</td>
<td>0.92</td>
</tr>
<tr>
<td>Rey figure copy*</td>
<td>31.64±5.03</td>
<td>30.67±3.85</td>
<td>0.21</td>
</tr>
<tr>
<td>Rey figure delay*</td>
<td>18.14±6.71</td>
<td>10.50±7.46</td>
<td>-0.70</td>
</tr>
<tr>
<td>PVT lapses†</td>
<td>2.40±2.88</td>
<td>12.63±13.21</td>
<td>1.08</td>
</tr>
<tr>
<td>PVT fastest 10% RT†</td>
<td>194.28±60.24</td>
<td>235.16±40.87</td>
<td>-0.79</td>
</tr>
<tr>
<td>PVT slowest 10% RT†</td>
<td>481.54±49.08</td>
<td>905.85±564.38</td>
<td>-1.06</td>
</tr>
</tbody>
</table>

**NOTE.** Values are mean ± SD.

* N for Non-OSA group is 16; n for OSA group is 19.

† N for Non-OSA group is 16; n for OSA group is 18.

### References


Supplier

Development of a French Isometric Strength Normative Database for Adults Using Quantitative Muscle Testing

Jean-Yves Hogrel, PhD, Christine A. Payan, MD, Gwen Ollivier, PT, Véronique Tanant, PT, Shahram Attarian, MD, Annaelle Couillandre, PhD, PT, Arnaud Dupeyron, MD, Lucette Lacomblez, MD, PhD, Valérie Doppler, MD, Vincent Meininguer, MD, Christine Tranchant, MD, PhD, Jean Pouget, MD, Claude Desnuelle, MD, PhD


Objective: To establish a normative database for isometric strength measured by quantitative muscle testing (QMT) for a French adult population.

Design: Measurement of maximal voluntary isometric contraction.

Setting: Four clinical centers involved in neuromuscular disorders.

Participants: A total of 315 healthy adults (147 men, 168 women) ages 20 to 80 years.

Interventions: Not applicable.

Main Outcome Measure: Isometric torque values of 14 muscle functions (13 bilaterally and neck).

Results: This study led to the development of a French isometric strength normative database for adults measured by QMT. For each muscle function, predictive regression models using age, sex, and weight are proposed. Some methodologic issues concerning strength measurement are discussed.

Conclusions: This database can be used to compute relative deficits in muscle strength for 27 muscle functions and also to estimate composite scores for follow-up of patients either during the natural history of their disease or during a therapeutic trial.

Key Words: Isometric contraction; Muscles; Outcome assessment (health care); Rehabilitation.

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ANY PATHOLOGY INVOLVING the neuromuscular system can be longitudinally investigated with 1 or several methods to follow degenerative effects on muscle strength during the natural history of the disease or to detect small changes during a therapeutic trial. As already described,1,2 several methods may be used to assess muscle strength. Depending on the aim of the assessment, each presents several advantages and drawbacks. Methodologic issues are fundamental because patients present with different motor capacities, changes in strength may be fairly small over the duration of the trial, and different evaluators may be involved in different clinical centers.

The term quantitative muscle testing (QMT) implies that quantification of strength is performed by a measurement device or sensor.3 It can be performed by handheld dynamometers, strain gauges with 1 extremity fixed to a wall-mounted frame, or isokinetic ergometers. Strain gauges have been frequently used in clinical trials concerning various neuromuscular diseases.4,8 Strength measurements are performed in isometric conditions to assess the maximal voluntary isometric contraction (MVIC) at a given position. Although muscles produce linear forces, motions at joints are generally rotary. Strength generated around joints should be measured as torque (in newton meters) because the degrees of freedom of joints are mainly rotational. When strength estimates are made, the moment arm must be carefully measured. Otherwise, the reproducibility of measurements cannot be assessed even when anatomic reference marks are methodically respected. According to Munsat,9 MVIC measurement provides a "direct, reproducible, sensitive and practical" method to assess changes in the voluntary motor system. The reliability of QMT was questioned in a report on a multicenter trial in amyotrophic lateral sclerosis (ALS).10 The authors10 argued that the development of precise procedures understood and applied by all the involved evaluators is a prerequisite to achieve consistent measurements. However, compared with manual muscle testing (MMT), which can require multiple training sessions to obtain acceptable reliability, a high level of agreement can be obtained with a single session of training in QMT.11

Andres et al12 developed standardized quantified tests known as the Tufts Quantitative Neuromuscular Exam (TQNE) for evaluating patients suffering from ALS. The TQNE includes measurements of pulmonary and oropharyngeal functions, timed motor activities, and QMT. The different measurements can be combined by using z scores based on the population mean and standard deviation to produce megacores. The TQNE was used for instance by Munsat13 and Conradi14 and colleagues to assess motor disability and disease progression in ALS patients. More recently, MVIC was used in children suffering from Duchenne muscular dystrophy to assess the efficacy of creatine or glutamine supplementation by using QMT and MMT.5 QMT was found to be more sensitive than MMT in detecting muscle loss of strength.
Because the range of strength differs between the different muscle functions tested, the computation of composite scores requires the use of predictive models to express data in relative terms such as by z scores or as percentages of predicted values. In 1996, The National Isometric Muscle Strength Database Consortium established a normative database for the population of the United States in 493 adult healthy subjects by using 10 muscle groups. Separately, Tawil et al computed a regression model on the elbow flexion strength of 32 healthy subjects by using the variables age, sex, and height to show the possibility of computing composite scores (z scores) for the assessment of the strength of patients suffering from facioscapulohumeral dystrophy (FSHD). This first normative database was enlarged to 168 healthy subjects. Personius et al used these models for an FSHD natural history study. Recently, Meldrum et al published median and percentile predicted MVIC values for 9 muscle groups according to age and sex by using quantile regressions based on a sample of 494 healthy subjects in Ireland. It is, thus, possible to locate individual values for a given patient within or under the predicted range. However, the calculation of composite scores, which can be useful as outcome measures in the assessment of therapeutic interventions, is not possible.

The main objectives of this study were to establish a normative database for isometric strength measured by QMT for the French population and to propose regression models for clinical use for a larger number of muscle functions to assess patients' weakness on follow-up. Intra- and interrater reproducibility was also questioned.

METHODS

Sites

Four clinical centers treating patients with neuromuscular disorders participated in the study. The centers were chosen because of their involvement in clinical trials and expertise in neuromuscular disorders.

Participants

The study involved 315 healthy men (n=147) and women (n=168) aged 20 to 80 years who able to understand and perform the testing procedures. Subjects were uniformly distributed according to age. Exclusion criteria included muscle pathology; inflammatory disease or any disease involving joints; cardiovascular, pulmonary, or metabolic disease; use of regular medication over the past month (except oral contraceptives and hormone replacement therapy); or use of analgesic, anti-inflammatory, or sedative medication over the 2 days before testing and athletes involved in international sports competitions. Inclusion and exclusion criteria were verified through thorough interview and clinical examination by 1 of the medical investigators. Subjects were recruited from hospital personnel, relatives, patient families; advertisements placed in hospitals; or publications of patient associations. All the subjects signed an informed consent form before inclusion in the study. The ethics committee of Nice, France, approved the study.

Instrumentation

All centers used the same QMT system. Such systems are designed to measure muscle-force production during isometric contraction. The system included the following items: a wall-mounted frame, a load cell that used strain-gauge technology for measuring force, straps to attach the load cell to the frame and to the patient, a mobile examination table, a grip dynamometer, and a computer for feedback and recording using Quantitative Muscle Assessment (QMA) software. Strength signals were sampled at 30Hz and recorded for further analysis.

Experimental Procedure

We performed strength measurements for 14 muscle functions (13 bilaterally and neck flexion). Patients were placed on the mobile examining table. Wall-mounted traction bars were used to stabilize the pull straps attached to the strain gauge. Testing positions were standardized (table 1). The examiner provided appropriate stabilizations for maximal efforts of each function tested. QMT was performed bilaterally on the individual muscle listed groups. Each subject completed a series of 3 trials in which he/she was asked to produce a maximal voluntary contraction lasting 2 to 4 seconds. The subject was verbally encouraged. A 30-second rest period was allowed between each trial. If at least 2 trials differed by 10% or more, a further trial was performed. MVIC was taken as the maximum value of the trials. Test order was standardized as indicated in the second column of table 2. QMT was performed by recording force (in kilograms) through a direct computer interface linked to the strain gauge. The whole testing examination lasted 90 minutes on average.

We recorded dominant side, weight (in kilograms) and height (in centimeters) for each subject. Body mass index (BMI) was computed (in kilograms per meter squared) as the ratio between the weight and the height squared. The distance between the rotation axis of the joint and the line of application of force (taken at the center of the strap) was measured. Raters were trained for reliable level arm measurement. When procedures and anatomic references are respected, the relative measurement error was generally less than 5% in our experience, which is lower than the expected intrinsic variability of strength measurements (10%–15% for healthy subjects). The straps were positioned in accordance with anatomic references as given in table 3. The torque was then computed (in newton meters) as the product of the recorded force and this moment arm.

Reliability Study of Testing Procedures

Before the study, all examiners attended a training session. A reliability study was performed to assess intra- and interrater reliability and validate the procedure of testing established during training. Ten subjects participated in an intrarater reliability tests involving 4 physiotherapists, and 10 subjects participated in an interrater reliability study involving 6 physiotherapists. QMT was performed twice at a maximum interval of 1 week.

Data Analysis

Strength values are given as torque in newton meters. Analysis of variance (ANOVA) was performed to analyze differences between centers. To take into account the number of comparisons, P-level significance was adjusted according to the Bonferroni procedure. Reliability results (inter- and intrarater agreement coefficients for each muscle group) are expressed as intraclass coefficients (ICCs) computed with a random-effects ANOVA model. To study the relation of strength with the following covariates: age, sex, height, weight, and BMI, stepwise multiple linear regressions were performed to identify significant parameters. The most common significant parameters found for the 27 muscle groups were age, sex, and weight. These covariates were, therefore, retained to calculate regression parameters for each muscle group by using multiple linear regressions. Ninety-five percent prediction intervals were calculated as the muscle strength value ± the square root of the mean square error. Statistical analysis was performed by using BMDP software.
<table>
<thead>
<tr>
<th>Muscle Function</th>
<th>Patient Position</th>
<th>Strap Position</th>
<th>Stabilization by Tester</th>
<th>Compensation to Avoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder abduction</td>
<td>Supine</td>
<td>Proximal to elbow above olecranon</td>
<td>Both hands over the acromion</td>
<td>Shoulder flexion and/or rotation</td>
</tr>
<tr>
<td></td>
<td>Shoulder at 90° abduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow at 90°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder flexion</td>
<td>Prone</td>
<td>Proximal to elbow above olecranon</td>
<td>Hand over the trapezius muscle</td>
<td>Shoulder abduction or adduction</td>
</tr>
<tr>
<td></td>
<td>Shoulder at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow in extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow at 90°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder extension</td>
<td>Prone</td>
<td>Proximal to elbow above olecranon</td>
<td>Hand over the trapezius muscle and</td>
<td>Shoulder abduction or adduction</td>
</tr>
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<td></td>
<td>Shoulder at 90° flexion</td>
<td></td>
<td>contralateral forearm on the pelvis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow in full extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow at 90°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder internal rotation</td>
<td>Prone</td>
<td>At wrist</td>
<td>Both hands on either side over the distal part of humerus</td>
<td>Shoulder abduction</td>
</tr>
<tr>
<td></td>
<td>Shoulder at 90° abduction and neutral rotation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm hanging down in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm hanging down in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>Supine</td>
<td>At wrist</td>
<td>One hand on anterior shoulder, other hand on lateral condyles of elbow</td>
<td>Shoulder flexion and/or rotation</td>
</tr>
<tr>
<td></td>
<td>Elbow at side at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow extension</td>
<td>Supine</td>
<td>At wrist</td>
<td>One hand on anterior shoulder, other hand on lateral condyles of elbow</td>
<td>Shoulder extension, abduction and/or rotation</td>
</tr>
<tr>
<td></td>
<td>Elbow at side at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip flexion</td>
<td>Supine</td>
<td>Proximal to knee</td>
<td>One hand supporting the leg, the other hand on the ASIS</td>
<td>Pelvis swing</td>
</tr>
<tr>
<td></td>
<td>Hip at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knee at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip extension</td>
<td>Supine</td>
<td>Proximal to knee</td>
<td>One hand supporting the leg, the other hand on the ASIS</td>
<td>Pelvis swing</td>
</tr>
<tr>
<td></td>
<td>Hip at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knee at 90° flexion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle flexion</td>
<td>Supine</td>
<td>Around metatarsals</td>
<td>One hand proximal to ankle, the other above the knee</td>
<td>Hip or knee flexion</td>
</tr>
<tr>
<td></td>
<td>Hip at full extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heel raised calf on a cushion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee flexion</td>
<td>Sitting</td>
<td>At ankle, proximal to malleolus</td>
<td>Examiner seated behind subject</td>
<td>Hip external rotation</td>
</tr>
<tr>
<td></td>
<td>Hip and knee at 90° flexion</td>
<td></td>
<td>Both hands on shoulders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thigh on a cushion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee extension</td>
<td>Sitting</td>
<td>At ankle, proximal to malleolus</td>
<td>Examiner seated behind subject</td>
<td>Hip flexion</td>
</tr>
<tr>
<td></td>
<td>Hip and knee at 90° flexion</td>
<td></td>
<td>Both hands on homolateral shoulder; the other on the contralateral hip</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thigh on a cushion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck flexion</td>
<td>Supine</td>
<td>Under the chin, around cheeks</td>
<td>None</td>
<td>Avoid full cervical spine flexion</td>
</tr>
<tr>
<td></td>
<td>Head on a cushion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Arms alongside</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip</td>
<td>Sitting</td>
<td>Handgrip width adapted to hand size</td>
<td>Support forearm (not the wrist)</td>
<td>Shoulder abduction, internal rotation or flexion</td>
</tr>
<tr>
<td></td>
<td>Elbow alongside at 90° flexion</td>
<td></td>
<td>Support the upper extremity of the ergometer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forearm and wrist in neutral position</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: ASIS, anterior superior iliac spine.
## RESULTS

### Between-Center Variability

Despite precise measurement procedures and careful evaluator training, ANOVA revealed a significant center effect on torque estimates ($P<.001$) for 13 of 27 muscle functions. These differences were because 1 center reported lower values, even after adjusting for age, sex, and weight (although there were no differences between centers for these parameters). After close examination of the data and a complementary study examining how the different examiners followed the measurement procedures, we decided to exclude this center for further analysis. When data were reanalyzed without the excluded center, 3 muscle functions still presented a significant difference between the remaining centers: shoulder abduction and hip flexion and extension. The standard errors of the predicted models were not significantly increased by reducing the number of subjects (53/315).

### Strength Value in a Referent Population

Data from the 3 remaining centers were pooled. Two hundred sixty-two subjects were finally analyzed. Their characteristics are given in table 4. Mean strength values ± standard deviation (SD) are given in table 2. The right side was dominant for 86% of the subjects. The dominant side was significantly stronger than the nondominant side ($P<.05$) for all functions except hip flexion and extension, knee flexion, and shoulder internal rotation, for which strength was similar for both sides (not shown).

Regression parameters of the covariates age, sex, and weight are listed in table 5 for each muscle group. Height was not considered in the regression model because this parameter was nonsignificant in the model for most of the muscle functions. All regression models were significant at $P$ less than .001. Using these equations, it was possible to compute for a patient of any age, sex, and weight a predicted strength value for each muscle group and, hence, a relative deficit with respect to a normative value. It was also possible to standardize the mea-

### Table 2: Torque Values

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Test Order</th>
<th>Men (n=122)</th>
<th>Women (n=140)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abduction right</td>
<td>1</td>
<td>51.3±17.7</td>
<td>28.4±7.5</td>
</tr>
<tr>
<td>Abduction left</td>
<td>4</td>
<td>50.1±17.4</td>
<td>26.3±7.5</td>
</tr>
<tr>
<td>Flexion right</td>
<td>19</td>
<td>55.0±17.6</td>
<td>30.4±8.7</td>
</tr>
<tr>
<td>Flexion left</td>
<td>23</td>
<td>52.9±17.8</td>
<td>28.7±9.0</td>
</tr>
<tr>
<td>Extension right</td>
<td>20</td>
<td>73.5±27.9</td>
<td>34.3±11.2</td>
</tr>
<tr>
<td>Extension left</td>
<td>24</td>
<td>71.1±26.6</td>
<td>33.4±10.5</td>
</tr>
<tr>
<td>Internal rotation right</td>
<td>21</td>
<td>41.1±10.1</td>
<td>19.4±4.6</td>
</tr>
<tr>
<td>Internal rotation left</td>
<td>25</td>
<td>40.8±10.0</td>
<td>18.7±5.0</td>
</tr>
<tr>
<td>External rotation right</td>
<td>18</td>
<td>38.3±9.1</td>
<td>20.7±5.2</td>
</tr>
<tr>
<td>External rotation left</td>
<td>22</td>
<td>36.4±8.8</td>
<td>19.3±4.4</td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>2</td>
<td>70.9±15.9</td>
<td>39.4±7.7</td>
</tr>
<tr>
<td>Flexion left</td>
<td>5</td>
<td>68.5±14.1</td>
<td>38.5±7.9</td>
</tr>
<tr>
<td>Extension right</td>
<td>3</td>
<td>44.3±9.8</td>
<td>22.0±4.7</td>
</tr>
<tr>
<td>Extension left</td>
<td>6</td>
<td>43.9±10.0</td>
<td>21.3±4.8</td>
</tr>
<tr>
<td>Hip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>10</td>
<td>97.4±24.8</td>
<td>62.0±17.1</td>
</tr>
<tr>
<td>Flexion left</td>
<td>9</td>
<td>101.9±26.7</td>
<td>63.9±16.7</td>
</tr>
<tr>
<td>Extension right</td>
<td>7</td>
<td>194.5±70.5</td>
<td>116.5±36.5</td>
</tr>
<tr>
<td>Extension left</td>
<td>8</td>
<td>189.9±64.0</td>
<td>121.7±43.2</td>
</tr>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>11</td>
<td>38.4±8.6</td>
<td>22.9±6.1</td>
</tr>
<tr>
<td>Flexion left</td>
<td>12</td>
<td>37.7±8.6</td>
<td>21.9±5.7</td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>14</td>
<td>80.6±23.4</td>
<td>48.8±15.1</td>
</tr>
<tr>
<td>Flexion left</td>
<td>15</td>
<td>79.7±21.5</td>
<td>48.4±14.2</td>
</tr>
<tr>
<td>Extension right</td>
<td>17</td>
<td>168.9±48.3</td>
<td>100.9±30.5</td>
</tr>
<tr>
<td>Extension left</td>
<td>16</td>
<td>164.1±46.6</td>
<td>96.2±28.6</td>
</tr>
<tr>
<td>Neck flexion</td>
<td>13</td>
<td>137.0±38.6</td>
<td>93.5±33.6</td>
</tr>
<tr>
<td>Handgrip right</td>
<td>26</td>
<td>411.3±73.5</td>
<td>250.4±54.8</td>
</tr>
<tr>
<td>Handgrip left</td>
<td>27</td>
<td>398.0±76.5</td>
<td>244.3±51.1</td>
</tr>
</tbody>
</table>

NOTE. Values are mean newton meters ± standard deviation (SD), except Neck flexion and Handgrip values, which are newtons. Raw data in kilograms are available on request.

### Table 3: Anatomic Reference Points

<table>
<thead>
<tr>
<th>Function</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder abduction, flexion, and extension</td>
<td>Acromial process</td>
</tr>
<tr>
<td>Shoulder external and internal rotation</td>
<td>Lateral humeral epicondyle</td>
</tr>
<tr>
<td>Elbow flexion and extension</td>
<td>Greater trochanter</td>
</tr>
<tr>
<td>Hip extension and flexion</td>
<td>Lateral malleolus</td>
</tr>
<tr>
<td>Ankle flexion</td>
<td>Lateral knee joint</td>
</tr>
<tr>
<td>Knee flexion and extension</td>
<td></td>
</tr>
</tbody>
</table>

Arch Phys Med Rehabil Vol 88, October 2007
surements using $z$ scores, as used for example by Tawil et al,\textsuperscript{16} according to the following equation:

$$z = \frac{\text{observed value} - \text{predicted value}}{\text{estimated SD about fitted model}}$$

Such scores give a quantified “distance” from normative data in number of SDs with respect to the average referent performance. It was then possible to compute composite scores for the whole body and for the upper and lower limbs. The mean of $z$ scores was calculated, taking as a rule that in cases of missing data (eg, because of pain or retractions), it was necessary to have at least half the functions available to compute the composite score. An illustration of the usefulness of these calculations is appended in an attached case study.

We compared our data with published normative data on the U.S. population.\textsuperscript{15} On the whole, the strength measurements yield significant higher values for the American population except for hip extension, which was significantly higher for the French population. We computed the predicted strength for each muscle function in our study population with both regression equations from the American study and the present one. The French strength predictions were 10% lower on average compared with the U.S. predictions. The differences varied from $-50\%$ to $26\%$ depending on the muscle function. The less comparable functions were hip (about $-50\%$ for flexion and $26\%$ for extension), shoulder (about $-15\%$ for flexion and $-17\%$ for extension), and elbow extension (about $-19\%$). The other functions gave smaller differences (close to $5\%$).

Intra- and Interrater Reproducibility

The ICC for intra- and interrater reliability data are given in table 6 for maximal values. Intrarater reliability can be considered as good to excellent on all functions (ICC $> .75$).

### Table 4: Subjects Characteristics

<table>
<thead>
<tr>
<th>Subjects</th>
<th>N</th>
<th>Age (y)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI (kg/m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>122</td>
<td>43.6 ± 15.8</td>
<td>78.0 ± 11.4</td>
<td>176 ± 7</td>
<td>25.1 ± 3.2</td>
</tr>
<tr>
<td>Women</td>
<td>140</td>
<td>46.5 ± 17.1</td>
<td>61.4 ± 10.3</td>
<td>164 ± 7</td>
<td>22.9 ± 3.3</td>
</tr>
<tr>
<td>Total</td>
<td>262</td>
<td>45.1 ± 16.5</td>
<td>69.2 ± 13.6</td>
<td>170 ± 9</td>
<td>23.9 ± 3.5</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD or as otherwise indicated.

### Table 5: Regression Parameters for Strength Prediction

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>N</th>
<th>Intercept</th>
<th>Age</th>
<th>Sex</th>
<th>Weight</th>
<th>$R$</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abduction right</td>
<td>252</td>
<td>7.93</td>
<td>-0.19</td>
<td>14.30</td>
<td>0.48</td>
<td>.73</td>
<td>11.98</td>
</tr>
<tr>
<td>Abduction left</td>
<td>259</td>
<td>12.43</td>
<td>-0.16</td>
<td>17.53</td>
<td>0.35</td>
<td>.72</td>
<td>12.33</td>
</tr>
<tr>
<td>Flexion right</td>
<td>258</td>
<td>9.02</td>
<td>-0.16</td>
<td>16.35</td>
<td>0.47</td>
<td>.74</td>
<td>12.41</td>
</tr>
<tr>
<td>Flexion left</td>
<td>259</td>
<td>11.07</td>
<td>-0.21</td>
<td>16.15</td>
<td>0.45</td>
<td>.73</td>
<td>12.55</td>
</tr>
<tr>
<td>Extension right</td>
<td>260</td>
<td>14.52</td>
<td>-0.26</td>
<td>29.80</td>
<td>0.52</td>
<td>.73</td>
<td>19.63</td>
</tr>
<tr>
<td>Extension left</td>
<td>261</td>
<td>15.89</td>
<td>-0.29</td>
<td>28.69</td>
<td>0.50</td>
<td>.74</td>
<td>18.42</td>
</tr>
<tr>
<td>Internal rotation right</td>
<td>258</td>
<td>10.20</td>
<td>-0.13</td>
<td>17.19</td>
<td>0.25</td>
<td>.86</td>
<td>6.85</td>
</tr>
<tr>
<td>Internal rotation left</td>
<td>259</td>
<td>11.44</td>
<td>-0.16</td>
<td>17.76</td>
<td>0.24</td>
<td>.86</td>
<td>6.87</td>
</tr>
<tr>
<td>External rotation right</td>
<td>255</td>
<td>7.64</td>
<td>-0.07</td>
<td>13.03</td>
<td>0.26</td>
<td>.82</td>
<td>6.62</td>
</tr>
<tr>
<td>External rotation left</td>
<td>250</td>
<td>9.70</td>
<td>-0.08</td>
<td>13.28</td>
<td>0.22</td>
<td>.82</td>
<td>6.31</td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>260</td>
<td>18.20</td>
<td>-0.19</td>
<td>22.72</td>
<td>0.49</td>
<td>.85</td>
<td>10.65</td>
</tr>
<tr>
<td>Flexion left</td>
<td>261</td>
<td>22.00</td>
<td>-0.16</td>
<td>23.17</td>
<td>0.39</td>
<td>.84</td>
<td>10.12</td>
</tr>
<tr>
<td>Extension right</td>
<td>258</td>
<td>9.31</td>
<td>-0.12</td>
<td>16.94</td>
<td>0.30</td>
<td>.86</td>
<td>6.51</td>
</tr>
<tr>
<td>Extension left</td>
<td>259</td>
<td>8.79</td>
<td>-0.10</td>
<td>17.69</td>
<td>0.28</td>
<td>.87</td>
<td>6.89</td>
</tr>
<tr>
<td>Hip</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>257</td>
<td>35.86</td>
<td>-0.29</td>
<td>23.80</td>
<td>0.64</td>
<td>.71</td>
<td>19.36</td>
</tr>
<tr>
<td>Flexion left</td>
<td>260</td>
<td>38.65</td>
<td>-0.29</td>
<td>26.37</td>
<td>0.64</td>
<td>.71</td>
<td>20.39</td>
</tr>
<tr>
<td>Extension right</td>
<td>255</td>
<td>23.56</td>
<td>-0.21</td>
<td>49.10</td>
<td>1.68</td>
<td>.64</td>
<td>52.18</td>
</tr>
<tr>
<td>Extension left</td>
<td>256</td>
<td>24.58</td>
<td>-0.17</td>
<td>39.77</td>
<td>1.71</td>
<td>.61</td>
<td>50.67</td>
</tr>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>257</td>
<td>11.65</td>
<td>-0.04</td>
<td>11.97</td>
<td>0.21</td>
<td>.75</td>
<td>7.20</td>
</tr>
<tr>
<td>Flexion left</td>
<td>256</td>
<td>10.55</td>
<td>-0.08</td>
<td>11.42</td>
<td>0.24</td>
<td>.79</td>
<td>6.61</td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion right</td>
<td>261</td>
<td>36.81</td>
<td>-0.49</td>
<td>20.85</td>
<td>0.57</td>
<td>.75</td>
<td>16.63</td>
</tr>
<tr>
<td>Flexion left</td>
<td>259</td>
<td>36.28</td>
<td>-0.42</td>
<td>21.46</td>
<td>0.51</td>
<td>.75</td>
<td>15.72</td>
</tr>
<tr>
<td>Extension right</td>
<td>258</td>
<td>66.37</td>
<td>-0.87</td>
<td>46.09</td>
<td>1.21</td>
<td>.75</td>
<td>35.05</td>
</tr>
<tr>
<td>Extension left</td>
<td>259</td>
<td>78.00</td>
<td>-0.87</td>
<td>49.70</td>
<td>0.96</td>
<td>.75</td>
<td>33.93</td>
</tr>
<tr>
<td>Neck flexion</td>
<td>257</td>
<td>110.35</td>
<td>-0.86</td>
<td>34.77</td>
<td>0.38</td>
<td>.63</td>
<td>32.91</td>
</tr>
<tr>
<td>Handgrip right</td>
<td>261</td>
<td>225.17</td>
<td>-1.22</td>
<td>134.93</td>
<td>1.34</td>
<td>.82</td>
<td>59.57</td>
</tr>
<tr>
<td>Handgrip left</td>
<td>268</td>
<td>211.93</td>
<td>-1.26</td>
<td>124.96</td>
<td>1.49</td>
<td>.81</td>
<td>58.88</td>
</tr>
</tbody>
</table>

NOTE. Values are newton meters, except Neck flexion and Handgrip values, which are newtons.
lower limbs and for both combined (fig 1). Although consid-
ered to be only a slowly progressive disorder, it was possible to
observe a decline in the strength of this patient with FSHD over
6 months. It was difficult for the same patient to assess any
change corresponds to a variation of 137%. If the same values
are expressed as z scores, the variation is only 4%.
A normative database also allows the computation of com-
posite scores, which may be more robust and more sensitive
than isolated muscle functions in the assessment of global
improvements of patients involved in a therapeutic trial. As
shown in the case study presented earlier, the analysis of
individual muscle functions was insufficient for the overall
evaluation of strength progression, which became possible by
looking at the composite scores (see fig 1). Direct computation
of composite scores from raw data is not valid because muscle
strengths of different magnitudes measured around joints with
different mechanical properties are not summative. This
is still less valid in the follow-up of patients because different
muscle functions can change inhomogeneously during a ther-
aputic trial.
We have also designed this protocol to get specific functions
that have not been assessed yet in previous publications, such
as shoulder internal and external rotation and neck flexion,
which were required for use in a therapeutic trial in FSHD
involving significant shoulder impairment.
Comparing our strength values with the American ones,15
significantly lower values were observed for our population,
apart from hip extension. The predictive values deduced from
our regression models were also lower than the predictive
values computed from the American predictive regression
models. The differences observed could have several origins
such as the morphology of the subjects and the variables used
in the models. The analyses in several studies on normative
strength show a marked variation depending on the country,
which can be partly explained by differences in methodologic
procedures. However, differences could also be caused by
morphologic, anatomic, ethnic, cultural, and social character-
istics of the healthy populations that have been involved in
such protocols. Interestingly, our strength values were slightly
higher than or similar to ones presented by Meldrum et al19 for
the Irish population.
When assessing strength around a joint, the measurement of
force alone is not sufficient to provide a good estimate of
muscle strength because it also depends on the lever arm. For
example, a measurement error of 2cm on a lever arm measur-
ing 20cm gives rise to an error of 10% in the force. It is, thus,
essential to record measurement of strength as torque and to
use the corresponding predictive regression models to give
consistent comparisons between individuals. This point is par-
ticularly crucial when children are involved in the protocols.20

<table>
<thead>
<tr>
<th>Muscle Group</th>
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NOTE. Values are kilograms.
*N=9.

considering intrarater reliability, only 3 functions had coeffi-
cients below .75: ankle dorsiflexion (left and right) and neck
flexion.

Case Report
To show the use of the normative database, we report the
case of a 50-year-old, right-dominant male patient with an
FSHD, weighing 64kg, who was seen at 1 of the centers for 3
visits at intervals of 3 months. The predicted values are listed
in table 7 for each visit; absolute values are also expressed as
a percentage of predicted values for each muscle function
tested. At the first visit (M0), grip strength apart, the observed
torques were severely reduced and ranged between 3.0% and
24.7% of normative values. Six months later (M6), strength
was globally more impaired and ranged between 7.0% and
17.0%. Overall evaluation of progress was difficult from com-
parison of single-muscle functions. Computing composite
scores allowed follow-up of the patient’s overall strength as
assessed by the increase of z scores computed on the upper and
lower limbs and for both combined (fig 1). Although consid-
ered to be only a slowly progressive disorder, it was possible to
observe a decline in the strength of this patient with FSHD over
6 months. It was difficult for the same patient to assess any
manifest decline with MMT scores.

Usefulness of a Normative Database
This study involved the development of a French isometric
strength normative database for adults measured by using
QMT. This will allow objective evaluation of patients with
respect to these normative data, assessment of the degree of
their neuromuscular deterioration, and collection of informa-
tion on the clinical course of the disease. Using relative
changes is not the same as using z scores. Indeed, for weak
forces, a small change would lead to a strong relative change
but only to a minor z-score change. Moreover, the use of z
scores allows the patient to be situated with respect to norma-
tive values and reveals the profile of the deficit. For example,
consider a patient presenting with a torque value for ankle
flexion of 1.02Nm increasing to 2.42Nm 6 months later. This
change corresponds to a variation of 137%. If the same values
are expressed as z scores, the variation is only 4%.

Intrarater Intrarater

Intrarater Intrarater

Table 6: Results of Reproducibility Studies (ICCs)

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<th>Muscle Group</th>
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Knee

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Fig 1. Changes in composite MMT (points) and QMT (bars) scores for an FSHD patient at 3 successive visits (M0, M3, M6) 3 months apart. Composite scores were computed from QMT data for the (A) upper limb and (B) lower limb separately and (C) total for the whole body. Compared with Table 7, for which it is difficult to see an overall trend in the patient’s levels of muscle strength because of the variability of results, the QMT data expressed as z scores gives a clear picture of the deteriorating strength if the patient.
Methodologic Issues

The factors leading to variability in strength measurement are numerous and can be classified as technical, methodologic, environmental, and human factors. This study involved 4 centers and 10 clinical evaluators, increasing the risks of measurement variability.

For each protocol, functions to be evaluated should be carefully determined according to the disease, taking into account fatigue of patients, especially if other tests are also required. The time of day of testing must be defined. A learning session should also be organized before the trial (eg, during prescreening) so that patients can get familiar with the apparatus and procedures and initiate a relationship of confidence with the evaluator. Evaluation procedures must be described precisely to prevent more than 1 possible interpretation of the measurement process. In our protocol, the modus operandi was defined for positioning, installing, and stabilizing the subject and the strap. It was stipulated that the evaluators maintain the position of subject, even with straps, to avoid any compensation. In 1 center, this was not done systematically because the evaluator was not strong enough to stabilize the strongest subjects, resulting in lower estimates of MVIC. Stabilization methods are a critical concern for strong subjects and may be inefficient or inadequate. This issue has been discussed in some studies for particular functions such as hip extension, but this is likely to be true for any strong muscle function. When the aim is to assess the MVIC, it does not seem consistent to ask the subjects to stabilize for themselves the position of their body segments because the maximal force cannot be attained. However, it may be more reproducible to ask the subjects to stabilize themselves when they are strong. In general, measurement procedures should be adapted to the aim of the study and the populations involved. If a source of error is detected during a clinical trial, such as modifications in stabilization procedures or relative body part positions, it should not be addressed during the protocol but should be addressed in subsequent trials.

When assessing torques, lever arms must be precisely measured in the testing position because the joint rotation axis may move with respect to its position. This is, for instance, the case for shoulder abduction for which we observed a center effect probably related to various measurement procedures of the lever arm. This is also why precise anatomic landmarks must be defined and documented for each testing position.

When repeated evaluations are planned during a trial, it is highly recommended that each patient should be tested by the same examiner. Also, in a multicenter trial, repeated training sessions with all examiners should be organized at regular intervals (every 3 or 6 mo).

The QMA software itself retains the highest value recorded on the force transducer during the effort. However, this maximal value can be situated on an overshoot or an artifact, which leads to an overestimation of the patients’ observed MVIC. Evaluators must make sure that such a situation does not occur.

Missing data can be a problem when computing megascore. Different situations can be responsible such as pain, rejections, or fatigue. If missing data are clearly caused by major impairment, the function should be recorded as 0. If other reasons apply, it is reasonable to compute the mean of the z scores if more than half the planned functions could be evaluated. However, simulations by bootstrapping have shown that scores computed from incomplete dataset are highly correlated with scores computed on complete datasets (R > 0.9). This last observation is true only for healthy subjects as considered in the current study and is, however, certainly not true for patients because the composite score can be greatly biased depending on which functions on which sides are lacking. This issue deserves further work.

Predictive Strength Reliability

We have proposed for each muscle function a predictive regression model performed using age, sex, and weight as well as recently proposed for children by Eek et al. In other predictive models, other variables were used instead of weight such as BMI or height. Only with standardized operated procedures and regression model performed using age, sex, and weight as also tested the significance of BMI to explain muscle strength. In most cases (19/27 functions when strength was expressed in kilograms and 22/27 when strength was expressed in newton meters), this variable was not a significant predictor of strength.

Moreover, as assessed by stepwise regression, height and BMI were less predictive variables with respect to age, sex, and weight. The regression coefficients were similar to previous studies with adults. These predictive regression models make it possible to assess the relative weakness of patients.

Reproducibility Issues

Although performed on few subjects and for few repeated measurements, our results concerning reproducibility are good to excellent for most of the muscle functions tested, in agreement with previous studies.

This good reliability underlines that the learning effect in healthy adults tested by trained raters is minor. Only with standardized operated procedures and repeated training sessions can satisfactory reproducibility be attained.

CONCLUSIONS

This study has led to the development of an isometric strength normative database for French adults by using QMT. The database will be used to compute composite scores in therapeutic trials to follow a global index of strength.

No consensus exists on the various methods to use for strength measurement.

No method is perfect or ideal yet, and none will probably ever be. The challenge is to provide each clinical trial with appropriate, standardized, reliable and sensitive outcome measurements.

Because therapeutic trials may concern rare disorders, multiple centers are often involved to reach the statistical power required to show treatment efficacy. Thus, it is fundamental that all centers use the same methodologic procedures to assess outcome measure such as strength. Rigorous training and monitoring are required before and during any therapeutic trial so as not to compromise the quality of its results.

Acknowledgment: We are grateful to Denis De Castro, MD, for his kind assistance in the language revision of the manuscript.

References


Suppliers
a. Rose & Krieger GmbH, Potsdamer Str 9, 32423 Minden, Germany.
b. SM-250; Interface Inc, 7401 E Butherus Rd, Scottsdale, AZ 85260.
c. Qbitus, Units 11 & 12 Victoria Park, Lightowler Rd, Halifax, HX1 5ND, UK.
d. Neuro 40; Plinth 2000, Wetheringsett Manor, Wetheringsett, Stowmarket, Suffolk, IP14 5PP, UK.
e. Jamar; Kinetec, Tournes, 08014 Charleville-Mézières Cedex, France.
f. The Computer Source, 6045 Circle of Light, Gainesville, GA 30506.
g. Statistical Solutions, 999 Broadway, #704, Saugus, MA 01906.
Measurement of Energy Cost by the Physiological Cost Index in Walking After Stroke

Anna Danielsson, RPT, Med fac lic, Carin Willén, RPT, PhD, Katharina S. Sunnerhagen, MD, PhD


Objective: To compare the Physiological Cost Index (PCI) with direct measurement of oxygen consumption (V˙O2) as an estimate of energy cost in persons with stroke and healthy subjects.


Setting: A university hospital.

Participants: A convenience sample of 20 persons with hemiparesis more than 6 months after stroke and 16 healthy subjects, ages 30 to 63 years.

Interventions: Five minutes of treadmill walking at self-selected speeds while recording V˙O2 levels and heart rates. Additional data was recorded for 11 of the stroke subjects with and without an ankle-foot orthosis.

Main Outcome Measures: V˙O2 and the PCI.

Results: No significant differences were found in the PCI or V˙O2 between test and retest. Both PCI and V˙O2 per distance were higher for the stroke subjects compared with healthy subjects. PCI showed a larger dispersion than V˙O2 between test and retest. The regression analysis for PCI showed that the model including age, sex, group assignment, and V˙O2 could explain 53% of the variation. The PCI did not show a significant difference in walking with or without an orthosis, whereas V˙O2 differed significantly.

Conclusions: The PCI showed limited reliability and validity as a measure of energy cost after stroke due to the extensive variability between test and retest.

Key Words: Cerebrovascular accident; Energy expenditure; Rehabilitation; Walking.

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From the Sahlgrenska Academy at Göteborg University, Institute of Neuroscience and Physiology/Rehabilitation Medicine, Göteborg, Sweden (Danielsson, Willén, Sunnerhagen); and Summaas Rehabilitation Hospital and Faculty of Medicine, University of Oslo, Norway (Sunnerhagen).

Supported by the Council of Research and Development of Gothenburg and Southern Bohuslan, the Foundation of the Swedish Stroke Association, Hjalmar Svensson’s Research Foundation, John and Brit Wenerström’s Foundation for Neurological Research, the Swedish Association of Persons with Neurological Disabilities, the Norrbacka-Eugenia Foundation, and the Swedish Research Council (grant no. VR K2002-27-VX-14318-01A).

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METHODS

Persons with stroke recruited from patient records in a rehabilitation department were asked to volunteer for the study. Our inclusion criteria were first time stroke according to World Health Organization criteria at least 6 months previously, 18 to 65 years of age, hemiparesis, a stable heart condition, and walking ability without manual assistance for 5 minutes (if necessary with a walking aid or orthosis). Exclusion criteria were severe cardiac disease or arrhythmia, pain during walk-
ing, walking impairment other than stroke-induced, inability to understand information or follow instructions, and severe discomfort while wearing a face mask. We included 20 subjects (17 men, 3 women). They were 30 to 63 years of age (median, 54 y) with a mean body mass index (BMI) of 25 kg/m². Eleven subjects had a cerebral infarction and 9 had a cerebral hemorrhage. Twelve had lesions in the right hemisphere and 8 in the left. Time elapsed from stroke ranged from 7 to 96 months (median, 19 mo). Motor function of the lower-limb section of the Fugl-Meyer Assessment scored a median of 22 (normal, 25). Thirteen subjects used a cane and 15 an AFO. Ten of the stroke subjects were on antihypertensive medication; 5 had a β-blocker, 4 a calcium channel blocker, 5 an angiotensin-converting enzyme inhibitor, 1 an angiotensin II antagonist, 1 an α-blocker, and 4 had a combination of 2 or 3 of these medications. Eleven of the stroke subjects equipped with an AFO formed a subgroup additionally assessed without the AFO.

As a reference group, we recruited 16 healthy volunteers (11 men, 5 women) without walking impairments or known cardiac disease, 33 to 64 years of age (median, 49 y), with a mean BMI of 24.5 kg/m² from the staff at the clinic.

Participants received verbal and written information and gave their signed consent. The study was approved by the Ethics Committee at Göteborg University.

**Equipment**

Data collection took place in a quiet room. A treadmill used 0.5 to 1.6 m with a handrail providing speeds from 0 to 2 m/s was used for the walking tests. A light hand support for balance was allowed. Energy expenditure was measured by a stationary system for breath-by-breath analysis and electrocardiography. A face mask covering the nose and mouth, attached by a head net, collected expired gas. Three self-adhesive chest electrodes were used for monitoring electrocardiography and heart rate. V̇O₂, carbon dioxide output, respiratory exchange ratio (RER), and heart rate were continuously monitored, printing mean values every 30 seconds.

**Procedure**

We carried out 2 trials within a week with a minimum interval of 1 day between trials. Each participant’s self-selected walking speed on the treadmill was determined at the first session. Five to 10 minutes were allowed to become accustomed to the treadmill and to select the speed. Speed was slowly increased to a comfortable level with the participant’s approval.

Data on energy expenditure were simultaneously collected for each method. The subject sat for 5 minutes to achieve resting heart rate while electrocardiography was displayed. The face mask was then applied and 2 minutes were allowed to become accustomed to it. Measurement was initiated in the sitting position with 2.5 minutes for recording resting values. The participant then stood up and walked for 5 minutes at the previously determined, self-selected speed. Immediately after stopping, perceived exertion was rated on the Borg Category Ratio Scale (CR-10). Sixteen stroke subjects with an AFO were measured at random with and without the AFO.

We used the data from the final 3 minutes of walking to calculate energy cost. The procedures for measurement of V̇O₂ and heart rate were identical in the 2 sessions except that the order with and without the AFO was reversed on retest.

**Statistics**

We analyzed group differences with the Mann-Whitney U test due to heterogeneity. The Wilcoxon signed-rank test was used for within group comparisons with and without the AFO. The paired t test was used for differences between first and second test sessions where there was a normal distribution. Reliability was analyzed for the stroke and healthy groups separately by intraclass correlation model 2,1 (ICC₂,₁) and the 95% limits of agreement method, visualized using Bland-Altman plots. A person could be expected (with 95% probability) to have a retest difference between the limits of agreement. Validity was analyzed by linear regression of PCI (dependent variable) based on values from the second session. Both stroke and healthy subjects were included in the regression analysis. Variables included in the model were sex, age, group (stroke, healthy), and V̇O₂ (in mL·kg⁻¹·min⁻¹). The rationale for including healthy participants was to obtain better estimates of the association between PCI and low values of V̇O₂.

A P value of less than .05 was considered statistically significant.

**Table 1: Data From First and Second Test Sessions for the Stroke and Healthy Reference Groups**

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<th>Variable</th>
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<th>Stroke</th>
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<td>Walking heart rate (beats/min)</td>
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<td>91±16</td>
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</tr>
<tr>
<td>PCI (beats/m)</td>
<td>1</td>
<td>0.76±0.50</td>
<td>0.28±0.08</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.76±0.59</td>
<td>0.32±0.10</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>V̇O₂ (mL·kg⁻¹·min⁻¹)</td>
<td>1</td>
<td>9.1±2.1</td>
<td>11.5±2.0</td>
<td>.004</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>9.1±2.3</td>
<td>11.5±2.0</td>
<td>.002</td>
</tr>
<tr>
<td>V̇O₂ (mL·kg⁻¹·m⁻¹)</td>
<td>1</td>
<td>0.41±0.21</td>
<td>0.19±0.04</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.40±0.19</td>
<td>0.19±0.04</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Perceived exertion†</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>.004</td>
</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>1, 2</td>
<td>0.48±0.28</td>
<td>1.01±0.15</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± standard deviation.

Abbreviation: NS, not significant.

†Median score on the Borg CR-10 (perceived exertion range, 0–10).
RESULTS

Data from the 2 test sessions are presented in table 1. Energy cost was approximately double for the stroke subjects compared with that of the healthy subjects, reflected by PCI and \( \text{V} \dot{\text{O}}_2 \) levels. There were differences between mean treadmill walking speeds which, in addition to \( \text{V} \dot{\text{O}}_2 \) per unit time, were lower for the stroke group (table 1). The stroke group had higher \( \text{V} \dot{\text{O}}_2 \) per unit distance, PCI, and perceived exertion than the reference group, although walking heart rate or RER did not differ between groups for any of the sessions (see table 1). The significance test showed no differences between the 2 test sessions for any of the variables with the exception of resting heart rate in the healthy group, which was lower at retest (\( P=0.027 \)). No differences in heart rate, PCI, or \( \text{V} \dot{\text{O}}_2 \) were found for the stroke subjects with respect to lesion site, diagnosis, time elapsed from stroke onset, or administration of antihypertensive medication.

The ICC coefficients are shown in table 2. Visual analysis of Bland-Altman plots for the differences between first and second test sessions (figs 1, 2) showed a normal distribution. A larger error interval was seen for PCI than for \( \text{V} \dot{\text{O}}_2 \) (in \( \text{mL} \cdot \text{kg}^{-1} \cdot \text{m}^{-1} \)) (see table 2, figs 1, 2), particularly for the stroke group. The regression analysis for PCI showed that the model including age, sex, group assignment, and \( \text{V} \dot{\text{O}}_2 \) could explain 53% of the variation (table 3). Because site of lesion, stroke diagnosis or elapsed time from stroke onset were not significant in the bivariate analysis, they were not included in the regression model.

The subgroup of stroke subjects measured both with and without an AFO had a mean PCI value of .75 (median, .62) without and .73 (median, .66) with the AFO, which was not significantly different (\( P=0.722 \)). Oxygen costs were .52 (median, .51) and .46 (median, .47) \( \text{mL} \cdot \text{kg}^{-1} \cdot \text{m}^{-1} \), which were significantly lower with the AFO (\( P=0.032 \)). The perceived exertion did not differ between the 2 test conditions.

DISCUSSION

In the present study, the reliability and validity of the PCI in a clinical sample of stroke subjects were found to be limited when compared with direct measurement of \( \text{V} \dot{\text{O}}_2 \).

No systematic differences between 2 test sessions were detected in either PCI or \( \text{V} \dot{\text{O}}_2 \). The ICCs for PCI were high for the stroke group and moderate for the healthy subjects. The ICC for PCI in the stroke subjects was comparable with that in another study of adults with brain injuries.24 For \( \text{V} \dot{\text{O}}_2 \), the ICC was very high in the stroke group and high in the healthy subject group. A correlation coefficient is influenced by the range of variation between subjects, so the high correlation in the stroke group might have been false. Analysis of test-retest differences with Bland-Altman plots and the method of 95% limits of agreement showed small mean differences but wide error intervals in the case of PCI, which implies that, compared with \( \text{V} \dot{\text{O}}_2 \), the measurement precision was poorer for PCI. This was seen in both the stroke and healthy groups but was more obvious among those with stroke. The greater dispersion seen in the stroke group could be explained by their heterogeneity in neurologic deficit and walking speed, which was reflected in the stroke participants’ larger spread in the \( \text{V} \dot{\text{O}}_2 \) measures as well. Surprisingly, the increase in heart rate between rest and work did not differ between groups. The small increase could be explained by the low walking speed in the stroke group, because heart rate is related to walking speed. Heart rate increase could be suppressed by antihypertensive medication, but no differences were found between subjects with and without these drugs. Impaired heart rate variability (HRV)31,32 reflecting autonomic cardiac dysfunction may theoretically be another explanation. Structural lesions in the nervous system resulting in changes in vagal and/or sympathetic activity may contribute to an altered heart rate response to exercise. Measures of HRV have been shown to be lower than in control subjects, mainly in the early phase after stroke, but even 6

---

Table 2: Differences and Correlations Between Test Sessions 1 and 2 in the PCI and \( \text{V} \dot{\text{O}}_2 \)

<table>
<thead>
<tr>
<th>Test</th>
<th>Subjects</th>
<th>Mean Difference</th>
<th>95% CI</th>
<th>95% LOA</th>
<th>ICC2,1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI (beats/m)</td>
<td>Stroke (n=20)</td>
<td>-.009</td>
<td>-.142 to .125</td>
<td>.55 to -.57</td>
<td>.86</td>
</tr>
<tr>
<td></td>
<td>Healthy (n=16)</td>
<td>-.037</td>
<td>-.083 to -.009</td>
<td>.13 to -.21</td>
<td>.57</td>
</tr>
<tr>
<td>( \text{V} \dot{\text{O}}_2 ) (mL·kg(^{-1} )·m(^{-1} ))</td>
<td>Stroke (n=20)</td>
<td>.012</td>
<td>-.008 to .033</td>
<td>.10 to -.08</td>
<td>.98</td>
</tr>
<tr>
<td></td>
<td>Healthy (n=15)</td>
<td>.003</td>
<td>-.008 to .014</td>
<td>.04 to -.04</td>
<td>.67</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; LOA, limits of agreement.

Fig 1. Individual differences in PCI (in beats/m) between the 2 test sessions in the (A) stroke and (B) healthy reference groups, respectively. Abbreviation: SD, standard deviation.

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months later. In the present group, however, more than 6 months had passed. Signs of cardiovascular comorbidity in the acute or later stage have been reported in 75% of stroke patients. There are indications that right-sided cerebral lesions may involve reduced HRV, but HRV was not examined in the present study. In the small subgroups, no lesion side differences were found for heart rate response to exercise.

The aim of the present work was to investigate the PCI method in a clinical situation with as much control as possible without interfering with prescribed medications. A limitation in the study design is the lack of control of the role of antihypertensive medication. A purely physiologic study of the relationship between PCI and VO₂ would require a population not taking medication that could affect the heart rate response. Additionally there were no data on aerobic fitness collected in this study group. Heart rate also may have been affected by other factors such as stress, environmental conditions, or other comorbidity.

Burridge et al. reported a significant reduction in PCI values in stroke subjects that walked with functional electric stimulation. Olney et al. showed a significant reduction in PCI in a group of stroke subjects after an exercise program. In the present study, we were not able to detect any reduction in the PCI when an AFO was applied, in contrast to the VO₂ measure, which differed significantly. The inability to detect significant differences with PCI may be explained by the large variation seen in the test-retest analysis. Our sample for this comparison consisted of only 11 subjects and the size of this difference was not clinically relevant because no change in the perceived exertion was reported.

PCI values from both healthy and stroke subjects in the present study were within the range reported by other authors. However, reliability studies carried out in healthy persons cannot be generalized to patient populations, where variability is larger. Several authors have questioned the PCI as an outcome measure in group comparisons owing to the large variability. Caution must be taken in interpreting PCI measurements in patients, and it should not be the only outcome measure in a research study. PCI might be useful on the individual level as a clinical tool to obtain some information on energy cost.

It may be that the increase in energy cost in persons with hemiparesis is not high enough to be measurable by PCI because of a large variability or low responsiveness to change. The energy cost of walking after stroke is about twice as high as normal. Perhaps PCI would be more suitable in patient groups with even higher levels of energy cost, for example, in persons with paraparesis or after lower-limb amputation. Presenting the level of change by percentage may be very misleading, depending on the initial level; a 50% change for a healthy person is not so remarkable, but it might be extraordinary if the initial level is increased many times. The clinically significant size of a change in PCI is not known.

Another limitation of the present study is that the measurement equipment required testing on a treadmill. The idea of PCI is that a self-selected speed is used. In our study, each person’s self-selected speed was used but then held constant at both sessions, which might have resulted in too high a PCI reproducibility. Our results therefore might reflect the reproducibility of heart rate more than PCI because no change in walking speed was allowed between the 2 test sessions. There was a high variability of gait speeds in the stroke group. The reliability of the measurement of self-selected walking speed was not determined in the present study but high test-retest reliability for walking speed and distance has previously been shown in healthy persons as well as stroke patients. A handrail support was allowed for maintaining balance on the treadmill, but there was no control as to what extent this differed between test sessions. Measurement of walking at free speed on the ground would have been preferable because treadmill walking might involve higher energy expenditure, at least in the elderly, although conflicting opinions on this matter exist.

Further studies on the reliability and responsiveness to change of the PCI after stroke are needed. There is also a need to investigate how large a change in the PCI must be to reflect a clinically important difference.

### CONCLUSIONS

The PCI has limited reliability and validity as a measure of energy cost after stroke due to large individual variation between test and retest in comparison with measures of VO₂.
It may, however, be useful as a simple measure for patients in a clinical situation. Caution must be exercised when drawing conclusions considering the large variability between test and retest. Measurement of $\dot{V}O_2$, on the other hand, is more precise and can be recommended for studies of energy cost.

Acknowledgment: We thank Frida Källman Domack, BSc, for technical service and data collection.

References


Suppliers

a. TR Spacetrainer; TR Equipment AB, Box 116, Rundelgatan 2, SE-573 22 Tranås, Sweden.
b. Cardiopulmonary exercise testing system; Medical Graphics Corp, 350 Oak Grove Pkwy, St. Paul, MN 55127.
Validity of the Trunk Impairment Scale as a Measure of Trunk Performance in People With Parkinson’s Disease

Geert Verheyden, PhD, Anne-Marie Willems, PhD, Lieve Ooms, MSc, Alice Nieuwboer, PhD


Objective: To evaluate construct validity of the Trunk Impairment Scale (TIS) as a measure of trunk performance in Parkinson’s disease (PD).

Design: A cross-sectional study of PD patients and healthy subjects.

Setting: University rehabilitation research unit.

Participants: Twenty-six PD patients (Hoehn and Yahr stages 2–4) and 26 healthy subjects.

Intervention: Not applicable.

Main Outcome Measures: The TIS and its subscales; static and dynamic sitting balance and trunk coordination.

Results: Compared with healthy controls, PD patients showed significantly lower scores on the total TIS, static sitting balance, and coordination subscale. Healthy subjects scored significantly better on the total TIS and coordination subscale compared with patients in the early stage of PD. Patients with PD in the early stage scored significantly higher for the total TIS as well as static and dynamic sitting balance in comparison with PD patients in a later stage. Forward stepwise multiple linear regression analysis showed that trunk impairment in PD patients was significantly related to a combination of older age and a higher score on part III of the Unified Parkinson’s Disease Rating Scale, which assesses motor impairments.

Conclusions: Early detection of trunk deficits and the significant relation with PD severity advocates further evaluation and use of the TIS in PD.

Key Words: Parkinson disease; Rehabilitation.

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Activities of Daily Living (ADLs) require head and trunk stability as well as trunk mobility. Bed mobility for instance is dependent on selective rotation of the head, shoulder, and pelvic girdle.1 Schenckman et al1 were the first to identify a relationship between decreased trunk mobility and impaired physical activities in the elderly. They observed healthy subjects and found a relation between decreased axial mobility and problems in movements such as looking over the shoulder while driving or climbing stairs, but also in more complex ADLs such as using public transport.

According to Lakke,2 motor symptoms of Parkinson’s disease (PD), such as bradykinesia, akinesia, and rigidity, have a distinct axial distribution. In general, 2 important trunk impairments in PD patients are described: the en-bloc movement of the trunk and the occurrence of thoracic kyphosis. The en-bloc movement was observed by Van Emmerik et al,3 who noted a more in-phase movement of the shoulder and pelvic girdle during gait analysis in PD patients compared with age-matched healthy subjects. En-bloc movement was also present in the horizontal and sagittal plane between head and trunk during a 10-meter walk test.4,5 In addition, it was suggested that en-bloc movement of the head-shoulder unit in parkinsonian gait may hinder normal dissociated rotation of the head and trunk when turning.6 Freezing most commonly appears while patients are making turns.7 The asymmetric nature of turning, and the reduced trunk rotation and incomplete center of mass displacement found before freezing,8 suggests that there may be a relationship between freezing and trunk mobility.

Thoracic kyphosis or the so-called stooped position is a second parkinsonian trunk abnormality. According to Bloom et al,9 it may constitute a compensation mechanism for the retrospulsion instability in PD patients. Also, stiff posture is thought to contribute to poorer dynamic postural control and falling.9 Ryan and Fried10 reported a positive correlation between severity of thoracic kyphosis and impairment of ADLs.

To our knowledge, no standardized clinical tool is available to measure impairments of the trunk in PD patients. Clinical scales can be of great value for both therapists in clinical practice and scientists in rehabilitation research to identify problems, enhance communication, and monitor progress. The Trunk Impairment Scale (TIS) is a clinical scale originally developed to assess impairment of trunk function after stroke. It measures (1) static sitting balance, (2) dynamic sitting balance, and (3) trunk coordination by means of assessing (a) stability while sitting, (b) selective lateral flexion, and (c) selective rotation of the upper and lower part of the trunk. Psychometric properties for the TIS have been successfully examined for patients after stroke, persons with multiple sclerosis (MS) and subjects after traumatic brain injury (TBI). For patients after stroke, test-retest and interobserver intraclass correlation (ICC) coefficients for the total TIS score were .96 and .99, respectively.11 Spearman rank correlation with the Barthel Index ($r = .86$) established construct validity.11 For persons with MS, test-retest and interrater ICC coefficients were .95 and .97, respectively.12 Bland and Altman analysis showed consistency of scores without observer bias.12 The total TIS score was correlated with the functional independence measure score ($r = .81$) to establish construct validity.12 For subjects after TBI, test-retest and interobserver ICC coefficients for the total TIS score were .88 and .95, respectively.13 Construct validity was evaluated by means of Spearman rank correlation between the TIS and Barthel Index ($r = .59$).13
The primary purpose of this study was to determine the construct validity of the TIS in people with PD. By assessing persons with PD and age- and sex-matched healthy controls, we wanted to examine if the TIS could detect trunk problems in patients with PD. Because PD patients appear to have problems with the dissociation between shoulder and pelvic girdle, we expected to see a significant difference in scores on the coordination subscale of the TIS between persons with PD and healthy subjects. A secondary purpose was to determine the determinants of trunk impairment in this population by exploring if TIS scores were related to disease severity and other clinical and motor determinants such as age, freezing, falling, and rolling in bed. This would be a first step in testing the psychometric properties of the TIS in this population.

METHODS

Participants

PD patients were screened when they visited the consultant neurologist at the University Hospital in Leuven, Belgium. Subjects were also recruited from the neurology ward, receiving inpatient care, as well as from local PD groups, attending outpatient rehabilitation. The consultant neurologist confirmed the diagnosis of PD and determined the Hoehn and Yahr stage. Only patients from Hoehn and Yahr stages I to IV were eligible for inclusion.

Exclusion criteria were evaluated by the observer (LO) after the people with PD agreed to participate in the study. The criteria included the presence of dyskinesia, defined as a grade of more than 2 on the Modified Dyskinesia Scale; any comorbidity which could impair sitting balance or trunk movements; the presence of a subthalamic deep brain stimulator; a hip endoprosthesis; and dementia, defined by a score of less than 24 on the Mini-Mental State Examination.

We collected age- and sex-matched healthy controls from an existing database. People with PD and healthy controls were informed about the aim and procedure of the study and were asked to voluntarily sign consent after having agreed to participate in the study. Ethics approval was obtained from the local ethics committee.

Assessments

We collected age, sex, disease duration, and Hoehn and Yahr stage of the disease from the updated medical records for every PD patient when they visited the consultant neurologist. All patients included in the study were assessed with part III of the Unified Parkinson’s Disease Rating Scale (UPDRS). This part of the UPDRS evaluates motor deficits of persons with PD by looking at the presence of rigidity, bradykinesia, tremor, and gait disorders. Items 12 (turning in bed and handling blanket [hereinafter, turning in bed]) and 13 (falling) of the UPDRS part II were evaluated for every participant as well, because they represented possible important aspects of functional trunk performance. The UPDRS is a widely used scale, used across the clinical spectrum of PD, and has established clinimetric properties, including reliability and validity. To detect differences in trunk impairment between freezers and nonfreezers, freezers were defined as freezing at least once a week (score >1 on item 3 of the Freezing of Gait Questionnaire [FOGQ], presently the only valid scale to evaluate freezing of gait). We also used the FOGQ total score to determine the severity of freezing.

We assessed trunk performance by means of the TIS. The TIS evaluates static sitting balance, dynamic sitting balance, and trunk coordination on a scale from 0 to 23 points, a higher score indicating a better performance. Patients’ starting position entailed sitting on the edge of a plinth without back and arm support. The thighs made full contact with the table. The feet were placed hip width apart and flat on the floor. The knee angle was 90°. The arms rested on the legs. Both head and trunk were in a midline position. Static sitting balance (score range, 0–7) evaluated if a subject could maintain a seated position, also with the legs crossed passively by the observer and actively by the subject. Dynamic sitting balance (score range, 0–10) assessed movement pattern and quality of movement when performing lateral flexion of the trunk, initiated from the upper and lower part of the trunk. Finally, coordination (score range, 0–6) scored the possibility to selectively rotate the shoulder and pelvic girdle.

All assessments were carried out by the same observer (LO), carefully instructed in administering the TIS. Applying the TIS was shown by the principal investigator (GV) by means of an instruction video and pilot session with feedback. The items of the UPDRS and FOGQ were administered by experienced PD researchers (A-MW, AN). All assessments were completed within 1 session.

Age and scores on the TIS and its subscales were collected from a healthy controls’ database of 40 subjects. Controls were selected consecutively based on the matching criteria for sex and age. Assessment of healthy controls was carried out by 2 observers who evaluated subjects independently. Both observers trained together in administering the TIS by means of an instruction video and pilot session with feedback by the principal investigator of this study (GV).

Statistical Analysis

To detect differences in trunk performance between PD patients and healthy controls, we compared scores on the TIS and its subscales statistically using the Wilcoxon ranked-sum test. The unpaired Wilcoxon test was used to evaluate if there were differences in trunk performance between patients in the early stage of the disease (defined as Hoehn and Yahr stages 2 and 2.5) and in the late stage of the disease (defined as Hoehn and Yahr stages 3 and 4) and between freezers and nonfreezers. Spearman rank correlations were calculated and a univariate linear regression analysis was performed between TIS total score and age, sex, disease duration, Hoehn and Yahr stage, UPDRS part III score, score on the UPDRS part II items turning in bed and falling, and FOGQ score to examine the relation between trunk performance and other PD impairments. Significant parameters (P < .05) were retained and were entered as explanatory variables in a forward stepwise multiple regression analysis with the TIS total score as outcome variable to evaluate the combination of variables that determine trunk performance in PD patients. The level of significance for all analyses was P < .05. Data were statistically analyzed by means of SAS, version 8.2, and SAS Enterprise Guide, version 2.0.

RESULTS

Participants

We recruited 26 PD patients and 26 healthy controls. Our PD subjects included 17 men (65%) and 9 women (35%) with a mean ± standard deviation age of 65.5 ± 9 years and a mean disease duration of 9.4 ± 4 years. Descriptive characteristics for the PD patients are shown in table 1. Our sample of healthy controls included 16 men (62%) and 10 women (38%) with a mean age of 65.12 years.

Seven PD patients were in Hoehn and Yahr stage 2, 7 in stage 2.5, 11 in stage 3, and 1 in stage 4. Scores on the turning
in bed item of the UPDRS part II showed that 6 patients had no difficulty during turning in bed. Twelve subjects were slow and clumsy but independent. Five persons were able to turn in bed only with great effort and 3 subjects were able to initiate the movement but could not conclude it without assistance. Nineteen patients had no history of falls. Three subjects fell rarely, 2 subjects indicated to fall less than once a day, and 2 patients fell more than once a day. According to our definition, the sample consisted of 10 freezers and 16 nonfreezers. All patients were evaluated in the on-phase of the medication cycle.

Trunk Performance in PD

The results of the Wilcoxon rank-sum test, evaluating differences in trunk performance between PD patients and healthy controls, are shown in table 2. Patients with PD had significantly lower scores on the total TIS ($P<.000$), static sitting balance subscale ($P=.005$), and coordination subscale of the TIS ($P<.000$). Although the PD patients obtained relatively lower scores on the dynamic sitting balance subscale of the TIS in comparison with the healthy controls, the difference did not reach the level of significance ($P=.053$).

Further analysis revealed that healthy controls scored significantly better on the total TIS (Mann-Whitney $U=12.91$, $P<.000$) and coordination subscale ($U=22.51$, $P<.000$) compared with the PD patients in the early stage of the disease (Hoehn and Yahr stages 2 and 2.5). Patients with PD in the early stage scored significantly higher for the total TIS ($U=4.19$, $P=.047$), static sitting balance subscale ($U=5.89$, $P=.029$), and dynamic sitting balance ($U=4.79$, $P=.033$) in comparison with the PD patients in Hoehn and Yahr stages 3 and 4. We found no significant differences for the scores on the total TIS and its subscales between freezers and nonfreezers ($U=0.7$, $P=.484$).

No PD patient obtained the lowest score on any of the subscales or on the total TIS. From our sample of patients, 19 (73%) reached the maximum score on the static sitting balance subscale, 10 (38%) on the dynamic sitting balance subscale, 2 (8%) on the coordination subscale, and 1 patient (4%) reached the maximum score on the total TIS.

Determinants of Trunk Performance in PD

Table 3 shows the Spearman correlation coefficients and the results of the univariate linear regression analysis between TIS total score and age, sex, disease duration, Hoehn and Yahr stage, UPDRS part III score, UPDRS part II scores on items turning in bed and falling, and FOGQ score for the PD group. Our analysis showed that lower scores on the total TIS correlated significantly with older age and a higher score on part III of the UPDRS and the turning in bed and falling items of part II of the UPDRS, although the latter item did not show a significant result in the univariate analysis. Therefore the falling item was not retained for the forward stepwise multiple linear regression analysis. This analysis showed that trunk performance in PD patients correlated significantly with a combination of part III score of the UPDRS (partial $R^2=.54$, $P<.000$) and age (partial $R^2=.09$, $P=.030$).

**DISCUSSION**

PD patients often show trunk performance deficits in clinical practice. It was the aim of this study to examine the construct validity of the TIS in PD patients and evaluate the relation between trunk performance and common PD motor impairments.

The results of our study demonstrated construct validity of the TIS in people with PD, because they had significantly lower scores than controls on the total TIS and static sitting balance and coordination subscale of the TIS. Although not significant, scores on the dynamic sitting balance subscale were lower for the PD patients as well. The coordination subscale of the TIS evaluates selective rotation of the shoulder and pelvic girdle and assesses performance of these tasks against time. The fact that PD patients showed deficits in this area may be explained by the lack of dissociation between the upper and lower part of the trunk, described in the literature as an en-bloc pattern. This may be due to the presence of rigidity in the muscles of the trunk or

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PD Patients Median (IQR)</th>
<th>Healthy Controls Median (IQR)</th>
<th>Wilcoxon U Statistic</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total TIS (0–23)</td>
<td>18 (16–20)</td>
<td>22 (21–23)</td>
<td>23.60</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Static sitting balance (0–7)</td>
<td>7 (6–7)</td>
<td>7 (7–7)</td>
<td>7.91</td>
<td>.005</td>
</tr>
<tr>
<td>Dynamic sitting balance (0–10)</td>
<td>9 (7–10)</td>
<td>10 (9–10)</td>
<td>3.74</td>
<td>.053</td>
</tr>
<tr>
<td>Coordination (0–6)</td>
<td>3 (2–4)</td>
<td>6 (5–6)</td>
<td>30.88</td>
<td>&lt;.000</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, interquartile range.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$r$</th>
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<th>$P$</th>
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<tbody>
<tr>
<td>Age</td>
<td>−.66*</td>
<td>.32</td>
<td>.003</td>
</tr>
<tr>
<td>Sex</td>
<td>−.32</td>
<td>.10</td>
<td>.117</td>
</tr>
<tr>
<td>Disease duration</td>
<td>−.23</td>
<td>.03</td>
<td>.408</td>
</tr>
<tr>
<td>Hoehn and Yahr stage</td>
<td>−.39</td>
<td>.09</td>
<td>.130</td>
</tr>
<tr>
<td>UPDRS part III</td>
<td>−.68*</td>
<td>.54</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>UPDRS part II, turning in bed</td>
<td>−.48*</td>
<td>.15</td>
<td>.049</td>
</tr>
<tr>
<td>UPDRS part II, falling</td>
<td>−.41*</td>
<td>.07</td>
<td>.182</td>
</tr>
<tr>
<td>FOGQ</td>
<td>−.27</td>
<td>.09</td>
<td>.152</td>
</tr>
</tbody>
</table>

NOTE: Values are Spearman rank correlation coefficients ($r$), explained variance as a result of the univariate regression analysis ($R^2$), and accompanying $P$ value.

* $P$ value for the Spearman rank correlation coefficients was less than .05.
bilateral coordination deficits in PD. Recently, Ponsen et al.\(^\text{19}\) found that even in early PD there is a tendency to perform a bilateral coordination task in an anti-phase pattern less accurately than in an in-phase condition.

Scores on the coordination subscale of the TIS discriminated between PD patients in the early stages of the disease and healthy controls. This is an important finding because early detection opens the possibility for targeting adequate rehabilitation for this deficit. PD patients in the later phase of the disease scored significantly lower on the static and dynamic sitting balance subscales of the TIS in comparison with patients in the early phase. These results suggest that selective rotation of the trunk is impaired in the early stage of the disease and with disease progression, sitting balance, and selective lateral flexion of the upper and lower part of the trunk become affected. However, the ceiling effect for the static and dynamic sitting balance subscales found in this study could have an important impact on the scale’s sensitivity to change, which needs to be addressed in future studies. Based on the current results, we believe that the TIS is a useful tool to further examine in PD patients. Although PD patients reached the ceiling of the static and dynamic sitting balance subscales, the discriminant ability of these subscales between the early and late phases of the disease in PD patients argues against the exclusion of these subsections from the measurement of trunk performance in PD at the present time. The full range of the scale was not used in this sample, which may reflect the inclusion of only a few patients from Hoehn and Yahr stage IV. Further research on a larger number of patients throughout the different stages of the disease is therefore warranted.

This study also evaluated other variables that are related to trunk impairment in PD patients. Significant correlations were found between total TIS score and age, UPDRS part III, and the turning in bed and falling items of part II of the UPDRS. Older, more disabled patients, who experienced problems with turning in bed and had a history of falls showed a more impaired trunk performance. Stack and Ashburn\(^\text{20}\) showed that bed mobility in PD is hampered by difficulties with turning in bed in 4 out of 5 patients. Bloem et al.\(^\text{21}\) also discussed the relation between trunk performance and falls in PD patients. They observed that falls were frequently caused by a change in posture including rotation of the trunk. However, falling was not maintained as a significant variable in our univariate regression analysis. Further analysis showed that the combination of disease severity, as measured by part III of the UPDRS, and age were independently related to trunk deficits in PD patients, confirming previous findings in healthy subjects and stroke subjects.\(^\text{12,21}\)

**Study Limitations**

A limitation of this study was that the PD patients and healthy controls were not exactly matched for sex and age. Control subjects were selected retrospectively from an existing database. The first matching criterion that we used was sex; the second criteria was age. Future studies could ask the participation of the partner of the PD patient as a control subject. This could also control for characteristics such as level of activity between both groups. Another limitation of this study was that a reliability study of the TIS in PD was not carried out. However, extensive psychometric analysis has been performed for the TIS in stroke patients, persons with multiple sclerosis and subjects after traumatic brain injury, in which reliability, validity, internal consistency, and measurement error were established.\(^\text{11-13}\) Because the TIS seems a useful tool for PD patients on the basis of the present findings, an evaluation of its reliability, measurement error, predictive validity, and responsiveness needs to be undertaken. Our results point to various trunk impairments in different stages of PD that might be amenable to rehabilitation intervention. The effectiveness of certain aspects of trunk rehabilitation for PD patients has already been investigated.\(^\text{22-24}\) A specific standardized and responsive clinical tool for measuring trunk performance would contribute to setting up further experimental studies in this domain.

**CONCLUSIONS**

This study demonstrated the construct validity of the TIS in PD and supports its further development as a clinical tool in PD patients. The TIS appeared to be able to detect motor deficits of the trunk in PD patients in the early stages of the disease. Trunk impairment was also an important parameter which was significantly related to disease severity and age. Future research should evaluate the psychometric properties of the TIS, continue to explore trunk performance in PD, and further develop evidence-based treatment applications.

**References**


Supplier

a. SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.
The Effect of a Dual-Task on Obstacle Crossing in Healthy Elderly and Young Adults

Hyeong-Dong Kim, PhD, Denis Brunt, EdD


Objective: To investigate the effect of a dual-task on step initiation over an obstacle.

Design: Repeated-measures design between groups.

Setting: University laboratory.

Participants: Ten healthy, community-dwelling elderly adults and 10 healthy young adults.

Interventions: Not applicable.

Main Outcome Measures: The effect of a reaction time task on ground reaction forces, toe clearance, and temporal events in stepping over an obstacle.

Results: Ground reaction forces of the swing limb before toe-off did not differ between the groups and was not affected by task difficulty. Stepping with a random stimulus after toe-off was the most difficult task, whereas stepping with a predictable stimulus before toe-off was the easiest task. Reaction time and stepping time were greater and toe clearance was less for the elderly subjects. Both groups had a decrease in toe clearance and an increase in reaction time and stepping time as the task became more difficult.

Conclusions: Our findings indicate that even healthy older adults may be at risk for falls in situations where they are engaged in concurrent tasks. The data support the inclusion of dual-task activities in fall prevention programs.

Key Words: Accidental falls; Aging; Gait; Reaction time; Rehabilitation.

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WHEN 2 TASKS ARE performed simultaneously, "attention capacity" must be apportioned effectively. The difficulty of these tasks, or how tasks are prioritized, will influence how attention is partitioned. If, however, the combined difficulty of the tasks requires excessive attention, then interference between tasks could occur. That is, the quality of performance of both tasks could decrease, or 1 task be performed in preference to the other. This "dual-task" paradigm has become an important focus of research in elderly populations. The effect of balance in a secondary task has been of particular interest because of the risk of falls and their subsequent medical complications. Older adults have increased postural sway or loss of balance and take compensatory steps when presented with a secondary task during quiet stance.

Melzer and Oddsson extended the dual-task paradigm from quiet stance to the initiation of a single step. Subjects stepped as quickly as possible in response to a cutaneous stimulus. In general, time to initiate the step and temporal phases of step initiation increased for older subjects when performed simultaneously with a cognitive task. In this study, we asked healthy young and elderly subjects to not just initiate stepping from quiet stance, but to step over an obstacle while simultaneously performing a reaction-time task.

Such an investigation appears to be important for 2 reasons. First, tripping over an obstacle is among the most commonly reported causes of falls in the elderly.16-14 Second, there are only small differences in stepping over an obstacle from quiet stance between young and elderly subjects15 and between healthy and frail elderly.16 Therefore, changing the attention capacity of the elderly while stepping may reveal differences that place them at risk for tripping and possibly falling. In addition, increasing the difficulty of a task during walking also increases attention demands.17 We therefore introduced 2 levels of task difficulty into the protocol. First, presentation of the reaction time stimulus was either predictable or randomized. Second, the stimulus cue was presented at different levels of stability, that is, either in single- or double-limb stance.

In this study, the predicted task-dependent consequences of the dual-task paradigm were a decrease in toe clearance over an obstacle, an increase in temporal parameters of stepping, and an increase in reaction time.

METHODS

Participants

Ten healthy, community-dwelling elderly adults (mean age, 74.6±5.0y) and 10 healthy, younger adults (mean age, 27.7±4.1y) participated in the study. Criteria for inclusion of the elderly subjects was a score greater than 50 on both the Berg Balance Scale and Frenchay instrumental activities of daily living, and greater than 20 on a physical function test. Elderly participants reported no falls in the previous 12 months and scored greater than 24 on the Mini-Mental State Examination. The reliability and validity of these tests have been reported as satisfactory.

The study was approved by the university institutional review board and all participants signed an informed consent form before their participation.

Experimental Procedures

Subjects stood with each foot on a force platform and, after receiving a visual cue, stepped over a 10-cm high obstacle at a self-paced speed with the right (swing) limb. The visual cue was a light-emitting diode placed in the center of the obstacle. Subjects were instructed to continue walking after stepping over the obstacle. Lines were marked on the forceplate to ensure that foot placement remained constant for all subjects. A mat switch detected heel-strike of the swing limb. Amplified force platform

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signals were sampled on-line at a rate of 1000Hz for 5 seconds. Reflective markers were placed on the head of the fifth metatarsal of the right stepping limb and the front edge of the obstacle. The vertical distance between the markers provided an estimate of toe clearance. Motion data were captured at 100Hz for 5 seconds. Figure 1 illustrates the experimental setup.

Subjects first completed reaction time trials while standing and trials of baseline stepping. This was followed by stepping trials in which subjects were asked to press a handheld microswitch in response to a threshold cutaneous stimulus (reaction time task). The stimulus was a single 1-ms square wave pulse delivered to 1 arm from a stimulator and stimulus isolation unit. The cutaneous stimulus was presented either before and after toe-off with the swing limb. In addition, the trials were blocked so that the stimulus was presented either at every trial or randomly during the trials. After the practice trials, the subjects completed approximately 100 successful experimental trials. Rest periods were provided to avoid fatigue.

**Statistical Analysis**

All trials of all subjects were averaged for each condition; we used analysis of variance techniques to determine main and interaction effects. We used single degree of freedom mean contrasts to determine significant comparisons ($P<.05$). The independent variables were the 2 groups (young and healthy elderly adults) and 5 levels of stepping conditions (baseline and random or predictable stimulus trials before and after toe-off). Dependent measures included timing, slope, and amplitude measures of the anteroposterior ground reaction force ($F_x$) under the stance and swing limbs (normalized to body weight [BW]), time to swing limb toe-off, and swing time. Timing data were referenced from movement onset, defined as the first detectable onset of force platform activity ($F_x$), as determined visually with an interactive cursor of 1-ms resolution. Simple reaction time was analyzed from the onset of the stimulus to the subject’s response. Toe clearance was assessed as the perpendicular distance from the marker placed on the metatarsal head to the marker on the obstacle. Figure 2 shows data from an individual trial by a young subject that illustrate the dependent variables.

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**Fig 1. Experimental setup.**

**Fig 2. Anteroposterior ($F_x$) ground reaction force dependent variables of a trial for a young subject, where the cutaneous stimulus was presented at every trial and before toe-off. The vertical arrows represent time of stimulus and reaction time (RT). Vertical lines represent movement onset, swing toe-off, swing heel-strike, and stance toe-off. Dependent measures of the stance and swing limb ground reaction forces are indicated. In this trial, reaction time was 360ms and peak shear force ($F_x$) of the stance limb was 57% of BW.**
RESULTS

The timing of the cutaneous stimulation after movement onset for both the predictable and randomized trials before swing limb toe-off was 285.6±3.3ms and 292.4±4.3ms, respectively. Corresponding times of stimulation after toe-off were 449±7.5ms and 493±11.1ms, respectively. The timing of the stimulus presentation between predictable and randomized trials did not differ significantly. Previous research has shown thatFx of the swing limb correlates significantly with the velocity of step initiation.27,28 There were no main effects for peak Fx or the slope and time to peak Fx. The velocity of the initiation of stepping, therefore, was not influenced by the secondary task.

Group Effects

Toe clearance was greater for the younger adults than for the older adults (14.1±0.65cm and 12.6±0.86cm, respectively) (F_{4,15}=4.97, P<0.05), and reaction time of the elderly (418±104ms) was significantly longer than the young adults (297±68ms) (F_{1,18}=8.61, P<0.01). Stance peak Fx was significantly greater for younger adults (46%±13% of BW) than for the older adults (26%±12% of BW) (F_{1,18}=12.67, P<0.01). Stance peak Fx coincides with swing toe-off and will increase with a faster lift.15 Time to swing toe-off was significantly earlier for the young than for the older adults (385±25ms, 435±40ms, respectively) (F_{1,18}=5.44, P<0.05). Swing time was also significantly shorter for the young than for the older adults (533±31ms, 621±38ms, respectively) (F_{1,18}=4.78, P<0.05).

Condition Effects

There was a condition effect for toe clearance (F_{4,64}=8.17, P<0.01). It was greater for baseline stepping (14.6±0.78cm) versus stepping with the reaction time tasks (combined mean, 13.0±0.96cm). In addition, toe clearance for predictable trials before toe-off (13.5±1.2cm) was significantly greater than for the random trials after toe-off (12.6±1.31cm). The data were similar for reaction time (F_{4,72}=36.93, P<0.001), where baseline reaction time (219±42ms) was significantly less than the dual-task conditions (combined mean, 393±383ms), and reaction time was less for predictable trials before toe-off (338.5±86ms) versus random trials after toe-off (442.5±116ms).

Stance peak Fx was significantly greater when the stimulus was provided at every trial (38%±16% of BW before toe-off, 39%±18% of BW after toe-off), compared with respective random trials (34%±18% of BW before toe-off, 34%±19% of BW after toe-off) (F_{4,72}=2.72, P<0.05). As would be expected, time to swing toe-off was significantly earlier when the stimulus was provided for every trial (361±113ms before toe-off, 393±74ms after toe-off), compared with respective random trials (441±76ms before toe-off, 425±95ms after toe-off) (F_{4,18}=3.06, P<0.05). Further, there were significant condition effects for swing time (F_{4,18}=5.78, P<0.01). Similar to the swing toe-off, swing time was less when the stimulus was provided at every trial (553±72ms before toe-off, 556±36ms after toe-off), compared with respective random trials (583±62ms, 601±57ms).

Degree of Task Difficulty

These data imply a degree of difficulty with respect to the presentation of the independent variables. That is, a certain combination of the levels of stepping condition had greater influence on the task-dependent consequences. For example, figures 3 and 4 show the mean data for reaction time and toe clearance where a predictable cue before toe-off is the least difficult task and a random cue after toe-off is the most difficult task. That is, toe clearance decreased and reaction time increased when the secondary reaction time task was randomly presented during single-limb stance. It is reasonable to assume that the degree of difficulty of a random cue before toe-off is similar to a predictable cue after toe-off.

DISCUSSION

In this study, we investigated the effects of a secondary reaction time task when stepping over an obstacle from a position of a quiet stance in healthy young and older adults. We hypothesized that the performance of the stepping task (toe clearance) and/or the reaction time task would decline with presentation of the secondary task, especially in older adults. The presentation of the reaction time task was predictable or random and during single- or double-limb stance. Reaction time and swing time increased and toe clearance decreased as the task became more difficult. Random presentation of the reaction time stimulus after swing limb toe-off appeared to be the most difficult stepping condition. Regardless of when the reaction time stimulus was presented, the components of the ground reaction force to peak Fx of the stepping limb did not differ between stimulus conditions and between young and older adults. This is important because it eliminates the potential influence of the velocity of step initiation on reaction time, toe clearance, and other task parameters.

Although this study demonstrated significant group differences in toe clearance and reaction time, we did not detect any group-by-condition interaction. That is, group-related differences in toe clearance, temporal events after swing toe-off, and reaction time remained similar as task parameters were manipulated to make the task more demanding. Nevertheless, toe clearance was consistently less and reaction time and swing time greater for the elderly compared with young adults. These data are consistent with previous findings in dual-task experiments in which older adults had increased reaction time and decreased performance in gait or postural control paradigms.29-32

The notion of task-appropriate scaling of toe clearance during obstacle crossing is crucial to ensuring a safe and efficient obstacle crossing. Falls are more likely to occur with inadequate toe clearance rather than through contacting the obstacle with the heel.33 It has been reported that the toe clearance over an obstacle ranges from approximately 9 to 13cm for either
while walking. There was only a small decrement in the difficulty was a plausible explanation for there being no change posture of decreased stability. In fact, a low level of task attention-demanding task is unexpected when a subject is in a swing and stance time may reflect the fact that older adults tend adults. Swing and stance time were longer for the older adults and resulted in a slower stepping speed. Using a longer swing and stance time may reflect the fact that older adults tend to use a more cautious strategy in this test condition.

These data suggest that both the timing and the uncertainty of the presentation of the secondary reaction time task influenced toe clearance. The notion of task difficulty may therefore be significant in placing the elderly at risk for falls. Our findings suggest that an increase in risk for falls occurs when an attention-demanding task is unexpected when a subject is in a posture of decreased stability. In fact, a low level of task difficulty was a plausible explanation for there being no change in foot clearance in elderly subjects stepping over an obstacle while walking. There was only a small decrement in the secondary task, which was continuous throughout the walk. Analysis of a single subject, however, where the change in the secondary task was significant revealed definite changes in gait-related variables. Other studies have reported a performance decrease in the secondary but not the primary task. For example, Brown et al asked subjects to step over a foam obstacle while walking. A secondary reaction time task was presented before, or while, stepping over the obstacle. They reported an increase in reaction time for both old and young subjects before crossing the obstacle and for older subjects while crossing the obstacle. No subjects hit the obstacle, but the authors did not provide any performance data on actual obstacle clearance. Reaction time was also increased for older adults when heel strike was constrained to a specific target while walking. In both the Brown and Sparrow studies, manipulation of the reaction time signal altered the degree of difficulty of the task; however, neither study reported the potential impact of task difficulty on the consequences of the primary task.

CONCLUSIONS

The results of this study provide an increased understanding of the interaction of age and dual tasking in stepping over obstacles. Many distractions encountered in daily life are unexpected and can reduce attention to stepping mechanics. Our findings indicate that, depending on the difficulty of the task, even healthy older adults may be at risk for falls. Several clinical assessment tools have been devised that include a dual-task component. These tests have been effective in identifying people with a history of falls and/or are at a greater risk of falling. This study, therefore, seems to support the inclusion of dual-task activities in fall prevention programs. Finally, our results raise 2 interesting questions for future study: (1) whether the group differences we found in this study would be exaggerated under more demanding or dynamic conditions than those we investigated, and (2) whether frail and balance-impaired older adults would have more difficulty performing the same tasks than would healthy older adults.

Fig 4. Toe clearance for the baseline and dual-task conditions. The dual-task stimulus was presented at every trial and random trial both before and after toe-off. Abbreviations: see fig 3.

References


33. Chou LS, Draganich LF. Stepping over an obstacle increases the motions and moments of the joints of the trailing limb in young adults, Biomechanics 1997;30:331-7.


Suppliers
a. Advanced Mechanical Technology, 176 Waltham St, Watertown, MA 02472.

b. BIOPAC Systems, 42 Aero Camino, Goleta, CA 93117.

c. Qualisys Inc, 148 Eastern Blvd, Ste 110, Glastonbury, CT 06033.

d. Grass Instrument Co, 101 Old Colony Ave, Quincy, MA 02169.

Objective: To determine the reliability, concurrent and predictive validity, and responsiveness of the Functional Ambulation Category (FAC) in hemiparetic patients after stroke.

Design: Prospective cohort.

Setting: An early rehabilitation center for patients with neurologic disorders.

Participants: Fifty-five nonambulatory patients after first-ever stroke, with duration of illness between 30 and 60 days, were included.

Interventions: Not applicable.

Main Outcome Measures: FAC, Rivermead Mobility Index (RMI), walking velocity, step length, and six-minute walking test (6MWT) were assessed at the beginning, after 2 and 4 weeks of rehabilitation, and again 6 months later.

After 6 months, community ambulation was also assessed. Test-retest and interrater reliability, concurrent, discriminant, and predictive validity and responsiveness of the FAC were calculated.

Results: Based on video examinations, high test-retest reliability (Cohen κ=.950) and interrater reliability (κ=.905) were found. FAC scores at the beginning and after 2 weeks, 3 weeks, and 6 months correlated highly with the RMI (Spearman ρ=.686, ρ=.787, ρ=.825, respectively), distance walked in the 6MWT (ρ=.949, ρ=.937, ρ=.931, ρ=.906, respectively), walking velocity (ρ=.952, ρ=.939, ρ=.902, ρ=.901, respectively), and step length (ρ=.952, ρ=.932, ρ=.896, ρ=.877, respectively) at the same time points (all P<.001). The RMI, walking velocity, step length, and distance walked in the 6MWT differed for each FAC category (P<.001). After 4 weeks of rehabilitation, an FAC score of 4 or higher predicted community ambulation at 6 months with 100% sensitivity and 78% specificity. FAC scores changed significantly between the first 2 and second 2 weeks (Wilcoxon 𝑧=8.7, 𝑧=7.9, respectively; both P<.001) of the inpatient rehabilitation program.

Conclusions: The FAC has excellent reliability, good concurrent and predictive validity, and good responsiveness in patients with hemiparesis after stroke.

Key Words: Gait; Outcome assessment (health care); Rehabilitation; Stroke.

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MANY PATIENTS REMAIN unable to walk or have difficulties with walking after stroke. Gait rehabilitation that aims to improve walking ability is therefore of high importance to patients and their relatives. Evidence supports that gait training in specialized rehabilitation facilities improves walking function after stroke. However, there is still a need for specific walking assessment tools to measure the progress of patients (eg, during gait rehabilitation). Currently available gait-assessment tools range from complex and expensive laboratory techniques involving detailed analyses of kinematic and kinetic variables to simple measures used in the clinical setting for measuring such variables as walking speed. However, high costs, difficulties in interpretation and communication of the results, and problems with accessibility can sometimes make laboratory gait analysis impractical for everyday clinical use.

Clinically based assessments of walking ability such as the Timed Up & Go test and the timed walk test may therefore have advantages of immediate availability; ease of administration and interpretation; and, of course, low costs. However, walking scales have to be validated with respect to reliability, responsiveness, and predictive and concurrent validity. The Functional Ambulation Category (FAC) is a common clinical gait assessment scale first described by Holden et al in 1984. The FAC distinguishes 6 levels of walking ability on the basis of the amount of physical support required. The FAC is a quick visual measurement of walking, is simple to use, easy to interpret, and cost-effective because only stairs and 15m of indoor floor are needed to administer the test. Research indicates that the FAC score correlates with walking velocity and step length. Predictive validity and responsiveness to change (caused, eg, by recovery) have not before been investigated for the FAC, although they are very important in decision making regarding treatment and for intervention trials.

The aim of the present study was therefore to evaluate these essential but unknown psychometric properties of the FAC in a population of initially nonambulatory patients with hemiparesis after stroke.

METHODS

Participants

Patients immediately after admission to inpatient rehabilitation, who had a first-time supratentorial stroke, either ischemic or hemorrhagic, were aged 18 to 80 years and had a duration of illness shorter than 60 days were included in the study. Patients were all able to sit without holding on to any support (eg, on the edge of the bed and with feet unsupported by anyone and without contact with the floor), were either completely nonambulatory or required the assistance of 1 or 2 therapists to walk irrespective of the use of an ankle-foot orthosis or a walking aid (except rolling walker), were able to understand the meaning of the study and to follow instructions, and had signed an in-
formed consent of participation approved by the local ethics committee. All patients took part in a multicenter research project called the Deutsche Gangtrainer Studie (DEGAS). In the DEGAS, patients were randomized to receive either 20 minutes of locomotor training on an electromechanical gait trainer and 25 minutes of physiotherapy (PT) or only 45 minutes of PT without locomotor training every day for 4 weeks during an inpatient rehabilitation program. Only the patients from the authors’ center who had complete data and video sets of all assessment time points were included in this study.

Assessments

All patients were assessed at the beginning (baseline), after 2 and 4 weeks of therapy, and again after 6 months (follow-up). FAC, gait speed, stride length (measured with the ten-meter walk test [10MWT]), and walking distance (measured with the six-minute walking test [6MWT]) were assessed. The FAC discriminates 6 levels of walking abilities on the basis of the amount of physical support required (see appendix 1 for details).

The Barthel Index (score range, 0–100) is a valid and reliable index measuring activities of daily life. Included are 10 items relating to the degree of independence from any help. The Barthel Index score was used to describe activities of daily life at baseline.

The Rivermead Mobility Index (RMI; score range, 0–15) is comprised of 15 mobility-related items, from turning over in bed to running, and is a reliable and valid measure of mobility restrictions and body functions.

The 10MWT and the 6MWT were used to assess walking velocity, stride length, and walking distance. For walking-velocity evaluation, patients walked a distance of 15m twice at their maximum speed. The time was taken for middle 10m, and the mean velocity was calculated. During the 10MWT, we assessed step length according to prior publications.

To assess walking distance, patients walked 6 minutes without interruption (6MWT), and the maximum distance was noted. If patients had to stop during the 6MWT because of exhaustion, the distance covered to that point was considered.

Intra- and Interrater Reliability

One week after the first rating of each examiner, the second rating was performed to reduce the chance that the raters would remember the last rating, thus biasing the test-retest reliability. Every rater was kept blinded to any results of the other examiners. We determined interrater reliability and test-retest reliability of the FAC by using $\kappa$ statistics. According to Altman, the results of the $\kappa$ statistics were considered as “excellent” if $\kappa$ values were .80 or above.

To measure the reliability of the FAC, video sequences for every patient at every time point were recorded. The FAC video sequences were standardized for all 4 FAC assessment time points and included a video taken from the rear and from the side while the patients walked a 15-m distance. The videos gave information on the physical support needed by patients while walking, irrespective of the technical aids used. If the patients could climb stairs, an additional video helped to distinguish between FAC level 4 and 5.

Examiners

All video sequences were assessed twice by each of the 4 examiners. All examiners were physiotherapists and had at least 5 years experience in stroke rehabilitation. Nonetheless, in addition to the described FAC, we used key questions for each of the 6 categories to identify the appropriate FAC level (appendix 2).

Concurrent Validity

Concurrent validity was evaluated by correlating the FAC scores with RMI scores, walking velocity, stride length, and 6MWT of patients at baseline, after 2 and 4 weeks, and after 6 months. The RMI was chosen because it measures body function, (eg, sitting and standing balance), which is known to be associated with walking function.

Walking velocity, stride length, and distance walked in the 6MWT were used because these parameters represent basic gait tests broadly used in rehabilitation facilities and rehabilitation research.

The time points were chosen according to the DEGAS study protocol. These time points were rated to observe trends in the relationship across the time bands (increasing or decreasing over time).

The changes of FAC scores between study onset and 6 months later were correlated with changes in RMI scores, walking velocity, stride length, and 6MWT. Additionally, Spearman rank correlation coefficients were calculated for all comparisons.

To examine whether the RMI, walking velocity, stride length, and 6MWT differ for each of the FAC categories, an analysis of variance approach was used.

Predictive Validity

To measure predictive validity, functional community ambulation was used as a target outcome at 6 months after the study onset. The term “community ambulation” was used according to previous publications and was defined as the ability to walk faster than 73m/min, ability to walk longer than 332m, and ability to climb stairs and curbs as described by Lernier-Frankiel et al and Lord and Rochester. If patients met all 3 predefined conditions, patients’ ability to walk was graded as “community ambulation.”

Receiver operating characteristics (ROCs) for all possible FAC cutoff points at 4 weeks were used. Sensitivity, specificity, negative and positive predictive values, and the area under the curve (AUC) were calculated to identify community ambulation at 6-month follow-up.

Responsiveness

To measure responsiveness to change, standardized response means (SRMs) were calculated. This was done because SRMs may better reflect individual changes than effect sizes (SRM is equal to mean change divided by standard deviation [SD] of the difference). Differences were calculated between FAC scores at baseline compared with 2 weeks, 3 weeks compared with 4 weeks, and 4 weeks compared with 6 months. Wilcoxon signed-rank tests (a nonparametric alternative to the paired $t$ test) were used to check for statistical significance of differences. The global $\alpha$ was set for all comparisons to .05. We used SAS/STAT software for all calculations.

RESULTS

Between August 2002 and May 2003, a total of 55 patients were eligible and fulfilled the inclusion criteria. The patient characteristics are shown in table 1; the descriptive statistics of the study parameters are shown in table 2.

Reliability

The test-retest and interrater agreement of ratings of the FAC were excellent, with kappas of .950 and .905, respectively.
Table 1: Patient Characteristics at Baseline

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patients (N=55)</th>
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<tr>
<td>Age (y)*</td>
<td>62.8±10.2 (65, 40–78)</td>
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<tr>
<td>Sex (female/male)</td>
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</tr>
<tr>
<td>Diagnosis</td>
<td>Stroke (ischemic/hemorrhagic) 41/14</td>
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<tr>
<td></td>
<td>Side of lesion  Hemisphere (left/right) 30/25</td>
</tr>
<tr>
<td></td>
<td>Duration of illness (d)* 30.6±15.5 (28, 9–60)</td>
</tr>
<tr>
<td></td>
<td>Barthel Index (score, 0–100)* 34.3±11.8 (30, 25–65)</td>
</tr>
</tbody>
</table>

*Mean ± SD (median, range).

Concurrent Validity

The results of the correlations between the absolute values of the FAC, RMI, 6MWT, walking velocity, and step length are shown in table 3. Changes in FAC scores between baseline and 6 months after the end of the study correlated significantly with changes in the RMI (Spearman ρ=.841, P<.001), 6MWT (ρ=.795, P<.001), walking velocity (ρ=.767, P<.001), and step length (ρ=.805, P<.001). For each of the FAC categories, the RMI, walking distance, walking velocity, and step length differed significantly (all P<.001).

Predictive Validity

The highest AUC was found for the cutoff FAC of 4 or higher (AUC=89%) than specific (78%) in predicting community ambulation 6 month after study end. All results of the ROC are shown in table 4.

Responsiveness

The FAC scores changed over time; the median FAC score was 0 (mean ± SD, 0.44±0.69) at baseline, 2 (mean, 1.98±1.5) after 4 weeks, and 4 (mean, 2.79±2.12) 6 months after study end. The responsiveness of the FAC was good. FAC scores changed significantly between the first 2 study weeks (SRM=1.016, Wilcoxon z=−8.691, Bonferroni-adjusted P<.001), between the second 2 study weeks (SRM=.842, z=−7.900, Bonferroni-adjusted P<.001), and between study week 4 and 6 months after study end (SRM=.699, z=−6.368, Bonferroni-adjusted P<.001).

DISCUSSION

The present study shows that the FAC has excellent test-retest and interrater reliable, has good concurrent and predictive validity, and is sensitive to change in the assessment of patients after stroke who cannot walk without personal assistance at the beginning of their inpatient rehabilitation.

Reliability

Walking scales cannot be seen as valid without knowledge of reliability. The reliability of the FAC is only described in studies by Holden10 and Collen24 and colleagues. In a first description of the FAC, Holden10 described good interrater reliability (κ=.72) when tested by 9 therapists on 5 patients. In contrast, Collen24 achieved only fair interrater reliability (κ=.36) in 25 chronic patients after stroke. In both studies, test-retest reliability was not described. In our study, the interrater reliability was very good (κ=.91) and therefore slightly higher than previously reported.10,24 This could mainly be attributed to the use of key questions and videos and to the fact that our rater had at least 5 years experience in stroke rehabilitation.

Concurrent Validity

Changes of FAC scores correlated significantly with changes in walking speed, step length, and the distance walked in the 6MWT. These walking variables are commonly regarded as indicators of progress in gait performance.8,17,25,26 Therefore, the results of the present study suggest that improvements in FAC scores are associated with improvements in gait performance. These results are in line with the findings of Holden who showed a close relationship between the FAC and measures of gait performance such as walking velocity, cadence, step and stride length, and temporal-distance measures.10,11 On the one hand, we observed a slight decrease of the correlation between FAC and walking distance over time. On the other hand, we found a minor increase in the relation between FAC and RMI over time.

Kollen et al12 recently described that walking velocities associated with the specific FAC vary in time from higher to lower speeds. In contrast in our study, we found only a 5% decrease in the relationship between FAC and walking velocity. Six months after stroke, however, 81% of the variance of the FAC scores was still explained by walking velocity.

The relationship between FAC scores and the RMI underscores an association between gait ability and some body functions. This could be interpreted in the sense that motor control of tasks such as rolling from one side to another, sit-to-stand maneuvers, and sitting and standing balance may be useful during walking.

Predictive Validity

Our results suggest that the ability to ambulate after a 4-week rehabilitation program measured with the FAC predicts community ambulation at 6 months after stroke. We conclude, therefore, that a dichotomized FAC (in FAC ≥4 and FAC <4) may be useful in predicting a level of community ambulation with high sensitivity and specificity. This could be important for clinical rehabilitation goal planning and future studies investigating walking outcome.

Table 2: Descriptive Statistics of Study Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>At Baseline</th>
<th>After 2 Weeks</th>
<th>After 4 Weeks</th>
<th>At 6-Month Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAC (score, 0–5)</td>
<td>0.44±0.69 (0, 0–3)</td>
<td>1.22±1.32 (1, 0–5)</td>
<td>1.98±1.50 (2, 0–5)</td>
<td>2.79±2.12 (4, 0–5)</td>
</tr>
<tr>
<td>RMI (score, 0–14)</td>
<td>2.51±1.62 (2, 1–10)</td>
<td>4.04±2.88 (3, 0–12)</td>
<td>5.76±3.93 (5, 1–14)</td>
<td>7.38±5.01 (8, 0–14)</td>
</tr>
<tr>
<td>6MWT (m)</td>
<td>15.9±34.3 (0, 0–175)</td>
<td>50.9±81.1 (15, 0–315)</td>
<td>83.9±107.8 (40, 0–460)</td>
<td>112.3±143.9 (60, 0–560)</td>
</tr>
<tr>
<td>Walking velocity (m/s)</td>
<td>0.07±0.14 (0.01, 0.01–0.82)</td>
<td>0.19±0.28 (0.08, 0.01–0.96)</td>
<td>0.33±0.46 (0.15, 0.01–1.96)</td>
<td>0.38±0.51 (0.15, 0.00–1.96)</td>
</tr>
<tr>
<td>Step length (m)</td>
<td>0.09±0.13 (0, 0.00–0.48)</td>
<td>0.18±0.19 (0.18, 0.00–0.61)</td>
<td>0.27±0.20 (0.22, 0.00–0.74)</td>
<td>0.28±0.26 (0.26, 0.00–1.06)</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD (median, range).
Predicting community ambulation at follow-up 6 months after study end.

Routine clinical use and additionally for a valid assessment of gait after stroke, there is a need for reliable walking scales for playing an important role in better understanding hemiparetic walking outcome after stroke. Despite gait analysis systems assessing walking function, our results suggest, therefore, that the FAC can be used in clinical research to measure improvement and outcome in gait performance in primary nonambulatory patients after stroke.

Assessment of Walking

There is no true criterion standard for the assessment of walking outcome after stroke. Despite gait analysis systems playing an important role in better understanding hemiparetic gait after stroke, there is a need for reliable walking scales for routine clinical use and additionally for a valid assessment of gait outcome in research projects. An argument for the use of walking scales is that they are often easy to interpret. Walking scales such as the FAC measure functional aspects, which are often more important for patients after stroke and for their relatives (eg, how much personal assistance is required for walking). Additionally, the FAC allows a precise documentation of walking progress. Thus, the FAC is useful as a routine clinical assessment tool and also for research purposes to measure walking outcome.

Study Limitations

The lack of a uniform time basis (the duration of illness of our cohort was between 9 and 60 days) limits the interpretation of our results with respect to nonlinear patterns of recovery after stroke. However, for logistical reasons, all patients immediately after entering the inpatient rehabilitation program were included.

Furthermore, our results may be limited in the sense that only patients who were initially nonambulatory were included in the study. Therefore, the responsiveness and concurrent validity (eg, walking distance) of the scale may be overestimated to some extent. However, in planning clinical trials, it is desirable to include patients who are most responsive to change.

The revealed excellent reliability was at least partly influenced by the use of key questions to each FAC. The questionnaire was used to train the examiners but was, however, not tested for its reliability and validity.

Additionally, the video-based assessments are of limited practicability in everyday use. Therefore, the revealed reliability may be overestimated compared with the use of the FAC in clinical practice.

Recent studies have questioned the common opinion that clinical walking scales are appropriate and valid measures for community ambulation. In this vein, the FAC and our definition for community ambulation are limited because crucial environmental and cognitive factors were not considered. However, given the predictive validity of the FAC, the categories of the FAC could be used as a screening tool to identify patients who are at higher risk of not achieving community ambulation during rehabilitation. This might be an advantage in therapy planning and rehabilitation goal setting.

We have used the term “responsiveness” in our study. However, because “responsiveness” has different meanings in science, some authors would argue that the term “sensitivity to change” would be more appropriate. Different and sometimes contradictory recommendations exist in the literature for using these terms. In preparing this article, all authors decided to use the term “responsiveness,” which can be seen as the result of time but also could be the result of applied interventions.

CONCLUSIONS

In patients with hemiparesis after stroke, the FAC has very good reliability, good concurrent and predictive validity, and is responsive to change over time. For clinical practice and research purposes, the FAC may be an appropriate assessment tool in the measurement of walking ability.

Acknowledgment: We thank Derek Barton for his assistance in preparing the manuscript.

Table 3: Concurrent Validity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FAC Scores at Baseline</th>
<th>FAC Scores After 2 Weeks</th>
<th>FAC Scores After 4 Weeks</th>
<th>FAC Scores at 6-Month Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMI</td>
<td>.686</td>
<td>.787</td>
<td>.825</td>
<td>.893</td>
</tr>
<tr>
<td>6MWT</td>
<td>.949</td>
<td>.937</td>
<td>.931</td>
<td>.906</td>
</tr>
<tr>
<td>Walking velocity</td>
<td>.952</td>
<td>.939</td>
<td>.902</td>
<td>.901</td>
</tr>
<tr>
<td>Step length</td>
<td>.952</td>
<td>.932</td>
<td>.896</td>
<td>.877</td>
</tr>
</tbody>
</table>

NOTE. Values are Spearman ρ (all P<.001).

Table 4: Results of the ROC

<table>
<thead>
<tr>
<th>Cutoff</th>
<th>Sensitivity (%)*</th>
<th>Specificity (%)*</th>
<th>AUC (%)*</th>
<th>Positive Predictive Value (%)*</th>
<th>Negative Predictive Value (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAC score ≥1</td>
<td>100</td>
<td>16</td>
<td>58</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>FAC score ≥2</td>
<td>100</td>
<td>47</td>
<td>74</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>FAC score ≥3</td>
<td>100</td>
<td>73</td>
<td>86</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td>FAC score ≥4</td>
<td>100</td>
<td>78</td>
<td>89</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>FAC score 5</td>
<td>67</td>
<td>100</td>
<td>83</td>
<td>100</td>
<td>98</td>
</tr>
</tbody>
</table>

*Predicting community ambulation at follow-up 6 months after study end.
APPENDIX 1: THE FUNCTIONAL AMBULATION CATEGORIES\textsuperscript{10,11}

- A FAC of “0” (nonfunctional ambulator) indicates a patient who is not able to walk at all or needs the help of 2 therapists.
- A FAC level of “1” (ambulator, dependent on physical assistance [level II]) indicates a patient who requires continuous manual contact to support body weight as well as to maintain balance or to assist coordination.
- A FAC of “2” (ambulator, dependent on physical assistance [level I]) indicates a patient who requires intermittent or continuous light touch to assist balance or coordination.
- A FAC of “3” (ambulator, dependent on supervision) indicates a patient who can ambulate on level surface without manual contact of another person but requires standby guarding of one person either for safety or for verbal cueing.
- A FAC of “4” (ambulator, independent, level surface only) indicates a patient who can ambulate independently on level surface but requires supervision to negotiate (e.g., stairs, inclines, nonlevel surfaces).
- A FAC of “5” (ambulator, independent) indicates a patient who can walk everywhere independently, including stairs.

APPENDIX 2: KEY QUESTIONS FOR EACH FAC

Key questions for a FAC level of 0:
“If walking really only possible if two persons hold this patient?”
If answer is “yes” then FAC=0

Key questions for a FAC level of 1:
1. “Would the patient fall without assistance of the therapist?”
2. “Is the patient supported by the therapist during the whole video sequence?”
3. “Is it clearly visible that the chest is supported by the therapist?”

Two or more answers have to be “yes” for FAC=1. Two or more answers have to be “no” for FAC=2

Key questions for a FAC level of 2:
1. “Is there no visible bearing of weight by the therapist?”
2. “Does the therapist at least once move the affected leg of the patient?”
3. “Is it clearly visible that the chest is NOT supported by the therapist? Is only hand support visible?”

Answer to question 1 and 3 have to be “yes” and the answer to question 2 has to be “no” for FAC=2

Key questions for a FAC level of 3:
1. “Is it clearly visible that the affected leg of the patient is NOT moved by the therapist?”
2. “Is it clearly visible that the therapist does NOT support the patient, although stand by is allowed?”
3. “Would this patient probably not able to walk alone in his room?”

If one answer to the three questions is “no”, choose FAC=3

Key questions for a FAC level of 4:
1. “Is it clearly visible that the therapist does NOT support the patient at any time?”
2. “Would this patient probably able to be walk alone in his room?”

Both answers have to be “yes” for FAC=5. If one answer is “no”, choose FAC=4

Key questions for a FAC level of 5:
“Would this patient be able to walk alone over a variety of surfaces, such as uneven ground, grass, stairs etc.?”
Answer with “yes” for FAC=5

References
Supplier
a. Version 9.1.3; SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.

Objective: To propose a new model of integrated, multidisciplinary postoperative care of the patients with deep brain stimulation (DBS).

Design: Observational cohort study with follow-up at 3 months and 1 year.

Setting: Academic medical center movement disorder clinic.

Participants: Seventy-three consecutive patients with medically refractory Parkinson’s disease underwent bilateral DBS. Patients were then transferred directly to an inpatient rehabilitation facility.

Intervention: DBS and inpatient programming and rehabilitation. Simultaneous programming and rehabilitation was carried out by a multidisciplinary team.

Main Outcome Measures: The FIM instrument, Unified Parkinson Disease Rating Scale (UPDRS), and levodopa dosage.

Results: The average rehabilitation stay was 17.3 days, with a mean of 6.2 stimulator adjustments during that time. FIM scores improved from 62.1 (admission) to 98.5 (discharge), an average improvement of 36.4 (58.6%). Average UPDRS scores improved from 52.5 (preoperative off) and 30.1 (preoperative on) to 20.4 (3mo postoperative on-medication, on-stimulation), a 32.2% improvement from the preoperative on score. Levodopa dosages decreased by an average of 48.3% (all P<.001).

Conclusions: We describe our fast-track protocol, which allows for rapid DBS programming and tapering of Parkinson’s medications. It also provides for treatment of concomitant medical and psychologic problems and optimized physical performance.

Key Words: Brain stimulation, deep; Neurosurgery; Parkinson disease; Rehabilitation.

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DEEP BRAIN STIMULATION (DBS) is a standard treatment for movement disorders that are refractory to medical management. Among all movement disorders, DBS has been most widely used and comprehensively studied for Parkinson’s disease. Targets include the subthalamic nucleus (STN), nucleus ventro-intermedius of the thalamus, or globus pallidus interna (GPi), with the choice of stimulation site dependent on the patient’s individual symptom complex.1

Whichever site is used for stimulation, much effort is expended postoperatively for programming of the stimulator, adjustment of Parkinson’s disease medications, and for rehabilitation of these functionally impaired patients.2 In addition, medication adjustments and stimulator changes interact in complex ways to affect the patients’ symptoms and functional capabilities.

The traditional model of postoperative DBS patient care in the United States involves neurosurgeons and movement disorder neurologists spending many months after surgery to fine-tune DBS programming and medication management.3 This process can extend the time involved for the patient to realize the beneficial clinical effect of DBS. It also requires patients to make multiple office visits for programming, because clinical changes after programming adjustments often are not evident for hours or even days.

To maximize both efficiency of programming and patients’ functional outcome, we developed a multidisciplinary, integrated program for the postoperative management of Parkinson’s disease patients. Neurosurgery, movement disorder neurology, physiatry, physical therapy, speech therapy, occupational therapy, and psychiatry all participate in an intensive 2- to 3-week program that incorporates inpatient rehabilitation with up-to-date DBS programming and rapid medication titration. This study describes the methods and results of this integrated approach to postoperative DBS patient care.

METHODS

Seventy-three consecutive patients with Parkinson’s disease underwent DBS surgery and then entered fast-track programming and rehabilitation. Institutional review board approval was not required because we examined existing, deidentified data collected during the course of routine patient care.

Preoperative Evaluation

All patients underwent evaluation by a movement disorder neurologist and received the best possible medical treatment. Patients selected for DBS were those who showed dopamine sensitivity but who required escalating doses and/or were developing significant side effects (ie, dyskinesias) and had disabling symptoms. These symptoms included freezing, tremor, and rigidity. Neuropsychologic testing was performed prior to surgery, with a score of 130 on the Mattis Dementia Rating Scale being the minimum cutoff for cognitive performance. The entire test battery included the Mini-Mental State Examination, clock drawing test, Disability Rating Scale, Wechsler Adult Intelligence Scale—III, Wechsler Memory Scale—III, Hopkins Verbal Learning Test, verbal fluency, Boston naming,
have been published elsewhere.4-9 Stage I was performed under methods for microrecording and electrode implantation that fusion and microelectrode recording for electrophysiologic tar-
discharged to home the next day. 

obtained to check for intracranial hemorrhage. MRI was not changed to the regular form. Postoperatively, a brain CT was extended-release form of carbidopa-levodopa, they were for washout of these medications. If patients were taking the agonists were held for 2 weeks before the procedure to allow irreversible coagulopathy or other general medical condition that would preclude surgery, lack of response to dopamine, or poor neuropsychologic testing performance (Mattis Dementia Rating Scale score <130).

Perioperative Details 

Patients receive implants in the STN or GPi. The surgery is performed in 2 stages. In stage I, quadripolar DBS electrodes (model 3389) are implanted bilaterally using CT and MRI fusion and microelectrode recording for electrophysiologic target confirmation. Our surgical technique followed closely the methods for microrecording and electrode implantation that have been published elsewhere.

Stage I was performed under local anesthesia with minimal intravenous sedation. Dopamine agonists were held for 2 weeks before the procedure to allow for washout of these medications. If patients were taking the extended-release form of carbidopa-levodopa, they were changed to the regular form. Postoperatively, a brain CT was obtained to check for intracranial hemorrhage. MRI was not routinely performed to examine electrode position; it was only performed in the event of lack of benefit from the stimulator. Patients were observed in the hospital overnight and then discharged to home the next day.

The following week, patients returned for stage II, in which bilateral extensions and pulse generators (Soleta) were implanted in subcutaneous pockets in the chest under general anesthesia. If patients showed improvement in their symptoms after stage I due to lesioning effect, stage II was delayed until the lesioning effect abates. After the stage II procedure, patients were observed for several hours in the postanesthesia and ambulatory care units. As long as there were no complications, the patients were then transferred, on the afternoon of surgery, directly to an inpatient rehabilitation facility for our fast-track program.

Fast-Track Programming and Rehabilitation

Information obtained from the intraoperative mapping is shared with the physiatrists to facilitate initial programming. Specifically, the location of the electrode contacts relative to the borders of the nucleus (determined by intraoperative microrecording) is communicated to the physiatrists to provide a physiologically defined starting point for programming. Physiatrists receive special training in DBS programming, and all programming is done in consultation with the movement disorder neurologist. Baseline FIM instrument scores are obtained on admission to the rehabilitation facility by a physiatrist certified in its administration, along with a complete physical examination. Programming is started on the second day, with all parkinsonian medications having been held since the prior evening. FIM scores are repeated after discharge, and the average number of stimulator adjustments made during the inpatient stay is recorded. UPDRS scores are repeated at 3 months and 12 months in the on-medication, on-stimulation condition. Comparing these scores with the preoperative on-medication score provides a good measure of stimulation effect, because the presence of stimulation is the only difference between the preoperative and postoperative condition.

The FIM score is composed of 18 items, with the score on each item ranging from 1 (total assistance) to 7 (complete independence). The composite score ranges from 18 (lowest level of independence) to 126 (highest level of independence). The total score is composed of motor and cognitive components. The motor subscore contains 13 items (maximum score 91), whereas the cognitive subscore contains 5 items (maximum score 35). The FIM score is the most commonly used functional assessment scale and is designed to measure severity of disability and assess response to rehabilitation. The FIM describes patient’s abilities and limits with relation to activities involved in everyday life, and reflects a patient’s usual performance instead of their optimal performance. It has been shown to be both reliable, valid, and responsive.20 The UPDRS was developed to provide a single comprehensive rating scale for Parkinson’s disease patients. It consists of 4 subsections: behavior, activities of daily living, motor examination, and complications of therapy. We used the motor subsection to evaluate our patients. The motor subsection contains 34 items concerning various aspects of the clinical examination (eg, tremor, rigidity, bradykinesia, speech) with the score for each item ranging from 0 (normal function) to 4 (most severe symptoms). The overall scores on this subsection range from 0 to 108.

Initial stimulation parameters are a frequency of 130Hz and a pulse width of 60μs. Stimulation is first carried out in a unipolar mode (ie, using 1 of the 4 contacts on each electrode). Each electrode is tested for efficacy and threshold for side effects. Selection of which contact to use is made based on the contact(s) which give the greatest degree of symptomatic improvement at the lowest voltage without inducing side effects. After the initial electrode settings have been found, the stimulators are usually set to 1.0 to 1.5V. After holding all parkinsonian medications since the prior evening, on the morning that programming begins the patients’ levodopa-carbidopa dose (Sinemet CR) is decreased by 50% from the preoperative baseline. The dose is then further adjusted as necessary at the discretion of the movement disorder neurologist. During the inpatient stay, the DBS parameters are titrated every 1 to 2 days, depending on symptom response and the presence of dyskinesia.

Patient Care

While the patient undergoes inpatient programming, routine medical and postoperative wound care takes place. Residual functional and physical problems are managed in the context of a comprehensive therapy program. Physical, occupational, and speech therapists provide care individualized to each patient’s needs, and cognitive function is reassessed postoperatively. Nutritional counseling is provided to help patients manage the frequent weight gain that occurs after DBS. Psychologic counseling is available to help patients adjust to their greater degree of independence and autonomy and to help caregiving relatives cope with their changing role. Psychologists also provide assistance with alterations in patients’ moods following medication adjustments. Case managers help with insurance coverage and coordination of postdischarge therapy or care. Patients are discharged from the rehabilitation facility at the discretion of the physiatrist and movement disorder neurologist when they are judged to have obtained the maximum acute benefit from surgery.
Statistical Analysis

The changes in FIM scores from rehabilitation admission to discharge, including subanalysis of the motor and cognitive components, as well as the change in UPDRS scores from preoperative to postoperative and the change in daily levodopa dose, were statistically compared using a paired t test.

RESULTS

The average age of the 73 patients was 60.6 years. There were 50 men (68.5%) and 23 women (31.5%). Seventy-one (97.3%) patients were implanted in STN and 2 in GPi (2.7%). Demographic information is shown in table 1, and procedural details can be found in table 2.

FIM scores ± standard deviation at admission to the rehabilitation facility averaged 62.1 ± 18.3, and improved to an average of 98.5 ± 17.6 at discharge, yielding an average improvement of 36.4 (58.6%) (P < .001) (fig 1). The motor component of the FIM score increased from 37.2 ± 13.8 at admission to 66.2 ± 14.6 at discharge, an average improvement of 29.0 (78.0%) (P < .001). The cognitive subscore increased from 23.2 ± 6.7 at admission to 27.7 ± 6.1 at discharge, an average improvement of 4.5 (19.4%) (P < .001).

The average number of stimulator adjustments during the rehabilitation stay was 6.2 ± 2.5. From discharge from rehabilitation until 3 months postoperative, an average of 1.5 ± 1.2 further stimulator adjustments were made. Patients’ average daily dose of levodopa significantly decreased from 1084 mg preoperatively to 560 mg at 3 months postoperatively, for an average reduction of 524 mg (48.3%) (P < .001).

The average length of stay in the rehabilitation facility was 17.3 ± 8.5 days.

Average UPDRS scores improved from 52.5 ± 15.8 (preoperative off score) and 30.1 ± 13.6 (preoperative on score) to 20.4 ± 14.0 (3-mo postoperative score), an improvement of 9.7 (32.2%) from the preoperative on score (P < .001) (see fig 1). Although the sample size in whom 12-month postoperative UPDRS scores were available was limited (27 patients), there was evidence of maintenance of benefit, with an average UPDRS score of 26.0 ± 15.7 (P < .001 in comparison with preoperative on score). The 3-month and 12-month postoperative scores did not differ significantly (P = .94).

DISCUSSION

The process of programming after DBS surgery is complicated and time-intensive. The time involved to observe clinical effects after a programming change contributes to the many months that it often takes, using traditional methods, to realize full clinical benefit from DBS. As noted by Volkman et al, the response of bradykinesia and tremor to stimulation adjustments may be variable, and some complications of DBS may not occur for hours after a programming adjustment. Therefore, the time of day that a patient can safely undergo adjustment in the outpatient setting is generally limited to the morning. In contrast, in an inpatient setting, with constant supervision by and availability of the treating physician, programming changes can be made throughout the day. This could potentially allow for expediting the programming process.

The goal of our fast-track method of inpatient programming and rehabilitation of the DBS patient is to allow for rapid initial programming of the devices, prompt identification and treatment of medical complications, and early restoration of function. It also provides patients tools to quickly adapt to their improved level of function and lifestyle. A recent consensus report acknowledged that there is a lack of studies in the literature addressing immediate postoperative care and little information on medication management after surgery. In this initial report, we provide a description of our methods and the favorable results we have obtained using it, and adds to the literature on patient management following DBS; we do not claim superiority to traditional methods of postoperative care.

We have obtained rapid improvement in motor symptoms in our patients with this method as measured with UPDRS scores. The UPDRS, however, is not ideal at measuring overall functional improvement after surgical interventions. Other limitations of the UPDRS are the subjective nature of rigidity measurement and poor interrater reliability of some aspects of the motor section. For this study, the FIM score was felt to
provide a better measure for patients’ response to DBS and postoperative rehabilitation.

For patients who live a long distance away from programming facilities, the initial inpatient programming and rehabilitation spares the patient and their family the burden of repeated long travel for adjustments. With our method, over 80% of stimulator adjustments are completed during the 2- to 3-week inpatient stay, as compared with the many weeks to months that are required for initial programming on an outpatient basis. This may allow patients to realize the benefit of DBS sooner than if they were programmed entirely in the outpatient setting.

In our patients, most of the improvement in the FIM score was due to a large, statistically significant increase in the motor component. The functional improvement that we observed in our patients at discharge from fast-track rehabilitation and at 3-month follow-up was similar to the improvement noted at 3 months in 1 study and at least equivalent to the typical 6-month outcomes reported in the literature. The rapid tapering of medications also can often represent a substantial cost saving to the patient and their insurance carrier. For example, 60 tablets of Sinemet CR 25/100mg costs $61.35. Our average patient took 1084mg/d preoperatively ($331.29/mo) and 560mg/d postoperatively ($171.78/mo). For patients taking frequent doses of multiple medications, rapid tapering can thus have economic benefit. A cost-effectiveness analysis of our fast-track model could be of use to balance the cost of inpatient rehabilitation against the savings resulting from medication tapering.

Because Parkinson's disease frequently leads to a lifestyle of decreased physical activity, patients often present with muscle shortening and loss of joint range of motion (ROM), as well as varying degrees of deconditioning. The inpatient setting allows the physical therapist to tailor a stretching, ROM, and postural program to the needs of the patient. Ongoing gait and balance retraining occurs, and higher level gait and mobility skills that the patient may not have been able to manage prior to DBS can be undertaken. Occupational therapists are used to evaluate and treat the patients' functional loss in activities of daily living, and assist with community re-entry. Physical conditioning and endurance activities are included in both the inpatient program and home instructions. A specific exercise program is given for use after discharge, to maintain physical gains.

Speech and oral-motor symptoms are often less responsive to DBS. In these patients, speech therapists provide training to help the patient communicate more effectively. The speech therapist also examines the swallowing process, with the use of a modified barium swallow test in selected patients, to detect oral-motor problems and the risk of aspiration. Dietary modification to allow for easier food handling and to minimize the chances of aspiration is recommended if problems are found. The speech therapist also evaluates the cognitive aspects of language, and provides training to improve any deficits encountered. An audiologist is also available to screen hearing, and to make recommendations to improve auditory function.

Patients undergoing DBS go through cognitive testing as part of their initial evaluation. The neurobehavioral specialist of the treatment team re-evaluates cognitive function to assess pre- and postimplantation cognitive processing. The neurobehaviorist also remains available if any unexpected thought process or behavioral problems arise postoperatively during programming, because changes in certain stimulation parameters are associated with specific alterations in cognitive performance. We found that the cognitive component of the FIM score improved after DBS and fast-track rehabilitation. Although this change was relatively small (19.4%) compared with the motor improvement, it was statistically significant. The dynamics of family relationships may change following DBS, because patients realize a much greater degree of independence and autonomy. Psychologists provide counseling and training in coping and communication skills, and aid in the detection and treatment of any mood or affect changes. Changes in psychiatric symptoms have been noted after DBS, perhaps due to involvement of the limbic STN in mood disorders associated with Parkinson's disease. Preoperative psychologic screening and postoperative psychologic and psychiatric care are important, especially because many postoperative psychiatric problems may actually be related to emergence of previously existing disorders that had not been noted preoperatively. Although worsening of mood symptoms has been noted, antidepressant effects of DBS have been more commonly reported than depressant effects. DBS has also been shown to result in an improved health-related quality of life for Parkinson’s disease patients and showed a trend toward significant improvement (P=.15) in health-related quality of life over unilateral pallidotomy in a randomized study.

Study Limitations
There are several limitations of the present study. One weakness of this article is its retrospective nature, with all of the biases inherent in such a study design. Also, this initial report is intended only to serve as a description of our methods; we do not compare our results with a control group receiving usual care. The lack of a control group does not allow us to determine how much of the patients’ improvement is a result of our fast-track programming and rehabilitation protocol, and how much is simply a result of the DBS procedure itself. A randomized, controlled trial of fast-track programming and rehabilitation compared with usual care could provide stronger evidence for the efficacy of our method. Additionally, the inclusion of cost data in such a trial could provide the cost-effectiveness of the fast-track method. Stratifying patients into subgroups based on factors such as age, comorbidities, etc, was not performed in this study due to the relatively small study size and resulting small size of subgroups. We believe that post hoc analysis would not be statistically or clinically valid in this situation. We also did not analyze patients’ average stimulation parameters at various time points, because one point of this study is to show that most programming is done during the initial rehabilitation stay, as opposed to presenting our overall results with DBS for Parkinson’s disease. Finally, off-stimulation, off-medication UPDRS scores were not routinely obtained in our patients so as not to interfere with the intensive rehabilitation and programming protocol. Such scores would need to be included in a future study comparing our fast-track method with traditional programming methods.

Clinical Implications
Our fast-track, integrated inpatient rehabilitation and programming protocol, performed by a dedicated team, has several major benefits. First, the majority of initial programming can be accomplished over 2 to 3 weeks, instead of months. This study suggests that functional improvement is maximized after the inpatient stay and that there is little change noted at long-term follow-up. This expeditious programming may allow the patient to realize the benefits of DBS sooner than with traditional methods, although another, comparative study would need to be performed to prove this. Second, medications can be quickly tapered, resulting in cost savings to the patient and health system overall and reduction in medication side effects.
Both a retrospective study and a cost-effectiveness decision model have already provided evidence for overall cost savings from DBS. But a prospective randomized study to demonstrate the cost-effectiveness of DBS would be a valuable contribution to the literature. Third, physical performance can be optimized in the timeliest manner possible by combining rehabilitation services with DBS programming. Last, the patient receives close medical attention in the postoperative period. Greater attention can be given to concomitant medical and psychologic problems as well as to wound care. All of these benefits allow the Parkinson’s disease patient to address the myriad life changes that come with the rapid improvement in quality of life in a cohesive disease based fashion.

CONCLUSIONS
Our model of fast-track rehabilitation and programming after DBS for Parkinson’s disease allows for rapid programming and tapering of Parkinson’s medications. Concomitantly, patients’ physical performance can be optimized in a timely fashion. This protocol may represent a more efficient and efficacious method for postoperative DBS care.

References

Supplier
a. Medtronic Inc, 710 Medtronic Pkwy, Minneapolis, MN 55432.
Coordination Between Reaching and Grasping in Patients With Hemiparesis and Healthy Subjects

Paulette M. van Vliet, PhD, Martin R. Sheridan, PhD


Objective: To investigate the coordination of reach-to-grasp components in hemiparetic and healthy subjects. Design: Split-plot repeated-measures design with 3 factors (group, object size, movement speed).

Setting: Movement laboratory.

Participants: Twelve hemiparetic and 12 age-matched healthy subjects.

Interventions: Not applicable.

Main Outcome Measures: We used motion analysis to collect information on the kinematic variables of movement duration, peak velocity, peak deceleration, and maximum aperture, and the time of peak velocity, peak deceleration, and maximum aperture expressed as a percentage of movement duration during 32 reaching movements by each subject. We examined the coordination between the 2 components in 2 ways. First, we investigated the correlation between time of hand opening and start of hand transport, and between time of maximum aperture and time of peak deceleration. Second, we compared movements at preferred and fast speeds (manipulation of transport component) and to 2 different-sized cups (manipulation of grasp component).

Results: Both groups demonstrated a temporal coupling between grasp and transport components at the start of the reach and at the time of maximum aperture. Both groups increased the aperture of grasp for larger cups and increased the maximum grip aperture, and had a shorter deceleration phase for faster movements. The deceleration phase of the hemiparetic patients was longer than that of the healthy subjects, however, and the components were not as tightly coupled.

Conclusions: The hemiparetic patients, who had a moderate amount of functional recovery, were similar to healthy subjects in their ability to control reach-to-grasp components. Their performance was not as skilled, however.

Key Words: Arm; Hemiparesis; Physical therapy techniques; Rehabilitation; Stroke.

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Reach-to-grasp of objects is a key feature of normal upper-limb function. The kinematic analysis of these movements reveals at least 2 components. For a given movement, the hand follows a characteristic path and trajectory as it moves towards an object, described as the “transport” component (change over time of the position of the wrist marker), and the hand opens and closes on the object, described as the “grasp” component (change over time of the distance between the index finger and thumb markers).

Neurophysiologic evidence supports separate but interdependent visuomotor control channels for these 2 components.

Transport and grasp must be coordinated to ensure that the object is grasped successfully. There is evidence of an invariant temporal relation between the 2 components, where the start time of the opening of the hand is correlated with the start time of hand movement toward the object, and the time of maximum hand opening is correlated with the time of peak deceleration of the hand.

Further evidence of temporal interdependence is seen when 1 component adjusts in response to manipulations of the other component. For example, a faster transport results in an increased maximum grip aperture size. When grasping objects of smaller sizes, there is a proportionally longer deceleration phase and an increase in movement duration.

Moreover, performing an additional opening and closing of the grasp during the transport phase causes a longer movement duration, with a high correlation between peak velocity of the wrist and the second maximum grip aperture.

Analysis of the kinematics of reach-to-grasp in people with hemiparesis may help identify specific motor control deficits, with the findings serving as a basis for therapy. There have been, however, only a small number of kinematic studies of reach-to-grasp movements in hemiparetic patients. Those studies were primarily restricted to features other than temporal coordination of grasp and transport components, and many were concentrated on movements of the less affected arm.

In the hand contralateral to the lesion, peak velocity is lower and more variable than in control subjects, but occurs within the first 50% of the movement duration. Specifically reported on temporal coordination between grasp and transport and found this to be largely preserved, with the percentage time of maximum aperture and maximum aperture size not significantly different from that of control subjects, and with maximum aperture occurring in the deceleration phase.

Two other studies found that both transport and grasp showed deficits in accuracy and that grasp showed deficits in efficiency (directness of movement to target).

Previous studies of the hand contralateral to the lesion did not specifically assess the invariant temporal relation between transport and grasp at the start of the reach and at the time of peak deceleration, nor did they assess temporal interdependence when 1 component adjusts in response to manipulations of the other component. Therefore, our aim was to investigate whether a group of patients with hemiparetic arm movements...
had (1) temporal coupling of transport and grasp at the start of movement and at the time of peak deceleration, and (2) could adjust for manipulation of grasp on transport and vice versa, compared with age-matched controls. In contrast to Michaelsen et al,19 we analyzed movements of the hemiparetic arm in an earlier stage of recovery in order to better inform rehabilitation strategies for these patients. We used a task similar to those performed in every day activities because experimental constraints such as the selection of objects and the goal of the task may determine neural patterning.9 Our study provides a more detailed understanding of the coordination of grasp and transport in patients with stroke than has been previously presented. Given that the basic parameters of reach-to-grasp can be similar to that of healthy subjects, we hypothesized that the coordination between the 2 components would, to some extent, be preserved.

**METHODS**

**Participants**

Twelve patients with hemiparesis were recruited consecutively from 1 hospital and were selected according to their functional ability and stroke classification. Diagnosis was confirmed by computed tomography scan when possible (table 1). Inclusion criteria were: (1) a score between 5 and 12 on the arm section of the Rivermead Motor Assessment22 (a score of 5 requires the patient to “reach forward, pick up a large ball with both hands and place it down again”); (2) the ability to reach and grasp a cup containing water and attempt to take a drink; and (3) a middle cerebral artery infarct (classified as partial anterior circulation infarct or total anterior circulation infarct on the Bamford classification for cerebral infarction23). These patients commonly have arm impairments and constitute a large percentage of the patients who present for rehabilitation. The patients were 1 to 6 months poststroke and had sensory problems, spatial awareness problems, and mild increased muscle tone. There were 8 patients with nondominant lesions and 4 with dominant lesions. Table 2 lists their additional characteristics.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Scan Result</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Right parietal infarct</td>
</tr>
<tr>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>3</td>
<td>Right parietal infarct</td>
</tr>
<tr>
<td>4</td>
<td>Right frontal region infarct and ischemia in frontoparietal region</td>
</tr>
<tr>
<td>5</td>
<td>Left infarct in anterior-ganglio capsular region, corona radiata, and deep white matter frontoparietal regions</td>
</tr>
<tr>
<td>6</td>
<td>*</td>
</tr>
<tr>
<td>7</td>
<td>*</td>
</tr>
<tr>
<td>8</td>
<td>Right posterior frontal lobe and temporoparietal infarct</td>
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<tr>
<td>9</td>
<td>Right parietal infarct</td>
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<tr>
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</tr>
<tr>
<td>12</td>
<td>Left posterior cerebral artery infarct</td>
</tr>
</tbody>
</table>

*Scan was not performed.

Table 1: Computed Tomography Scan Results for the Stroke Group

<table>
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<th>Scan Result</th>
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<tbody>
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</tr>
<tr>
<td>12</td>
<td>Left posterior cerebral artery infarct</td>
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</tbody>
</table>

*Scan was not performed.

Table 2: Patient Characteristics

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<tr>
<th>Subject</th>
<th>Weeks since Stroke</th>
<th>Side of Lesion (hemisphere)</th>
<th>Bamford Classification</th>
<th>Dominant Hand</th>
<th>Hemianopia</th>
<th>Arm Function</th>
<th>Muscle Tone</th>
<th>Sensation</th>
<th>Spatial Ability</th>
<th>Pain</th>
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<tr>
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<td>0</td>
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<tr>
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<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3**</td>
</tr>
<tr>
<td>6</td>
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<td>TACI</td>
<td>Yes</td>
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<td>1</td>
<td>2</td>
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<td>0</td>
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<tr>
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<td>0</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>Left</td>
<td>PACI</td>
<td>No</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>2</td>
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<tr>
<td>9</td>
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<td>Left</td>
<td>TACI</td>
<td>Yes</td>
<td>12</td>
<td>2</td>
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<td>0</td>
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<td>Left</td>
<td>TACI</td>
<td>Yes</td>
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<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

Abbreviations: PACI, partial anterior circulation infarct; TACI, total anterior circulation infarct; UNK, unknown.

Muscle tone: Modified Ashworth Scale. Score range: 0, no increase in muscle tone; 4, affected part rigid in flexion or extension.

Arm function: Rivermead Motor Assessment. Score range: 0, no increase in muscle tone; 4, affected part rigid in flexion or extension.

Sensation: 2-Point. Score range: 0, no sensation; 2, normal (light touch, pressure); 3, normal (kinesthesis).

Spatial ability: Rey figure copy. Score range: 31–36.

Pain during test measurement: present pain intensity index of McGill Pain Questionnaire. Score range: 0, no pain; 5, excruciating.

Neglect (star cancellation): normal scoring range, 51–54; spatial ability (Rey figure copy): normal scoring range, 31–36.

Abbreviation: 2-Point Finger Press.
healthy subjects. Therefore, we recruited 12 healthy control subjects and matched them with the hemiparetic patients for age and sex, and according to where their dominant or non-dominant hand was used in the experiment. The 4 healthy men and 8 healthy women were within normative range (ie, normative mean ± 2 standard deviations [SDs]) on the Ten Hole Peg test.28 Their mean age was 64.8 years and the mean age of the 5 men and 8 women in the hemiparetic group was 66.9 years. Informed consent was obtained from all subjects according to the Declaration of Helsinki and the Nottingham City Hospital Ethics Committee approved the study.

Research Protocol

Subjects participated in 4 conditions aimed at testing the effect of a manipulation of the transport component on grasp and vice versa. Conditions 1 and 2 were reaches to large and small cups, respectively, at the subject’s preferred speed. Conditions 3 and 4 were reaches to the large and small cups, respectively, at faster speeds. Subjects reached for the 2 different-sized cups while seated on a height-adjustable chair, with their front waist touching the table edge. Movement was recorded in 3 dimensions with a MacReflex motion analysis system.27,28 The calibrated workspace measured 90cm long by 60cm wide and 125cm high. Two cameras with a charge-coupled device, infrared flash, and automatic gain control were positioned above the subject, one in front and one above the shoulder. The cameras recorded the movement of reflective markers attached to the wrist (radial styloid process), the lateral surface of the index finger (between the distal interphalangeal joint of the finger and the finger nail), and the medial surface of the thumb (between the distal interphalangeal joint of the thumb and the thumb nail). The markers were sampled at 50Hz. The mean static and dynamic constant spatial errors for this experimental set-up were calculated28 as .58 and .88mm, respectively. The variable error for the dynamic test was .21mm.

Reaches were made at 2 different speeds to cups of 2 different dimensions, placed at a constant distance (20cm anterior to the starting position of the hand). Subjects grasped either a large cup half filled with water (height, 11cm; top diameter, 7cm; weight, .17kg) or a small cup, also half filled with water (height, 7cm; top diameter, 6cm; weight, .07kg). Both cups tapered to a slightly narrower base (large diameter, 5.2cm; small diameter 4.7cm). Although the weights of the 2 cups were different, the weight of an object affects only the length of time the hand is in contact with the cup and does not affect the transport component.28 Subjects were instructed to grasp the upper portion of the cups so that the markers could be clearly seen by the cameras.

Data Acquisition and Analysis

The starting position specified that the finger and thumb tips were lightly touching, the forearm was in mid-pronation, the elbow was at approximately 100° flexion, and the wrist rested on a marker 20cm posterior to the cup that indicated the start position. The other arm rested in the subject’s lap. In all 4 conditions, subjects were instructed to “Reach forward, pick up the cup and have a sip of water, then place the cup back on the table. Use your whole hand to grasp the cup, if possible.” For conditions 3 and 4, an additional instruction was given: “Reach as fast as you can without knocking over the cup or spilling the water.” The computer emitted a tone as a signal for the subject to move. Subjects naturally used a whole hand grasp for both cup sizes, although some subjects did not contact the small cup with all 4 fingers.

Before data collection began, subjects practiced grasping both the small and large cups between 3 and 5 times, at their preferred speeds. There was a 5-minute rest between practice and the start of data collection. Eight trials were performed in each condition, for a total of 32. Trials at preferred reach-to-grasp speeds were performed before the 2 faster speed conditions in order to preserve 2 distinct reach-to-grasp speeds. To reduce fatigue and practice effects, trials in conditions 1 and 2 were randomized, and a separate randomization was done for conditions 3 and 4. To ensure that fatigue did not prevent hemiparetic patients from performing fast movements, a further 5-minute rest was permitted after conditions 1 and 2 were completed. Each of the 12 hemiparetic patients performed a different random order of trials and the random order for each healthy subject was matched to that of the appropriate hemiparetic subject.

For each recorded movement, the positions of the markers were identified manually in an editing process for 3 consecutive frames, after which the markers were automatically tracked through their trajectories using MacReflex software.4 Automatic tracking was observed onscreen and manual tracking was occasionally used when the software indicated that a marker position did not equate with the approximate position predicted by the program tracking the marker. Two-dimensional marker positions were then converted into 3-dimensional coordinates using MacReflex software. In cases where markers were invisible to the cameras, a cubic spline algorithm was applied to predict the missing values. Data were filtered using a Bartlett filter with 39 coefficients and with a cutoff frequency of 10Hz. The trajectory, velocity, and acceleration of the wrist marker were used to describe the transport component of the reach. Movement onset was designated as being the time at which the 3-dimensional velocity exceeded 25mm/s, using a Gaussian-weighted average (average velocity value was calculated by adding the velocity value at 1 frame to the values at the 2 frames before and after that frame and dividing the total by 5). The end of transport was defined as the first time the maximum distance of the wrist marker, in the combined x,y (horizontal) plane, was achieved. The z plane was not included because the task included bringing the cup to the mouth after grasp. Other determinants for the end of transport that have been used in investigations of normal reach-to-grasp, such as the time at which the distance between the thumb and finger markers becomes constant,9 or the time at which the velocity reaches a chosen low velocity or zero value,10 were found to be inappropriate for determining the functional abilities of the patients with hemiparesis in this study. Patients were occasionally unsuccessful at grasping the cup, and it is common for hemiparetic patients to reach a low or zero velocity during the reach, as their trajectory can occur in a stepwise fashion.17 Movement duration refers to the time between onset and end of transport. The time to wrist peak velocity and wrist peak deceleration were determined and expressed in absolute and proportional (ie, as a percentage of movement duration) terms.

The trajectory of the thumb and finger markers described the grasp component. The start of hand opening was defined as the time at which the planar (3-dimensional) distance between the thumb and finger marker exceeded .58mm (static spatial error), using a Gaussian-weighted average (using 5 values as for movement onset). Maximum grip aperture was defined as the maximum planar distance between the thumb and finger marker. The time to maximum grip aperture was determined and expressed in absolute and proportional terms.

To answer the first research question concerning whether there is a temporal relation between transport and grasp, we used Pearson product-moment correlation coefficients to assess whether the start of hand opening was correlated with the start.
of hand transport, and whether the absolute time of peak deceleration was correlated with the absolute time of maximum grip aperture. Within-group correlation coefficients were calculated separately for each condition. Thus, 8 coefficients (2 groups by 4 conditions) were calculated to examine the correlation at the start of the movement. Similarly, we calculated 8 coefficients to test the correlation at the time of maximum grip aperture. To test significance of $r$ values and whether correlations differed between the stroke and control groups, $r$ values were transformed to $z$ values and the significance of the difference between $z$ values tested according to Fisher, as reported by Snedecor and Cochran.30

To answer the second research question about interdependence between transport and grasp, we made a direct comparison between patients and age-matched controls using a split-plot repeated-measures analysis of variance (ANOVA) model with 1 between-subject factor (group: stroke, control) and 2 within-subject factors (speed, cup size). The kinematic variables inserted into this analysis were movement duration, peak velocity, maximum aperture, and time of peak velocity, peak deceleration, and maximum grip aperture, all expressed as a percentage of movement duration. Using the same analysis, we compared variability of the movements, indicated by the coefficient of variation (SD divided by the mean of a set of 8 trials) of maximum grip aperture, percentage time to peak velocity, percentage time of peak deceleration, and percentage time of maximum grip aperture. We set significance levels of $P < .05$ for all statistical comparisons.

In addition, we performed specific tests on the hemiparetic group data to assess the effect of neglect, spatial perception, pain, and increased muscle tone on coordination of reach-to-grasp. For each clinical variable, we divided patients into 2 groups according to whether they demonstrated the particular clinical deficit. Then, we performed a split plot with repeated-measures ANOVAs on the kinematic variables with the between-subject factor being the presence or absence of the clinical deficit (neglect, spatial perception, pain, muscle tone).

**RESULTS**

Relation Between Grasp and Transport at the Start of the Reach

In the healthy group, start time of aperture and start time of transport were significantly correlated in all conditions (condition 1: large, preferred $r = .80$; condition 2: small, preferred $r = .83$; condition 3: large, fast $r = .88$; condition 4: small, fast $r = .91$; all $P < .05$). In the stroke group, start time of aperture and start time of transport also correlated significantly in all conditions (large, preferred $r = .31$; small, preferred $r = .78$; large, fast $r = .69$; small, fast $r = .86$, all $P < .05$).

In the large cup conditions, the 2 events were significantly more highly correlated in healthy subjects than in stroke subjects for both fast and preferred speeds ($P < .05$). There was no difference in the correlations between groups in the small cup conditions.

Relation Between Grasp and Transport at the Time of Maximum Grip Aperture

The time of maximum aperture and time of peak deceleration correlated significantly in all conditions for both groups: healthy subjects (large, preferred $r = .30$; small, preferred $r = .57$; large, fast $r = .35$; small, fast $r = .68$; all $P < .05$); in the stroke group (large, preferred $r = .33$; small, preferred $r = .56$; large, fast $r = .71$; small, fast $r = .49$; all $P < .05$). In the fast conditions, the 2 events were more highly correlated in stroke subjects with the fast, large condition and in control subjects with the small, fast condition. There was no difference in correlations between groups in the slow conditions.

Comparison Among Groups, Speed, and Size Conditions

Stroke subjects were slower than healthy subjects (F1,22 = 29.94, $P < .01$). As expected, movement duration was shorter for fast movements (F1,22 = 94.58, $P < .01$). There were significant interactions for group by speed (F1,22 = 14.52, $P < .01$) and group by size (F1,22 = 7.53, $P < .01$), with larger differences between preferred and fast conditions in movement duration for stroke subjects compared with healthy subjects, and between large and small cups (movement duration was longer with the large cup).

Peak velocity was higher in healthy subjects (F1,22 = 56.98, $P < .01$) and higher for fast movements (F1,22 = 172.25, $P < .01$), corresponding to the results for movement duration. There was a significant interaction for group by speed (F1,22 = 9.23, $P < .01$), with larger differences for healthy subjects compared with stroke subjects in peak velocity between preferred and fast conditions.

Peak velocity and peak deceleration occurred earlier in the movement for stroke subjects than for healthy subjects (percentage time of peak velocity [TPV], F1,22 = 25.13, $P < .01$; percentage time of peak deceleration [TPD], F1,22 = 23.82, $P < .01$). Faster movements had a later percentage time of TPV (F1,22 = 32.82, $P < .01$) and percentage time of TPD (F1,22 = 23.08, $P < .01$). There were significant interactions for group by speed for percentage time of TPV (F1,22 = 4.35, $P < .01$) and percentage time of TPD (F1,22 = 6.18, $P < .01$), with larger differences for healthy subjects compared with stroke subjects between preferred and fast conditions.

There was no significant difference in maximum aperture size between the groups. As expected, the maximum aperture was larger for the large cup (F1,22 = 66.46, $P < .01$). Maximum aperture was larger for faster movements (F1,22 = 12.99, $P < .01$). Time of maximum aperture (TMA) was later for faster movements (F1,22 = 5.12, $P < .01$). There was a significant group by speed interaction (F1,22 = 11.41, $P < .01$), with larger differences for healthy subjects compared with stroke subjects in percentage time of TMA between preferred and fast conditions. There was a significant speed by size interaction (F1,22 = 4.16, $P < .01$), with larger differences in percentage time of TMA for the large compared with the small cup in between and preferred and fast conditions. There was also a significant group by speed by size interaction (F1,22 = 5.79, $P < .01$); for the small cup, percentage time of TMA was earlier for stroke subjects in the comparison between preferred and fast conditions, whereas it was later for healthy subjects.

**Table 3** shows the means and SDs of all kinematic parameters. Figure 1 shows sample velocity profiles from 1 stroke subject and 1 healthy subject.

Regarding variability (described by coefficients of variation), stroke subjects were significantly more variable than healthy subjects for percentage time of TPV (F1,22 = 25.33, $P < .01$), percentage time of TPD (F1,22 = 44.16, $P < .01$), percentage time of TMA (F1,22 = 16.46, $P < .01$), and maximum aperture (F1,22 = 31.68, $P < .01$). For faster movements, variability of percentage time of TPV was significantly greater for stroke subjects compared with those at preferred speeds (F1,22 = 8.32, $P < .01$), but there were no other effects of condition.

**Additional tests assessing effects of clinical parameters.** In the analysis of the effect of neglect, pain, muscle tone, and spatial loss, there were no significant differences between groups in any of the kinematic variables, and only 1 significant
interaction. This was a group by speed in movement duration between patients with or without spatial loss ($F_{1,22}=5.16, P<.01$), showing that subjects with spatial loss move faster in the fast condition than those without spatial loss.

**DISCUSSION**

**Relation Between Reach-to-Grasp Components**

The hemiparetic patients demonstrated a temporal coupling between grasp and transport resembling that of healthy subjects, because there was a significant correlation between start of aperture and start of transport and between time of maximum aperture and time of peak deceleration in all subjects. From the results, it would appear that compared with controls, correlations are lower at the start of the movement for stroke subjects when grasping the larger cup (at both speeds). Also, at the time of maximum aperture, their correlations were lower than those of the controls when grasping the small cup at a fast speed. So, although the stroke subjects behave similarly, the events are not so tightly coupled in stroke subjects as they are in controls.

**Interdependence Between the 2 Components**

**Effects of speed.** In response to faster movements, both healthy subjects and hemiparetic patients increased the maximum grip aperture. While temporal variability can decrease with faster movements,11 spatial variability can increase because there is less time to make corrections based on visual feedback.11 Patients with hemiparesis opened slightly wider in fast movements than did healthy subjects, which could be a compensation for their increased spatial variability above what occurs in healthy subjects. It is clinically significant that the hemiparetic patients had an increase in maximum grip aperture because it is a common clinical observation that they have difficulty in opening the hand12 and because Colebatch and Gandevia13 reported that the extensors of the fingers and thumb were weaker than the corresponding flexors. This aspect of the relation between grasp and transport has therefore been relatively unaffected, or has recovered well, in this group of patients.

The timing of transport events in faster movements was different than that of healthy subjects. In the hemiparetic group, peak velocity, peak deceleration, and maximum aperture occurred earlier. Therefore, the hemiparetic group spent relatively more time in the phase after peak deceleration than did the controls. Because this is the period where feedback is more likely to be used to adjust the movement, it may be that hemiparetic patients need to use this feedback control phase more than healthy subjects to compensate for increased movement variability, and thus improve accuracy. This contrasts with the results of Farne et al33 for the ipsilateral arm, where the deceleration phase was shorter than for control subjects, indicating that the motor control problems of contralateral and ipsilateral arms are not identical.

Both groups had later percentage times of TPV and TPD, and thus a shorter deceleration phase, in the faster movements. This response to the faster condition was less marked in the stroke subjects than in the healthy subjects. It is likely that the later percentage times of TPV and TPD reflect the fact that a greater part of the movement is centrally programmed (ballistic) and a smaller amount is used for adjustment to meet the demand of the increased speed. If this were true, it would seem that the stroke subjects show more reliance on the feedback control phase as speed increases than do healthy subjects. Both groups also showed a later percentage time of TMA in the faster movements. This response to the faster condition was less marked in the stroke subjects than in the healthy subjects. The later percentage time of TMA implies that the grasp phase of the movement was delayed to maintain coordination with the delayed percentage times of TPV and TPD in the transport phase.

**Effect of cup size.** It is usual for the maximum grip aperture to increase in size according to the size of the object.14 The hemiparetic group’s ability to adjust the aperture to the sizes of

| Table 3: Peak Deceleration and Maximum Grip Aperture Are Absolute Times From Movement Onset |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Duration and Component          | Subjects        | Large/Preferred | Small/Preferred | Large/Fast      |
| Movement duration (s)           | Healthy         | 0.97±0.14       | 0.96±0.12       | 0.59±0.50       | 0.61±0.50       |
| Stroke                          | 2.55±0.99       | 2.34±0.83       | 1.64±0.76       | 1.56±0.65       |
| Transport component             |                 |                 |                 |                 |
| Start time of transport (s)     | Healthy         | 0.37±0.50       | 0.37±0.60       | 0.31±0.50       | 0.31±0.70       |
| Stroke                          | 0.55±0.28       | 0.60±0.32       | 0.39±0.12       | 0.44±0.18       |
| Peak velocity (mm/s)            | Healthy         | 469±67          | 467±77          | 639±89          | 637±92          |
| Stroke                          | 247±86          | 244±81          | 354±92          | 349±95          |
| Time to peak velocity (%)       | Healthy         | 36±4            | 37±3            | 45±3            | 46±3            |
| Stroke                          | 28±9            | 30±8            | 32±8            | 34±8            |
| Time to peak deceleration (s)   | Healthy         | 0.61±0.80       | 0.59±0.90       | 0.41±0.40       | 0.41±0.50       |
| Stroke                          | 1.14±0.49       | 1.01±0.42       | 0.74±0.31       | 0.71±0.27       |
| Time to peak deceleration (%)   | Healthy         | 54±5            | 56±4            | 67±6            | 66±5            |
| Stroke                          | 46±11           | 44±11           | 49±12           | 49±11           |

**Grasp component**

| Start time of aperture (s)      | Healthy         | 0.42±0.60       | 0.4±0.70        | 0.32±0.50       | 0.33±0.80       |
| Stroke                          | 0.48±0.15       | 0.6±0.3         | 0.45±0.32       | 0.49±0.23       |
| Maximum aperture size (mm)     | Healthy         | 97.9±6.0        | 94.8±7.0        | 101±5.0         | 97.2±5.0        |
| Stroke                          | 102.1±9.0       | 97.6±7.0        | 103.9±9.0       | 101.5±9.0       |
| Time to maximum aperture (s)   | Healthy         | 0.61±0.80       | 0.59±0.90       | 0.41±0.40       | 0.41±0.50       |
| Stroke                          | 1.63±0.69       | 1.61±0.66       | 1.09±0.54       | 1.02±0.44       |
| Time of maximum aperture (%)   | Healthy         | 63±5            | 62±5            | 70±4            | 69±5            |
| Stroke                          | 65±13           | 68±12           | 66±7            | 64±8            |

**NOTE.** Values are mean ± SD.
The 2 cups that were less than 1 cm different in diameter indicates an ability to make subtle adjustments in grip aperture. Further work is needed to determine if this ability is present with a larger difference in the diameter of an object.

The difference in movement duration between cup sizes reached significance in the hemiparetic group but not in the healthy group. The smaller cup would be expected to produce a longer movement duration in the healthy group, as was found in previous studies. The healthy subjects, however, did not show a difference in movement duration for cup size. This may be attributed to the fact that the cups differed more in height than width, because Bootma et al. demonstrated that width is a more influential factor in determining the length of the deceleration phase. This may be attributed to the fact that the cups differed more in height than width, because Bootma et al. demonstrated that width is a more influential factor in determining the length of the deceleration phase. Another reason could be that the difference in cup width was relatively small compared with the size differences in previous studies. Interestingly, the stroke subjects did show a difference in movement duration for cup size, but in the opposite direction to that expected of healthy subjects, that is, the duration was longer for the larger cup. We hypothesize that the larger cup is more difficult to grasp for stroke subjects because of their weak finger extensors, and therefore more time is needed to accomplish the larger grasp. The large cup induced a more marked delay in percentage time of TMA with faster movements, and this was again more marked with healthy subjects than with stroke subjects.

In terms of the clinical significance of the statistically significant results, the differences across conditions for stroke subjects were generally smaller than that for normative percentage of all subjects (percentage times of TPA, TPD, and TMA). This may indicate that adjustments by stroke subjects are not as distinct and need to be improved to reach normal levels.

It is interesting to compare these results with those of Binkofski et al., who found that patients with good recovery and with lesions particularly involving the anterior bank of the intraparietal sulcus, had poor control of grip aperture, including poor preshaping in the acceleration phase, increased aperture in deceleration phase, increased variability of grip aperture, and a later percentage time of maximum grip aperture, compared with controls. In contrast, our group of patients with paretic movements, and with more generally defined lesions of the parietal cortex, had the necessary degree of control to adjust grasp for both object size and movement speed. It is possible that our patients did not have lesions of the anterior bank of the intraparietal sulcus, because the ability to adjust for size and speed implies an ability to perform preshaping in acceleration and deceleration phases and adjust the time of maximum grip aperture.

The neuronal pathways involved in planning and controlling reach-to-grasp are only partially understood, but the posterior parietal cortex, area 6 of the premotor cortex, prefrontal cortex, and the cerebellum are involved. These neuronal pathways were apparently functioning to some extent in our patient group.

**Study Limitations**

A limitation of our study was that the number of repetitions the patients could perform was relatively small compared with the numbers in studies of normal motor control. Also, had we had more exact information from magnetic resonance imaging of the site and size of the lesions, we would have had a greater understanding of the coordination problems of different patients. Future research should include larger sample sizes of homogenous patients so that generalizability can be increased. The coordination patterns of patients with different areas of brain damage need to be compared to see whether their problems are the same or different.

**CONCLUSIONS**

The performance of this group of patients with a moderate amount of functional recovery showed some similarities to healthy subjects in regard to having the ability to respond to changes in speed and cup size, and in temporal coupling of grasp and transport. As were healthy subjects, they were able to increase maximum aperture for faster movements and had a shorter deceleration phase and time after maximum aperture for faster movements. They could also increase maximum aperture size for a larger object. Compared with healthy subjects, however, their movements were slower and the deceleration phase was longer. The shorter deceleration phase and time after maximum aperture for faster movements were not as marked as that of healthy subjects. Their movement duration increased with the larger cup and their movements were more variable. Also, the temporal coordination of grasp and transport was not as tightly coupled.

Our results suggest several therapy applications. First, patients should practice tasks that involve the use of grasp and transport together, where possible, to necessitate activation of temporally linked central commands for arm and hand.

Second, because the start of transport and grasp is not as tightly coupled as it is in controls, practice could concentrate on planning and executing the 2 components together and not leaving the opening of the hand until it nears the object.

To further develop the ability to time grasp and transport components appropriately in faster movements, reach-to-grasp...
could be practiced at different speeds and with different-sized objects, with an emphasis on achieving grasp of larger objects, which appears to be more difficult for hemiparetic patients. These suggestions are more specific than those usually described in conventional physiotherapy, being targeted at the timing of reach-to-grasp in particular, and so they have the potential to improve the effectiveness of training of this aspect of upper-limb function. Further research is required to examine whether this potential can be realized.

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References

Supplier
a. Qualisys AB, Packhusgatan 6, S-411 13 Gothenburg, Sweden.
Effects of Robot-Aided Bilateral Force-Induced Isokinetic Arm Training Combined With Conventional Rehabilitation on Arm Motor Function in Patients With Chronic Stroke

Jyh-Jong Chang, PhD, Wen-Lin Tung, MS, Wen-Lan Wu, PhD, Mao-Hsiung Huang, MD, Fong-Chin Su, PhD


Objective: To analyze the effects of conventional rehabilitation combined with bilateral force-induced isokinetic arm movement training on paretic upper-limb motor recovery in patients with chronic stroke.

Design: Single-cohort, pre- and postretention design.

Setting: Rehabilitation department at a medical university.

Participants: Twenty subjects who had unilateral strokes at least 6 months before enrolling in the study.

Intervention: A training program (40min/session, 3 sessions/wk for 8wk) consisting of 10 minutes of conventional rehabilitation and 30 minutes of robot-aided, bilateral force-induced, isokinetic arm movement training to improve paretic upper-limb motor function.

Main Outcome Measures: The interval of pretest, post-test, and retention test was set at 8 weeks. Clinical arm motor function (Fugl-Meyer Assessment [FMA], upper-limb motor function, Frenchay Arm Test, Modified Ashworth Scale), paretic upper-limb strength (grip strength, arm push and pull strength), and reaching kinematics analysis (peak velocity, percentage of time to peak velocity, movement time, normalized jerk score) were used as outcome measures.

Results: After comparing the sets of scores, we found that the post-test and retention test in arm motor function significantly improved in terms of grip (P < .009), push (P < .001), and pull (P < .001) strengths, and FMA upper-limb scale (P < .001). Reaching kinematics significantly improved in terms of movement time (P < .015), peak velocity (P < .035), percentage of time to peak velocity (P < .004), and normalized jerk score (P < .008). Improvement in reaching ability was not sustained in the retention test.

Conclusions: Preliminary results showed that conventional rehabilitation combined with robot-aided, bilateral force-induced, isokinetic arm training might enhance the recovery of strength and motor control ability in the paretic upper limb of patients with chronic stroke.

It is estimated that upper-extremity functional recovery is achieved by 79% of acute stroke patients with mild paresis but by only 18% of patients with severe paresis. Traditionally, stroke rehabilitation has been emphasized during the first 3 months after onset, in accordance with the natural history studies of stroke recovery that show a plateau after 3 months. Recently, the paradigms for stroke rehabilitation and the period for possible upper-extremity motor recovery has been challenged. Studies in neuroscience have revealed that cortical plasticity is a process that can last for several months. Brain imaging, such as functional magnetic resonance imaging, has shown cortical reorganization in patients with complete or partial upper-limb recovery. These studies show activation not only of the contralateral but also of the ipsilateral sensorimotor cortex and other cortical regions such as the premotor areas, supplementary motor area, and parietal cortex, which suggests the involvement of a widespread network in the recovery of motor function.

A long-term alteration in brain function or cortical reorganization is associated with therapy-induced improvement in the rehabilitation of arm movement after neurologic injury. Intervention, which involves massed and sustained practice of functional arm movement, may produce a massive use-dependent cortical reorganization that will provide the basis for a long-term effect of the treatment. Results of neuroscience research into brain reorganization and motor recovery may encourage rehabilitation practitioners to develop effective new strategies for the restoration of upper-arm function after stroke or brain lesion.

Traditionally, bilateral movements are encouraged to increase body symmetry and decrease abnormal tone in the early stages of stroke rehabilitation. Recently, several studies reported that repetitive bilateral arm training is effective in arm and hand motor recovery in stroke patients. It is assumed that bilateral arm training may target facilitation of the affected hemisphere via both indirect and direct corticospinal pathways, and by triggering interhemispheric disinhibition. One study, however, found that short-term bilateral training after unilateral training may have limited effectiveness in enhancing upper-limb motor performance in people with acute and chronic stroke.

In another study of stroke patients, strength was impaired bilaterally but more so on the side contralateral to the brain lesion. Arm weakness in the affected arm of stroke patients is considered a motor control problem involving disorganization of motor output. Research suggests that disorganization factors such as a decrease in the number of motor unit activations, firing rate of motor units, and impairment of motor unit syn-
chronization, could be eliminated by strength training.\textsuperscript{17,18} Thus, strength training is a critical component of any rehabilitation program aimed at regaining upper-limb functional (skillful) movement. Additionally, strength deficits will decrease performance of hand-to-mouth maneuvers, and loss of strength is a more significant contributor to disability in stroke than is loss of dexterity.\textsuperscript{19-21} These data attest to weakness (lack of strength) as a factor that should be considered in enhancing the motor performance of patients with stroke.\textsuperscript{22} Stein et al\textsuperscript{23} reported that robot-aided therapy with active-assisted exercises may be as effective as progressive resistive exercise in increasing force generation in the impaired upper limb after stroke. Bourbonnais et al\textsuperscript{24} also showed that force-feedback treatment was not effective in increasing grip strength in patients with chronic stroke. Thus, more studies are needed to identify the most effective training programs for increasing paretic arm strength in stroke patients.

Robot-assisted motor rehabilitation has rapidly developed since the 1990s.\textsuperscript{25,26} MIT-Manus and the mirror-image motion enabler are sophisticated robot devices for training of arm recovery in stroke rehabilitation. Results from clinical trials of robot-aided therapy show that proximal arm strength and motor function improved after robot-aided training.\textsuperscript{26-27} It is believed that robot-aided therapy and the bilateral approach to arm rehabilitation may offer a patient more intensive practice opportunities without increasing the time the treating therapist spends in supervision. For example, Hesse et al\textsuperscript{30} reported severely affected stroke patients (in the subacute stage) regained upper-limb motor control and power after training with a computerized arm trainer.

Bilateral symmetric push and pull movements with resistance can be used to simulate sanding activity, which is among the popular therapeutic activities in early rehabilitation. Apart from this, resistance movements performed with a slow and constant velocity may not provoke the stretch reflex during exercise. Studies\textsuperscript{31,32} have shown isokinetic strength training may improve paretic lower-limb function in stroke patients. Few studies, however, have evaluated the effect of isokinetic strength training on paretic upper-limb recovery. For this study, we hypothesized that chronic stroke patients would benefit from affected upper-limb motor training if we included in the conventional rehabilitation program a robot-aided device to provide bilateral symmetric upper-limb movement and isokinetic strengthening.

**METHODS**

**Participants**

We recruited 20 subjects (12 men, 8 women) from the outpatient rehabilitation service to participate in this study. Eighteen subjects were right-handed. The patients were between ages 36 to 80 years (mean ± standard deviation [SD], 57.1±14.0y) and had unilateral lesions (cortical, n=14; subcortical, n=6; left hemisphere, n=9; right hemisphere, n=11) identified by neuroimaging done at least 6 months before the pretest (mean, 35.4±36.6mo). The subjects’ Fugl-Meyer Assessment (FMA) scores for upper-limb motor function\textsuperscript{33} ranged from 6 to 55. Criteria for inclusion included: (1) no specific perceptual-cognitive dysfunction that could limit comprehension of the experimental task; (2) no severe concurrent medical problems such as shoulder pain and orthopedic conditions affecting arm movements; (3) able to exert push and pull forces greater than .98N with the paretic upper limb; and (4) no uncontrolled cardiopulmonary diseases. All subjects gave their informed consent and our institutional review board approved all study procedures.

**Instrument and Intervention**

We used a simple robot-aided device called the bilateral force-induced isokinetic arm movement trainer (BFIAMT) in the study. The device provides 4 different treatment modes: bilateral passive, bilateral active-passive, bilateral reciprocal, and bilateral symmetric arm movement. The BFIAMT has the following components: 1 control panel system, 2 load cells, 2 servomotors, 2 roller guides, 2 cone-shaped handles, and 2 forearm troughs (fig 1).

Following Mudie and Matyas’s suggestion for arm movement training,\textsuperscript{12} we used the bilateral symmetric arm movement treatment mode to train the affected and unaffected upper...
 limbs in this study. This mode can simulate symmetric bilateral sanding activity and allows the subject to practice a bilateral symmetric push (shoulder flexion and elbow extension) and pull (shoulder extension and elbow flexion) movement at a preset constant velocity. When the bilaterally exerted push and pull forces (detected by 2 load cells in the device) are concurrently greater than the preset demanded forces for the affected and unaffected upper limbs, the control system drives the servomotor and lets the 2 cone-shaped handles move in a symmetrical and smooth manner. Accordingly, the resistances of both upper limbs would be equal to the forces exerted by both of the subject’s limbs. If any forces exerted by the upper limb cannot reach the preset demanded force criterion, the servomotor stops and no movement occurs. The moving speed of the cone-shaped handles can be set beforehand to a subject’s preferred pace. This mechanism allows a subject with moderate to mild upper-limb impairments to perform symmetric resistive isokinetic push and pull movements bilaterally. In addition, the mechanism can help a subject with severe upper-limb impairment perform smooth isokinetic push and pull movements bilaterally. The device can also be used to assess unilateral or bilateral isometric upper-limb push-pull forces by setting the movement velocity to zero.

Subjects participated in 24, forty-minute treatment sessions over an 8-week period. A treatment session was in 2 parts. In part 1 (30min) subjects completed 3 consecutive sets of 20 repetitions of bilateral symmetric arm push and pull movements with the BFIAMT. A subject’s isometric maximal arm push and pull strength in both the affected and unaffected upper limbs were identified before treatment. The preset demanded forces for the 3 sets were 10%, 20%, and 10% of maximal push and pull forces of the affected and unaffected arms. Additionally, subjects were instructed to perform bilateral symmetric push and pull movements at a comfortable cycling pace; the most preferred cycling frequency was 0.1Hz. During treatment, subjects were seated and encouraged to push and then pull (1 repetition) the 2 cone-shaped handles to generate smooth, bilateral symmetric movements with exerting forces greater than the preset demanded forces. The length of a subject’s upper limb determined the push-pull movement distance, which ranged from 35 to 45cm. The force demanded of the affected arm of subjects with severe upper-limb impairment determined the push-pull movement distance, than the preset demanded forces. The length of a subject’s limbs were identified before treatment. The preset demanded forces for the 3 sets were 10%, 20%, and 10% of maximal push and pull forces of the affected and unaffected arms. Additionally, subjects were instructed to perform bilateral symmetric push and pull movements at a comfortable cycling pace; the most preferred cycling frequency was 0.1Hz. During treatment, subjects were seated and encouraged to push and then pull (1 repetition) the 2 cone-shaped handles to generate smooth, bilateral symmetric movements with exerting forces greater than the preset demanded forces. The length of a subject’s upper limb determined the push-pull movement distance, which ranged from 35 to 45cm. The force demanded of the affected arm of subjects with severe upper-limb impairment could be set at zero.

The affected forearm was supported with a forearm trough and the affected hand was strapped to the cone-shaped handle to ensure that a subject pushed and pulled the handles bilaterally (fig 2). Such adaptations helped severely impaired subjects perform bilateral active-assistive arm movement practices. During training, the subject’s bilateral push and pull forces (exerted on the handles that were connected to the load cells) could be detected and displayed in the control panel. These force data were shown in real time to the subject for visual feedback so as to keep his/her attention focused on the treatment. Generally, the subjects had to keep exerting the demanded forces bilaterally for 10 seconds to complete a smooth push and pull movement. A belt that was fixed to the back of the chair restricted trunk compensatory movement across the lower thorax. A 5-minute rest was allowed between sets to prevent fatigue.

In part 2 of the treatment (10min), subjects received a specific conventional rehabilitation program focused on treatment that did not provide symmetric bilateral movement and resistance trainings to the upper limbs. This program included range of motion exercise, affected arm muscle tone normalization, compensatory activity of daily living training, postural control training, and gait correction. The program was provided to ensure that all rehabilitation needs of each subject were met during the study.

In the follow-up stage, all subjects participated in 24, forty-minute sessions of regular occupational therapy (20min/session) and physical therapy (20min/session), based on the neurodevelopmental therapy, over an 8-week period.

Outcome Measures

The measuring therapist and treating therapist were different medical personnel. Motor functions of the affected arm were evaluated with arm motor tests and kinetic analysis of reaching with the affected arm. Motor function tests of the affected arm included isometric grip strength, push strength, pull strength, FMA, Frenchay Arm Test (FAT), and the Modified Ashworth Scale (MAS). We assessed the arm reaching function of subjects who showed reaching ability with the affected arm in a pretest (n = 15). The following kinematic dependent variables were derived from the marker position to examine and quantify the affected arm reaching movement: peak velocity (in cm/s), percentage of time to peak velocity (PTPV), movement time (in seconds), and normalized jerk score (NJS).

We tested grip strength of the affected upper limb with the Jamar dynamometer. Measurements of the limb’s push-pull strength were obtained from the BFIAMT. The testing position for the maximal isometric push-pull strength test was as follows: subjects were seated in an upright position with both arms and shoulders adducted, elbows flexed at 90°, and forearms in the neutral position. To prevent compensatory trunk movement during the testing, they were restrained to the chair back with a strap positioned at the lower thorax. An increase of 25% in push or pull strength across the 3 trials was considered to be inappropriate involvement of trunk compensation. Subsequently, additional trials were conducted. Subjects rested for 5 minutes between tests. Three successful trials of maximal grip, push, and pull strengths were obtained for each subject.

We used a 3-dimensional optical motion capture system to collect the movement trajectories of the affected arm. An infrared light-emitting diode was positioned on the ulnar styloid process. During testing, subjects were seated in an upright position with the trunk restrained to the chair back and the wrist of the affected arm resting on the desk border. The elbow was flexed at an angle of 90° and the shoulder adducted to the trunk. Subjects were requested to reach and touch a cup, without picking it up, as rapidly as possible. The cup was...
placed on the table at a distance the length of the subject’s upper limb. Each subject completed 5 reaching trials.

The position of the marker on the wrist was recorded at a sampling rate of 70Hz and digitally filtered with a low-pass second-order forward and backward Butterworth filter with a cutoff frequency set at 5Hz.

**Data Reduction and Analysis**

We analyzed the kinematic data of the arm reaching trajectories with the VZAnalyzer software, version 3.0. The software gave a 3-dimensional reconstruction of the marker positions. A relative velocity above or below 10% of the maximum movement velocity on the sagittal plane (z-axis), which was parallel to the reach movement direction, was used to detect the start and end of each reaching movement. Peak velocity (the highest instantaneous velocity during the reaching movement) was regarded as being correlated with the force generation of a movement. Movement strategy measure was analyzed from peak velocity relative to movement time. A left shift of the peak in the velocity profile (decreased PTPV) indicates more time spent in deceleration, or a guided movement strategy is used. Movement time (the duration of execution of a movement) reflects the overall speed of a movement, as a faster movement might indicate a faster movement strategy.

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### Table 1: Arm Motor Function Scores (Pretest, Post-Test, and Retention Tests) of the 20 Subjects

<table>
<thead>
<tr>
<th>Motor Function</th>
<th>Pretest</th>
<th>Post-Test</th>
<th>Retention Test</th>
<th>F</th>
<th>P</th>
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<tr>
<td>FMA</td>
<td>32.70±15.26</td>
<td>35.55±14.50</td>
<td>35.35±14.63</td>
<td>15.09</td>
<td>.001</td>
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<tr>
<td>FAT</td>
<td>1.75±2.24</td>
<td>1.80±2.23</td>
<td>1.80±2.23</td>
<td>1.00</td>
<td>.33</td>
</tr>
<tr>
<td>MAS</td>
<td>0.95±0.74</td>
<td>0.77±0.63</td>
<td>0.77±0.63</td>
<td>1.00</td>
<td>.31</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD.

### Table 2: Grip and Push and Pull Strengths of 20 Subjects for the Pretest, Post-Test, and Retention Test

<table>
<thead>
<tr>
<th>Strength</th>
<th>Pretest</th>
<th>Post-Test</th>
<th>Retention Test</th>
<th>F</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Push strength (N)</td>
<td>83.30±85.16</td>
<td>127.69±107.50</td>
<td>135.53±109.46</td>
<td>8.98</td>
<td>.001</td>
</tr>
<tr>
<td>Pull strength (N)</td>
<td>91.23±58.99</td>
<td>125.04±71.44</td>
<td>131.51±72.32</td>
<td>9.34</td>
<td>.001</td>
</tr>
<tr>
<td>Grip strength (N)</td>
<td>73.90±64.88</td>
<td>95.55±71.73</td>
<td>90.84±70.76</td>
<td>5.65</td>
<td>.009</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD.
motor unit activations, increases in neural drive, and “overflow” effects might be more marked. Another possible contributive factor is that the BFIAMT might have enhanced a balancing effect on the between-hemispherical cortical motor excitability, that is associated with brain reorganization, and thus contributed to motor recovery. Brain reorganization studies with functional magnetic resonance imaging and electromyography are needed to confirm these assumptions.

The BFIAMT is designed to permit subjects to practice bilateral arm movement exercises with relatively slow and constant velocity to prevent provoking a stretch reflex. The device can induce subjects with severe levels of arm impairment to practice a full range of smooth, repetitive bilateral push and pull movements by detecting whether the strength being exerted is greater than the preset value. Such a mechanism will be beneficial to the subject in experiencing normal proprioceptive feedback while controlling bilateral multifunction arm movement. For subjects with moderate to mild arm impairments, the BFIAMT will provide isokinetic bilateral arm resistive push and pull movement practice; this may enhance the recovery of arm function for less impaired subjects. In this study, each subject needed to perform a total of 1440 repetitions of a bilateral shoulder-elbow coordinated movement while exerting submaximal push and pull strength. At the same time, subjects with active grasp ability needed to firmly hold the cone handles with both hands during the push and pull movement. Isometric grip strengths of both hands were also trained during the exercise. Thus, training with the BFIAMT demands that the patients learn control of bilateral activation with symmetric loading and upper-limb multijoint coordinative movement. The loading demand was greater than movement repetition in BFIAMT training. Additionally, a meta-analysis of studies of unilateral strength training showed that an average of 7% of initial strength, or about one quarter of the increase in strength on the trained limb, will transfer to the untrained limb after unilateral training. Because of the neural adaptations to resistive exercise, the training effects in the unaffected upper limb might lead to training effects in the affected upper limb after BFIAMT training. Therefore, the gains (as a percentage of the variable) in strength (grip, push, and pull) from BFIAMT training were at least 3 times greater than the gains in motor function, as assessed with the FMA. Such findings could both support our hypothesis and imply that the BFIAMT might be an appropriate therapeutic modality for strengthening the paretic upper limb in chronic stroke patients.

Kinematic analysis of arm reaching is considered a sensitive and objective method for analyzing upper-limb interjoint coordination and control strategy. Studies of recovery from neural injury suggest that movement smoothness is a result of learned interjoint coordination and it will increase with motor recovery in subjects with movement disorders. Peak velocity is considered to be linearly related to the force that is generated during movement process, and the location of peak velocity in the velocity profile is one indication of the control strategy used. For a normal preplanned movement, peak is located at 33% to 50% of the velocity profile, and the left shift of the peak in the velocity profile indicates increasing dependence on a visually guided strategy during reaching. Although there were improvements in reaching ability in the affected upper limb after BFIAMT training, retention test scores revealed that training gains in reaching control had significantly declined after 8 weeks. On the other hand, retention test scores of the paretic upper-limb motor function tests did not show a significant decrease. Such results reflect the idea that intensive bilateral activation with loading control training might enhance the maintenance or improvement of the control strategy and interjoint coordination of the paretic upper limb. Incidentally, our result shows that kinematic analysis may provide a sensitive way to monitor the early changes of treatment effects on upper-limb interjoint coordination and motor function.

Previous studies, designed to investigate the effects of 6 to 8 weeks of specific therapy on paretic upper limb in patients with chronic stroke (at least 6 mo since onset), showed significant gains in FMA scores, ranging from 2.8 to 3.5. The significant gain in FMA scores (2.9) in our study was within the gain range of previous studies. We did not however, find a significant improvement in FAT scores after BFIAMT training. We inferred that the gain in FMA scores might not reach a level significant enough to improve paretic upper-limb performance and to reflect such ability in FAT tasks. Finger coordination abilities when manipulating small objects also play an important role in hand function performance. Training with the BFIAMT, however, is not supposed to yield enhanced anti-gravity arm strength and finger dexterity control. Thus, using the BFIAMT with the robot-aided device set on an inclined plane, combined with distal motor and fingers dexterity control training, may improve paretic upper-limb performance in activities of daily living.

Study Limitations

We used a single-cohort design with no control group and concurrent physical and occupational therapies during the treatment stage and the retention stage. The incorporation of occupational and physical therapies into the treatment stage might limit the validity of BFIAMT training effects. We did not use electromyography to monitor the trunk muscle activities and we did not perform standardized measurements of arm push and pull tests in the study, thus the possible compensation of trunk movement during maximal isometric push and pull tests cannot be excluded. These confounding factors may have a bearing on our findings and precautions are needed in the application of our results. We did not assess the effects of conventional rehabilitation combined with BFIAMT training on bilateral arm reaching ability and bimanual arm ability. Accordingly, we recommend that the contribution of BFIAMT training to bimanual arm function be studied further. In the future, a group comparison with random assignment design and recruiting samples with subacute or chronic subjects could be made to analyze the effect of BFIAMT training on the paretic

Table 3: Scores of 15 Subjects for the Reaching Kinematics Pretests, Post-Tests, and Retention Tests

<table>
<thead>
<tr>
<th>Kinematics</th>
<th>Pretest</th>
<th>Post-Test</th>
<th>Retention Test</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement time (s)</td>
<td>1.24 ±0.45</td>
<td>0.80 ±0.29</td>
<td>1.02 ±0.58</td>
<td>4.91</td>
<td>.015</td>
</tr>
<tr>
<td>Peak velocity (cm/s)</td>
<td>81.14 ±34.71</td>
<td>100.40 ±38.33</td>
<td>82.48 ±36.46</td>
<td>4.39</td>
<td>.035</td>
</tr>
<tr>
<td>PTPV (%)</td>
<td>31.10 ±9.45</td>
<td>40.80 ±12.42</td>
<td>35.30 ±10.67</td>
<td>6.70</td>
<td>.004</td>
</tr>
<tr>
<td>NJS</td>
<td>173.35 ±114.10</td>
<td>76.15 ±68.44</td>
<td>136.94 ±93.95</td>
<td>5.88</td>
<td>.008</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD.
upper limb. Finally, further investigations are needed to test whether bilateral training is superior to unilateral training in the recovery of paretic upper-limb motor function following stroke.

**CONCLUSIONS**

This study suggests that conventional rehabilitation, combined with 24 sessions of robot-aided therapy in the form of BFIMT training over an 8-week period, may be beneficial for chronic stroke patients in recovering paretic upper-limb strength and motor control ability. It may provide an alternative therapy for the upper-limb rehabilitation of the stroke population in both clinical and community situations. Future study with randomized controlled trials is required to assess its effectiveness.

**References**


Suppliers
a. Sammons Preston Inc, PO Box 5071, Bolingbrook, IL 60440-5071.

b. Visualeyez; Phoenix Technologies Inc, 4302 Norfolk St, Burnaby, BC V5G 4J9, Canada.

Objective: To compare skin-surface cooling caused by the application of an ice bag (15 min) and the projection of carbon dioxide microcristals (2 min) under high pressure (75 bar) and low temperature (~78°C), a modality called hyperbaric gaseous cryotherapy.

Design: Randomized controlled trial with repeated measure.

Setting: Laboratory experiment.

Participants: Twelve healthy male subjects (mean ± standard deviation, 22.9 ± 1.8 y).

Interventions: Ice bag and hyperbaric gaseous cryotherapy were randomly applied on the skin of the nondominant hand.

Main Outcome Measure: Skin temperature of the cooled (dorsal and palmar sides) and contralateral (dorsal side) hands were continuously measured with thermistor surface-contact probes before, during, and after (30 min) cooling.

Results: Hyperbaric gaseous cryotherapy projection induced a large decrease ($P<.05$) of the dorsal skin temperature of the cooled hand (from 32.5 ± 0.5°C to 7.3 ± 0.8°C) and a significant decrease of the skin temperature of the palmar side and of the contralateral hand. The skin temperature of the dorsal side of the cooled hand was decreased with an ice bag (from 32.5 ± 0.6°C to 13.9 ± 0.7°C, $P<.05$). However, the lowest temperature was significantly higher than during hyperbaric gaseous cryotherapy, and no significant changes in the other skin temperatures were observed. Rewarming was equal after the 2 modalities, highlighting a more rapid increase of the skin temperature after hyperbaric gaseous cryotherapy.

Conclusions: Hyperbaric gaseous cryotherapy projection decreased the skin temperature of the cooled and contralateral hand, suggesting a systemic skin vasoconstriction response. On the other hand, the vascular responses triggered by ice pack cooling appeared limited and localized to the cooled area.

Key Words: Cold; Cryotherapy; Dry ice; Ice; Nervous system diseases, sympathetic; Rehabilitation.

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THE TERM CRYOTHERAPY refers to the achievement of a therapeutic objective through the lowering of the tissue temperature by the withdrawal of heat from the body. A critical level of tissue cooling is required for specific effects. Ice massage, mixture of water and alcohol, or nitrogen cold air are efficient cooling techniques, but among the various cryotherapy modalities available for use both in clinical and on-field settings, ice or a gel bag or pack are probably the most frequently used. A series of studies reported that critical temperatures are not typically achieved with these modalities, thus limiting the therapeutic effect.

Despite a general consensus regarding the physiologic effects of cryotherapy, there are no clear guidelines on the optimum application technique for acute cryotherapy. Thus, there is no strong evidence to justify the use of one cryotherapy modality over the others. It is generally believed that greater cooling leads to more profound metabolic suppression, suggesting that cryotherapy modalities that produce lower temperatures are more efficacious. Similarly, it is generally assumed that cryotherapy techniques that provide more rapid cooling of tissues may offer some advantage over slower cooling techniques. With traditional ice and a cold gel pack, achievement of temperatures low enough to produce local analgesia by conduction are usually obtained after 5 to 10 minutes.

With the intention of drastically shortening cooling time, the Cryonic Society developed a cryotherapy modality that lowers the tissue temperature by convection. A reduced skin temperature is achieved through sublimation on the skin of carbon dioxide microcristals under high pressure (75 bar) and low temperature (~78°C). The aim of this study was to directly compare the skin-surface temperature during and after the application of a commonly used latex ice bag and of hyperbaric gaseous cryotherapy by carbon dioxide application.

METHODS

Experimental Design

We used a repeated-measures design to compare the skin-surface temperature during the application of the 2 cryotherapy modalities. Time and cryotherapy modalities were the independent variables, whereas skin-surface temperature was the dependent variable. Subjects were tested with 2 cryotherapy modalities: an ice bag and hyperbaric gaseous cryotherapy on 2 occasions with at least a 24-hour interval between occasions. To control the order effects, subjects were randomly allocated. Subjects were also asked to refrain from consuming alcohol, caffeine, or food for 3 hours and from any vigorous activities for 24 hours before testing to help stabilize extremity blood flow. None of the subjects in this study reported negative reactions to the cold treatments.

Participants

Twelve male subjects (mean ± standard deviation [SD], 22.9 ± 1.8 y; height, 178.3 ± 2.0 cm; weight, 70.6 ± 2.2 kg) from a university student population voluntarily participated in this
study. Their medical history and a medical examination were used to exclude subjects with a history of smoking, cardiovascular or peripheral vascular disease, diabetes, neurologic pathologies, recent trauma or injury to the hand, presence of any sores or open wounds on the hand, local hot or cold insensitivity, and very fair skin. We chose these criteria to avoid any harm or discomfort to the subjects; they were in keeping with previous studies. Subjects were normotensive, and none was taking medication. They were informed of the organization and details of the study, which was approved by our local ethics committee, and they were reminded of their right to withdraw at any stage. All patients provided written informed consent according to the Declaration of Helsinki. None of the 12 prospects was excluded from the study.

### Experimental Procedures

A sole investigator made all data measurements to reduce measurement variability. Subjects were in the supine position on a treatment table during the entire test. A control period was imposed for a minimum of 20 minutes before starting temperature measurements in an effort to allow body temperatures to stabilize and to control for temperature fluctuations resulting from any pre-experiment physical activity.

The dorsal face of the nondonnant hand was cooled in each therapy. The ice bag was prepared from ice chips and had a diameter of 25cm. Air was evacuated from the bag to allow the bag to better form to the hand surface. Care was taken to cool only the hand from the distal part of the wrist to the extremity of the fingers. With hyperbaric gaseous cryotherapy, cold was applied on the same area by sweeping motions. Because of the ability of hyperbaric gaseous cryotherapy to rapidly withdraw heat, application time differed between modalities; cooling lasted 15 minutes with the ice bag and only 2 minutes with hyperbaric gaseous cryotherapy (manufacturer’s recommendations).

Skin temperatures were recorded at the following sites: (1) the center point of the cooled area (middle of the third metacarpus), (2) the opposite side (palmar side) of the same hand, and (3) the middle of the third metacarpus of the dorsal contralateral hand. Skin temperatures were recorded every 30 seconds during the first 2 minutes of application and then every 2 minutes until the end of application of the modality (ice bag only); every 30 seconds during the first 3 minutes of rewarming and then every minute from 3 to 6 minutes of rewarming; and, finally, every 2 minutes during the remaining 30 minutes of rewarming. Subjects were permitted to leave when sensation in the tested area returned to normal. No subjects experienced any adverse reactions to the experimental protocol.

### Materials

Skin-surface temperatures were measured by means of ther­mistor surface-contact probes fixed on the skin with thin, air-permeable, adhesive surgical tape. By using uniform amounts of tape covering an equal area for each treatment, we controlled the potential insulating effect of the tape, and it was assumed that a uniform effect would be produced across all treatments. Therefore, it would not interfere with our ability to discriminate among treatments. Room temperature was maintained at a mean of 25°C ±1°C for all testing sessions.

Ice bag and hyperbaric gaseous cryotherapy by carbon dioxide were the modalities used in this study. The ice bag was a 25-cm diameter latex bag filled with chipped ice (0°C–1°C). In this case, air was evacuated from the latex bag in an attempt to improve conforming of the bag to the body surface. The amount of ice was 400g. For hyperbaric gaseous cryotherapy, we used the Cryo+ apparatus. This device throws up carbon dioxide microcrystals under low temperature (−78°C) and high pressure (50 bars at the outlet pipes, 2 bars on the skin). Medical carbon dioxide, in liquid form, is stored in bottles with a valve and a dip tube. Cold was applied on the dry skin with sweeping motions by using a spray gun linked to the carbon dioxide bottle. The pipe was maintained at a distance of 7 to 10cm of the skin surface. With this technique, it was possible to see the action of the cold by observation of the microcrystals on the skin. Skin-temperature reduction is controlled by an infrared thermometer incorporated into the gun and application time of the gas is displayed on a screen.

### Statistical Analysis

Standard statistical methods were used for the calculation of mean ±SD. Statistical comparisons of skin surface temperature were made by using a repeated-measures 2-way analysis of variance. A Student-Newman-Keuls test was used post hoc when interactions were significant. The statistical significance was established at the P less than .05 level. All analyses were performed by using SigmaStat.

### RESULTS

The mean skin-surface temperatures for the 2 modalities at the end of the baseline periods were 32.5°C±0.6°C (ice bag) and 32.5°C±0.5°C (hyperbaric gaseous cryotherapy) for the dorsal cooled hand, 33.7°C±0.7°C (ice bag) and 33.5°C±0.6°C (hyperbaric gaseous cryotherapy) for the palmar cooled hand, and 31.0°C±0.7°C (ice bag) and 30.8°C±0.6°C (hyperbaric gaseous cryotherapy) for the dorsal contralateral hand (fig 1). At base-
line, no significant differences were observed between ice bag and hyperbaric gaseous cryotherapy.

Ice bag and hyperbaric gaseous cryotherapy decreased the temperature of the dorsal aspect of the cooled hand significantly throughout the cold application (see fig 1). However, the rate of skin temperature decrease and the drop in skin temperature was dependent of the technique used. With the ice bag, the skin temperature decreased to 26.5°C±0.7°C (−6°C) in the first 30 seconds (P<.05 vs baseline) and then more slowly to reach 21.8°C±0.6°C at 2 minutes (−11°C; range, −5.0°C to −8.1°C) and finally 13.9°C±0.7°C (−19°C; range, −15.6°C to −20.8°C) at the end of the 15-minute application. With hyperbaric gaseous cryotherapy, the skin temperature decreased to 12.8°C±1.2°C (−20°C; range, −14.4°C to −25.8°C) within 30 seconds (P<.05 vs baseline and ice bag) and then more progressively to reach 7.3°C±0.8°C (−25°C; range, −18.4°C to −30.0°C) at the end of the 2-minute application. The overall reduction in the skin temperature was larger with hyperbaric gaseous cryotherapy compared with an ice bag (P<.05). After removal of the application, rewarming was faster after hyperbaric gaseous cryotherapy, particularly at the very beginning of recovery. Thirty seconds after the removal of the ice bag, the skin temperature was 16.9°C±0.8°C (−3°C; range, 1.9°C to −4.0°C); whereas it was 13.5°C±0.6°C (−6°C; range, 3.8°C to −9.1°C) for hyperbaric gaseous cryotherapy (P<.05 vs ice bag). After 1 minute of rewarming, no significant difference in skin temperature was observed between ice bag and hyperbaric gaseous cryotherapy. After 20 minutes of recovery, neither cryotherapy modalities differed significantly from baseline values. Like the temperature reductions on the dorsal side of the cooled hand, the palmar skin temperature changes were also dependent of the cooling technique used (see fig 1). A trend for an increase in the skin temperature was observed during the first 6 minutes of ice bag application (up to 34.0°C±0.7°C; +0.3°C; range, −0.4°C to +1.2°C; P=not significant) before decreasing to reach 33.2°C±0.9°C at the end of the cooling period. At this time, no significant difference with the baseline skin temperature was observed. During hyperbaric gaseous cryotherapy, the palmar skin temperature decreased (P<.05) to reach 19.2°C±1.2°C (−14°C; range, −6.5°C to −21.5°C) at the end of the 2-minute application.

No significant change in the dorsal skin temperature of the contralateral hand was observed during ice bag application (see fig 1). However, a significant decrease was observed with hyperbaric gaseous cryotherapy; the temperature dropped to 30.5°C±0.6°C (−0.3°C; range, −0.1°C to −0.7°C) at the end of the cooling period. The skin temperature remained significantly lower than that of baseline during the 2 first minutes after the end of cold application.

**DISCUSSION**

This study investigated the effect of application of a traditional latex ice bag and a hyperbaric gaseous cryotherapy device on the surface skin temperature of the human hand. The results suggest that greater reductions in skin temperatures and a greater rate of heat removal are achieved with hyperbaric gaseous cryotherapy compared with an ice bag.

Cold modalities work by absorbing heat from their immediate environment, particularly from the tissues being treated. The transfer of heat and the capacity of the cold modality to absorb this heat determines the modality’s effectiveness and depend on several factors, such as the relative masses of the bodies, the size of the contact area, the difference in starting temperatures, and the heat capacity or specific heat of each material. In the present study, the only difference between treatments was caused by differences in the specific heat of the modalities used and their ability to absorb heat. Hyperbaric gaseous cryotherapy is based on a source of liquid carbon dioxide which converts, when applied on the skin, to a white solid phase (dry ice) through a process called deposition. Then, at atmospheric pressure, dry ice gradually sublimes to carbon dioxide gas (sublimation). The amount of heat absorption through this process is greater compared with the heat absorption operated through convection with the ice bag, explaining the greater and more rapid decrease in skin temperature. Also, condensation occurred at the surface of the ice bag during the 15-minute application, and, thus, a small amount of cool water was in contact with the skin of the subject’s hand. On the other hand, convection during hyperbaric gaseous cryotherapy involved dry gas. One potential advantage of such a difference is that pain is lessened during a dry cold than during a wet cold stimulation. However, pain sensation was not evaluated in the present study.

Comparing the present results with other research findings is difficult because of the different protocol used (time and site of cold application). However, the relative clinical merits of each modality can be established by reviewing the tissue temperatures achieved in relation to target tissue temperatures. Based on previous research, a skin temperature below 13.6°C is required to induce localized analgesia, a reduction of nerve conduction velocity is observed at a temperature of 12.5°C, and tissue temperatures between 10°C and 11°C reduced metabolic enzyme activity. It is of note that large variation exists in individual responses to cold. Clinically, this variation is a concern, given the importance of the actual skin temperature that must be achieved to induce the different physiologic effects. It is, therefore, worth questioning whether generic application protocols and times will always ensure clinically effective tissue cooling. The ice bag did not achieve a mean skin temperature below 13.9°C. This suggests that the ice bag would not be suitable to achieve these particular clinically relevant tissue temperatures when applied to the hand in this manner. In the present study, the skin temperature on the cooled surface was lower than 13.6°C in 6 subjects and lower than 12.5°C and 11°C in only 2 of 12 subjects after 15 minutes of ice bag application. The interindividual variation was large in this case because skin temperature ranged from 9.7°C to 17.7°C. Because there was a continual decrease in the mean surface temperature for the duration of ice pack application, clinically relevant temperatures may have been reached with a longer application time. However, a prolonged application at low temperatures should be avoided because this may cause serious side effects, such as frostbite and nerve injuries. On the other hand, hyperbaric gaseous cryotherapy led to a skin temperature below 11°C in every subject at the end of the 2-minute application. This suggests that hyperbaric gaseous cryotherapy has adequate heat abstraction capabilities to justify its use for achieving localized analgesia, reduced nerve-conduction velocity, and cell metabolism. It is not known if very rapid cooling could also have side effects, but, because the hyperbaric gaseous cryotherapy has a great capacity to absorb heat, this modality may also cause injuries if mismanaged.

Twenty minutes after the removal of the cryotherapy modalities, the mean skin-surface temperature was not significantly different from baseline. It is interesting to note that the 2 cryotherapy modalities achieved a similar level of mean skin surface temperature during the rewarming despite the fact that the mean skin surface temperatures before removal differed. Because heat always transfers from the warmer environment into the cooler environment, the similar level of the mean skin-surface temperature at the end of the rewarming may imply that the cooling effects of the topical cryotherapy appli-
ication in this study are short-lived. The important changes in the skin temperature observed with hyperbaric gaseous cryotherapy may be of interest based on the assumption that immediate cryotherapy application will be more beneficial than delayed application because the sooner the metabolic rate is reduced after injury, the less the secondary damage.\textsuperscript{24}

In the present study, we chose to cool the hand instead of the thigh, as usually performed in studies comparing different cryotherapy modalities.\textsuperscript{8,14} This was done because subjects’ skinfold thickness is thin at this site and the vascular bed is highly developed, therefore magnifying the thermal alterations. Also, changes in hand skin temperature could be used as an indicator of the sympathetic activity,\textsuperscript{21-23} giving information on the vascular autonomic control during cooling. In the present study, a significant decrease in the skin temperature of the palmar face of the cooled hand and of the contralateral hand was found with hyperbaric gaseous cryotherapy and not with ice bag cooling, suggesting that the cutaneous vasoconstriction triggered by hyperbaric gaseous cryotherapy was systemic, whereas that triggered by the ice bag was localized only to the cooled area. This should be noted because evidence has shown that sympathetic activity modulates inflammation and the release of cytokines\textsuperscript{24} and that involvement of the autonomic nervous system is important in the treatment of inflammation.\textsuperscript{25}

**Study Limitations**

Several methodologic restrictions limit the generalization of our findings. The subjects of the present study were a selected group of young healthy men, which enhances internal validity and data purity. However, they are not representative of the population as a whole,\textsuperscript{26-28} restricting the external validity of this study. Likewise, injured subjects may not respond in the same fashion because of their inflammatory status and higher temperature at the wounded site. During cold application, there is a direct relationship between adipose thickness,\textsuperscript{29} vascularity of the tissue, local blood flow,\textsuperscript{30} and both the required cooling time and the temperature change, suggesting that adjustments to cryotherapy duration may be necessary to produce similar temperature changes at different body segments. Hyperbaric gaseous cryotherapy was compared with the use of an ice pack because it is likely the most frequently used modality in clinics and on the field. However, more rapid and deeper tissue cooling compared with an ice bag could be achieved with other cryotherapy modalities.\textsuperscript{26} It is necessary to compare the efficacy of hyperbaric gaseous cryotherapy to these alternative modalities. Finally, in lieu of more direct measures, the clinical efficacy of cryotherapy is often assessed through skin-surface temperature measurements. It is assumed that skin-surface temperature declines in a fashion similar to that of intramuscular temperature during the course of cryotherapy application,\textsuperscript{7,14,20} however, this may be incorrect.\textsuperscript{31} Also, the duration of the intramuscular temperature reduction is dependent of the cooling modalities.\textsuperscript{15,32}

**CONCLUSIONS**

Hyperbaric gaseous cryotherapy was superior to the ice bag in reducing skin temperature. This modality decreased the mean skin-surface temperature to levels required for therapeutic effects in all subjects studied, whereas the ice bag did not. Unlike the ice bag, hyperbaric gaseous cryotherapy triggered a systemic vasoconstriction. Confirmation of these results with a larger population is necessary, and the clinical benefits of hyperbaric gaseous cryotherapy need to be evaluated.

**Acknowledgments:** We thank Melanie I. Stuckey, MS, for her helpful comments during the preparation of this manuscript. We thank the Cryonic Society, which placed the Cryo+ apparatus at our disposal for the study.

**References**


Suppliers
a. Thermistor surface contact probes, series 400, type 409B; Yellow Springs Instrument, 1725 Brannum Ln, Yellow Springs, OH, 45387.
b. DiGi-Sense thermistor thermometer; Eutech Instruments Europe BV, PO Box 254, 3860 AG Nijkerk, The Netherlands.
c. Laboratoires Clement-Thekan, Produits Burnet, 2 rue Chaintron, BP 850 92542, Montrouge, France.
d. Cryonic Medical SA, Le Martinet du Haut, 39110 Salins les Bains, France.
e. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
Alternating Frequencies of Transcutaneous Electric Nerve Stimulation: Does it Produce Greater Analgesic Effects on Mechanical and Thermal Pain Thresholds?

K. C. Tong, MSc, Sing Kai Lo, PhD, Gladys L. Cheing, PhD


Objective: To determine whether alternating frequency transcutaneous electric nerve stimulation (TENS) at 2 and 100Hz (2/100Hz) has a more potent hypoalgesic effect than a fixed frequency at 2 or 100Hz in healthy participants.

Design: A single-blind randomized controlled trial with a convenience sample.

Setting: University physiotherapy department.

Participants: Sixty-four healthy volunteers (32 men [mean age, 28.1±5.9y], 32 women [mean age, 27.7±5.6y]) were recruited and randomly divided into 4 groups.

Interventions: The 4 groups received TENS delivered at (1) 2Hz; (2) 100Hz; (3) 2/100Hz alternating frequency; and (4) no treatment (control group), respectively. Electric stimulation was applied over the anterior aspect of the dominant forearm for 30 minutes.

Main Outcome Measures: Mechanical pain thresholds (MPTs) and heat pain thresholds (HPTs) were recorded before, during, and after TENS stimulation. The data were analyzed using linear mixed models, with group treated as a between-subject factor and time a within-subject factor.

Results: During and shortly after electric stimulation, HPT increased significantly in the alternating frequency stimulation group (P=.024). MPT increased significantly in both the 100Hz (P=.008) and the alternating frequency groups (P=.012), but the increase was substantially larger in the 100Hz group.

Conclusions: Alternating frequency stimulation produced a greater elevation in the HPT, but a greater increase in the MPT was achieved using 100Hz stimulation.

Key Words: Pain; Rehabilitation; Transcutaneous electric nerve stimulation.

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THE INVOLVEMENT OF ENDOGENOUS opioids is believed to be among the mechanisms of transcutaneous electric nerve stimulation (TENS) analgesia. In the 1970s, Sjolund1,2 and colleagues demonstrated that low-frequency electroacupuncture increases the level of endorphins in cerebrospinal fluid (CSF) in patients with chronic pain. Later studies4,6 found that different frequencies of electroacupuncture or TENS7,8 activate the release of different endogenous opioids at both the supraspinal and spinal levels. Han et al7 examined the effects of low- (2Hz) and high- (100Hz) frequency TENS by measuring the CSF before and after stimulation in patients with neurologic disorders. There was a 367% increase in Met-enkephalin-Arg-Phe after 30 minutes of 2Hz stimulation, whereas 30 minutes of 100Hz stimulation produced a 49% increase in immunoreactive dynorphin A. It is believed that low-frequency (2-4Hz) stimulation mostly causes an increase in the release of enkephalin, β-endorphins, and endomorphins,9-11 acting on the μ- and δ-opioid receptors.12 High-frequency (100Hz) stimulation mainly enhances the release of dynorphin, which acts on the κ-opioid receptors.7 Therefore, high- and low-frequency electric stimulation analgesia trigger the release of different opioid peptides.13,14 Different stimulation frequencies therefore tend to involve slightly different analgesic mechanisms.15

Chen et al10 proposed that the delivery of TENS at an alternating frequency stimulation of 2 and 100Hz would produce an optimal release of both enkephalin and dynorphin simultaneously, thus achieving a more potent analgesic effect. The idea of using alternating frequency stimulation was mainly based on reports of the synergistic interaction between different opioid peptides. Studies17-19 have found that synergistic effects occur between the μ-opioid agonists and δ-opioid agonists, and interactions between the δ-opioid agonists and κ-opioid agonists,20,21 The relative contribution of each opioid was unknown, however, and the mechanism for the synergistic action produced by different combinations of opioid was not well understood. There is limited evidence or research showing that this synergistic effect of different endogenous opioids triggered by alternating frequency stimulation will lead to a more potent analgesic effect in human beings.

Chen10 applied a 2 and 15Hz alternating frequency stimulation of TENS to 12 orthopedic patients. The levels of Met-enkephalin-Arg-Phe and dynorphin A in CSF were measured before and after electric stimulation. There was an increase in opioids level in the CSF in all patients. No comparison was made with other fixed frequency stimulations or with a control group. Recent studies have compared alternating and fixed frequency stimulations. Hamza et al22 examined the effects of different stimulation frequencies of TENS on the postoperative opioid analgesic requirements and recovery profiles of patients. One hundred women who had undergone major gynecologic procedures were randomly assigned into 4 groups: (1) patient control analgesia plus sham TENS; (2) patient control analgesia plus 2Hz TENS; (3) patient control analgesia plus 100Hz TENS; and (4) patient control analgesia plus an alternating...
frequency TENS at 2 and 100Hz (2/100Hz). TENS was given for 30 minutes every 2 hours during the day. Visual analog scale scores (VASs) for pain and analgesic drug requirements were recorded as outcome measurements. There were no differences in VAS scores between the groups, but the use of alternating frequencies had a slightly greater effect in decreasing morphine requirements than did just the 2 or 100Hz frequencies.

Law and Cheing\textsuperscript{23} examined the optimal stimulation frequency of TENS in people with knee osteoarthritis. Thirty-four participants were randomly allocated into 4 groups: TENS at either a (1) 2Hz, (2) 100Hz, or (3) 2/100Hz alternating frequency stimulation, or (4) a placebo TENS. Treatment was given 5 days a week for 2 weeks. VASs, knee range of motion, and the results of a Timed Up & Go test were recorded. The results seem to suggest that 2, 100, and 2/100Hz alternating frequencies produced similar treatment effects.

The above studies focused on clinical pain. A patient’s medical history and severity of pain, as well as the course of the disease, however, can influence the effect of electric stimulation on clinical pain. The degree of confounding and variability might be lower if experimental pain was used. To date, there has been no study on the effectiveness of alternating frequency stimulation on experimental pain in healthy people. Our purpose in this study was to investigate whether an alternating frequency stimulation of TENS (2/100Hz) would produce greater analgesic effects than a fixed frequency delivered at 2 or 100Hz in healthy subjects.

**METHODS**

Participants

We recruited a convenience sample of 32 male and 32 female physiotherapy students and staff, aged 20 to 45. Excluded from the study were people with cardiac pacemakers, or with arrhythmia, tumors, diabetes mellitus, peripheral vascular disease, local skin infections, or pain conditions in the upper limbs. Participants also needed to pass both the hot and cold test and the pin-prick test before being randomly allocated to 1 of 4 groups. The Hong Kong Polytechnic University approved the study.

The 4 groups received TENS at: (1) 2Hz; (2) 100Hz; (3) 2/100Hz alternating frequency; or (4) were given no treatment (control group), respectively. In this study, we used a closed envelope method to randomize the participants and we randomized men and women separately because the 2 sexes may react differently to pain stimulation. Participants knew only that they would receive different protocols of TENS or placebo, but did not know the detailed implications of the stimulation protocols.

**Experimental Procedures**

Before the experiment, its purpose and procedures were explained to the participants and their written consent was obtained. We collected demographic data about age, sex, body weight, height, and body mass index (BMI) to compare the homogeneity between groups. The TENS machine\textsuperscript{a} was located in a quiet and isolated room, with the temperature maintained at 21° to 23°C and relative humidity at 55%. The participants were seated in a comfortable and upright position with their dominant forearm resting on a table. The pulse width was set at 1000μs for the stimulation frequency of 2Hz and at 700μs for the stimulation frequency of 100Hz. For the alternating frequencies of 2 and 100Hz, 3.5 seconds of 2Hz stimulation with a 1000μs pulse width were followed by 2.5 seconds of 100Hz stimulation with a 700μs pulse width.

Demonstrations on the recording of the heat pain threshold (HPT) and mechanical pain threshold (MPT) were performed on the nondominant forearm. Each stimulation site was cleaned with alcohol. A pair of 3.5×5cm\textsuperscript{2} rubber electrodes was prepared with gel and fixed over the anterior aspect of the dominant forearm with micropore tape. The electrodes were located over the distribution of the median nerve. The anode electrode was placed just proximal to the middle of the wrist crease and the cathode electrode was placed just distal to the middle of the elbow crease. HPT and MPT measurements were performed along the same dermatome (fig 1). For the 3 active TENS groups, the intensity of the current was increased to “strong but comfortable.” The current was adjusted if the participants accommodated themselves to the current 5 minutes into the stimulation. Participants in the control group did not receive any electric stimulation, and no electrodes were placed on their forearms.

The testing procedures were based on those used in a previous study.\textsuperscript{24} HPTs and MPTs were measured at 15-minute intervals before, during, and after the intervention (fig 2). There were a total of 6 recording periods, with 3 trials of HPT and 1 trial of MPT. Two baseline measurements were performed at −15 minutes (t1) and 0 minutes (t2) before the TENS intervention. Two measurements were obtained at 15 minutes (t3) and 30 minutes (t4) during the application. Two postintervention measurements were collected at 45 minutes (t5) and 60 minutes (t6) (see fig 2).

**Outcome Measures**

We measured the HPT with a thermal sensory analyzer,\textsuperscript{b} which is a computer-controlled device with a 30×30mm con-
Data Analysis

We used linear mixed models to analyze the data on HPT and MPT, with group treated as a between-subject factor and time as a within-subject factor. When the interaction between group and time was significant, we did a stratified analysis. To be specific, we performed 4, 1-way repeated-measures analyses of variance (ANOVA), one for each of the studied groups, to test the change in HPT and MPT from baseline to time 6. We used SPSS* for data analysis.

RESULTS

Demographic Characteristics of the Participants

The mean age of the male participants was 28.1±5.9 years old (range, 20–40y); and that of the female participants was 27.7±5.6 years old (range, 20–41y). For all participants, body weight and height ranged from 42.5 to 93.0kg, and from 1.5 to 1.8m, respectively. BMI varied from 15.9 to 30.1kg/m². Sixty of the 64 participants were right-hand dominant. There were no significant differences in age, height, weight, or BMI between the 4 groups (table 1).

Heat Pain Threshold

HPTs were recorded at 6 time intervals. The mean value of t1 (~15min) and t2 (0min) was taken as the baseline HPT. Table 2 shows the changes in HPT at different time intervals. Because the interaction between group and time was near the .05 significance level (P=.059; power .87), we did a stratified analysis, that is, repeated-measures ANOVA and post hoc comparisons were performed within each group.

Although figure 3 shows that all 3 stimulation groups seem to produce greater hypoalgesic effects than the control group during and after the stimulation, only the change in group 3 (2/100Hz) was statistically significant, as shown in the 1-way repeated-measures ANOVA (see table 2). Post hoc analysis revealed that the means at t3 (ie, 15min) to t5 (ie, 45min) were significantly different from those at the other time periods. In other words, for the 2/100Hz group, HPT during and shortly after electric stimulation was significantly higher.

Mechanical Pain Threshold

Table 3 presents the mean MPT at different time intervals. Figure 4 presents the percentage change of MPT in comparison with baseline. Again, all 3 stimulation groups seemed to produce greater hypoalgesic effects than the control group (interaction P=.009; observed power, .94) (see fig 4). Stratified analysis revealed that the change from baseline to t6 was significantly greater in comparison with baseline.

Table 1: Demographic Characteristics of Participants

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>2Hz</th>
<th>100Hz</th>
<th>2/100Hz</th>
<th>Control</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=64</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Men/women</td>
<td>8/8</td>
<td>8/8</td>
<td>8/8</td>
<td>8/8</td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>26.3±6.1</td>
<td>27.3±6.7</td>
<td>26.5±5.8</td>
<td>29.3±3.9</td>
<td>.49</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>57.0±8.9</td>
<td>59.4±14.7</td>
<td>54.5±7.8</td>
<td>56.9±7.0</td>
<td>.60</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.7±0.1</td>
<td>1.7±0.1</td>
<td>1.7±0.1</td>
<td>1.7±0.1</td>
<td>.97</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>20.6±2.3</td>
<td>21.5±3.9</td>
<td>19.8±1.6</td>
<td>20.4±1.7</td>
<td>.35</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± standard deviation (SD).

Table 2: HPT for Each Group at Different Time Intervals

<table>
<thead>
<tr>
<th>Intervals</th>
<th>2Hz</th>
<th>100Hz</th>
<th>2/100Hz</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>41.3±3.7 (0.0)</td>
<td>42.6±4.1 (0.0)</td>
<td>40.5±5.2 (0.0)</td>
<td>42.2±3.5 (0.0)</td>
</tr>
<tr>
<td>t3 (15min)</td>
<td>41.7±3.8 (1.0)</td>
<td>43.5±4.9 (2.1)</td>
<td>42.3±5.1 (4.4)</td>
<td>42.0±3.7 (0.5)</td>
</tr>
<tr>
<td>t4 (30min)</td>
<td>42.4±3.8 (2.7)</td>
<td>44.5±4.7 (4.5)</td>
<td>43.0±5.1 (6.2)</td>
<td>42.1±3.8 (0.2)</td>
</tr>
<tr>
<td>t5 (45min)</td>
<td>42.8±3.1 (3.6)</td>
<td>43.8±4.5 (2.8)</td>
<td>42.1±5.4 (4.0)</td>
<td>42.1±3.7 (0.2)</td>
</tr>
<tr>
<td>t6 (60min)</td>
<td>42.5±3.0 (2.9)</td>
<td>44.0±4.7 (3.3)</td>
<td>41.3±5.5 (2.0)</td>
<td>42.0±3.6 (0.5)</td>
</tr>
<tr>
<td>P*</td>
<td>.064</td>
<td>.229</td>
<td>.024</td>
<td>.803</td>
</tr>
</tbody>
</table>

NOTE. Values are group means ± SD (percentage change of HPT vs baseline).

*pValues were derived using 1-way within-group repeated-measures ANOVA and were corrected for type I error using the Bonferroni method.

*Significantly different from the rest of the time periods.
significant only in group 2 (100Hz) and group 3 (2/100Hz). Post hoc analysis further revealed that for group 2, mean MPT at t3 and t4 differed significantly from other time periods; whereas for group 3, only the mean at t4 differed significantly from other time intervals. The percentage change in MPT was substantially larger in group 2 (100Hz) than in group 3 (2/100Hz) during electric stimulation at both t3 (18.5% vs 3.6%) and t4 (25.9% vs 17.9%).

**DISCUSSION**

**HPT and MPT**

HPT significantly increased in the 2/100Hz group during and shortly after electric stimulation. MPT also significantly increased in the 2/100Hz group, but only near the end of stimulation and less than in the 100Hz group, in which there was a substantial increase (up to 25.9% from baseline). These findings are, by and large, in agreement with previous research. Several studies33-35 reported that TENS significantly increased in experimentally induced heat pain in healthy subjects. Walsh et al36 found that the MPT increased with high-frequency TENS (110Hz), but not with low-frequency TENS (4Hz).

Different responses in HPT and MPT to TENS stimulation may result from different afferent pathways that mediate heat pain and mechanical pain. Heat pain is mediated predominantly by unmyelinated C fibers.27 Torebjork et al37 found that HPT measurements are highly correlated with the activation of C nociceptors in human subjects. Sherrick et al38 suggested that low rates of increases in temperature (\(<2^\circ/s\)) during HPT measurements were signaled by small C-fiber activities. In our study, the rate at which temperatures rose was set at 1.5° per second. Thus, it is likely that the HPT was mediated predominantly by the activities of C fibers. In contrast, mechanical pain is mediated by the A delta fibers.39 Therefore, the pathways of heat pain and mechanical pain in the spinal cord are different. TENS stimulation may affect these 2 types of pain thresholds to a different degree. Furthermore, it is thought that chronic pain is mediated predominantly by C fibers, whereas acute pain is mediated by A delta fibers.40

Our findings suggest that the alternating frequency stimulation significantly elevated the HPT that is mediated predominantly by C fibers. This implies that alternating frequency stimulation may work better than single frequency stimulation on chronic pain. In the group receiving 100Hz, however, the MPT—which is mediated predominantly by A delta fibers—was significantly elevated. This implies that 100Hz stimulation may work better than other types of stimulation on acute pain. Precautions should be taken, however, in translating these results into clinical practice because this study did not include any physiologic measurements. The mechanisms of action suggested above can only be speculative, especially in the translation to the treatment of acute and chronic pain.

**Use of Alternating Frequency Stimulation**

The release of different types of opioid peptides and the synergistic interaction among them to produce a more potent analgesic effect is the basis for using alternating frequency

**Table 3: MPT at Different Time Intervals**

<table>
<thead>
<tr>
<th>Intervals</th>
<th>2Hz</th>
<th>100Hz</th>
<th>2/100Hz</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (0min)</td>
<td>2.7±1.1 (0.0)</td>
<td>2.7±0.9 (0.0)</td>
<td>2.8±1.2 (0.0)</td>
<td>3.6±1.0 (0.0)</td>
</tr>
<tr>
<td>t3 (15min)</td>
<td>2.9±1.2 (+.74)</td>
<td>3.2±1.0 (+18.5)</td>
<td>2.9±1.1 (+3.6)</td>
<td>3.6±0.9 (+0.0)</td>
</tr>
<tr>
<td>t4 (30min)</td>
<td>2.9±1.1 (+.74)</td>
<td>3.4±1.3 (+25.9)</td>
<td>3.3±1.3 (+17.9)</td>
<td>3.5±1.0 (+2.8)</td>
</tr>
<tr>
<td>t5 (45min)</td>
<td>2.9±1.2 (+.74)</td>
<td>3.0±1.4 (+11.1)</td>
<td>3.1±1.2 (+10.7)</td>
<td>3.6±0.9 (+0.0)</td>
</tr>
<tr>
<td>t6 (60min)</td>
<td>2.8±1.2 (+3.7)</td>
<td>2.9±1.4 (+7.4)</td>
<td>3.0±1.2 (+7.1)</td>
<td>3.5±1.0 (+2.8)</td>
</tr>
<tr>
<td>(P^*)</td>
<td>.541</td>
<td>.008</td>
<td>.012</td>
<td>.609</td>
</tr>
</tbody>
</table>

* NOTE. Values are group means ± SD (percentage change of MPT vs baseline).
* \(P^*\)values were derived using 1-way within-group repeated-measures ANOVA and were corrected for type I error using the Bonferroni method.
* Significantly different from the other time periods.
stimulation. Different types of endogenous opioid, however, process different characteristics of pain analgesia. During alternating frequency stimulation, the relative contribution of each opioid is unknown, and the mechanism for the synergistic action produced by different combinations of opioid is still not well understood. Therefore, with the synergistic actions of the different opioid peptides still unknown, the effectiveness of alternating frequency stimulation is difficult to predict. Moreover, the involvement of endogenous opioids is not the sole analgesic mechanism in the alternating frequency stimulation mode. Chen et al. found that analgesia induced by alternating frequency stimulation was only partially (50%) blocked by a high dose of naltrexone. Various stimulation frequencies may involve different mechanisms. Multiple inhibitory pain systems such as serotonin and noradrenaline are also believed to contribute to the analgesic effects. It is not clear, however, as to what extent these systems are involved and how they are coordinated during and after electric stimulation. Further study should be conducted to examine the underlying analgesic mechanisms of using alternating frequency stimulation.

Stimulation Parameters of Alternating Frequency Stimulation

Stimulation intensity is among the key factors in determining the effectiveness of electric stimulation. In this study, the stimulation intensity was set at a “strong but comfortable” level, as healthy participants find noxious stimulation to be intolerable. Some studies that used a “strong but comfortable” intensity stimulation, however, reported no effect on different types of pain thresholds. Although previous studies favored a noxious stimulation intensity, we found that the stimulation intensity was predominantly determined by that used in 100Hz for participants in the alternating frequency stimulation group. When we started the electric stimulation, more than half of the participants in that group reported that if a given intensity was tolerable for 2Hz, it would be too strong for 100Hz. Similarly, if the intensity was tolerable for 100Hz, it was too weak for 2Hz. Therefore, although we understood that this level of stimulation intensity may be too weak for 2Hz, we selected that particular intensity because it was the only tolerable intensity for participants receiving alternating 2 and 100Hz. Moreover, the alternating frequency stimulation group reported the least accommodation to electric stimulation because the stimulation they received involved a sudden change from a low frequency of 2Hz to a high frequency of 100Hz and vice versa. In the alternating frequencies group, only 1 participant requested an increase in stimulation intensity during stimulation. By contrast, 8 participants in the 2Hz group and 9 participants in the 100Hz group asked for an increase in stimulation intensity. This may explain why the 2/100Hz group received the lowest intensity of current. Furthermore, as explained earlier, the alternating cycle of low and high frequency was preset at 3.5 seconds of 2Hz, followed by 2.5 seconds of 100Hz. This alternating cycle was designed mainly on the basis of findings in an animal study, however, this may not be the optimal stimulation alternating cycle for human beings. The period of each frequency may be too short to produce enough opioid peptide to achieve an analgesic effect, or it may diminish the synergistic action between various opioid peptides.

CONCLUSIONS

We suggest that future studies investigate the optimal alternating cycle of low and high frequencies in clinical populations so as to obtain a better analgesic effect for acute or chronic pain conditions. It may also be necessary to refine the treatment parameters of alternating frequency.

References


Suppliers

a. Han’s acupoint nerve stimulator model LH202H; Neuroscience Research Center, Peking University, Beijing, China.

b. Medoc Advanced Medical Systems, One Ha’Dekel St, PO Box 423, Ramat Yishai 30095, Israel.

c. Version 14; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
Irreversible Spinal Nerve Injury From Dorsal Ramus Radiofrequency Neurotomy: A Case Report

Zachary Abbott, DO, Matthew Smuck, MD, Andrew Haig, MD, Oren Sagher, MD


Radiofrequency neurotomy (RFN) of the medial branches of the dorsal rami is a successful method of treating facet joint pain. Documented serious complications are rare. We discuss the case of a 33-year-old woman with low back pain (LBP) who sustained a right L5 nerve root injury during RFN. The patient had several months of axial LBP after a motor vehicle collision. She had no relief after anti-inflammatory medications, physical therapy, L5-S1 interlaminar epidural corticosteroid injections, and a right sacroiliac joint injection. She then received bilateral L3 and L4 medial branch and bilateral L5 dorsal ramus blocks with excellent temporary pain relief. Subsequently she underwent bilateral L3 and L4 medial branch and bilateral L5 dorsal ramus RFN. Afterward, she noticed new right leg pain and paresthesias extending throughout the L5 dermatome. Electromyography and magnetic resonance imaging were normal and she was diagnosed with a right L5 sensory radiculopathy. The right leg symptoms were unresponsive to multiple medications. After a successful trial with a spinal cord stimulator, she underwent permanent stimulator placement. Afterward, she had 90% relief of her right leg pain and discontinued all analgesics. Irreversible injury of nontarget nerves is a possible complication of RFN, and can be avoided by following proper procedural protocol.

Key Words: Case report; Facet joint; Injections; Pain; Rehabilitation.

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For more than 3 decades radiofrequency neurotomy (RFN) of the dorsal rami and their medial branches has been used to treat facet joint pain. When stringent patient selection criteria and meticulous needle placement are used, outcomes are typically good. There are few documented complications of RFN. Shealy reported local hemorrhage and superficial burns associated with early radiofrequency equipment. Van Kleef et al described dermatomal burning pain and hypesthesia after lesioning cervical dorsal root ganglia. Kaplan and Mekhail documented post-RFN muscular pain, superficial infections and postdenervation neuritis. North et al mentioned paradoxical exacerbation of pain secondary to deafferentation.

There have also been reports of injury to nontarget nerves with the use of radiofrequency equipment. Bogduk reported 1 case of transaction of the lateral branches of the upper lumbar dorsal rami during RFN. Coskun et al documented 3 cases of lumbosacral radiculopathy after radiofrequency ablation of a pelvic arteriovenous malformation and metastatic cancer. To our knowledge, there are no reports of radiculopathy after spinal medial branch RFN. We discuss the case of a patient with axial low back pain (LBP) who sustained a presumed right L5 nerve root injury during RFN.

CASE DESCRIPTION

A 33-year-old woman complained of axial LBP after a motor vehicle collision (MVC). She was the restrained driver of a stopped car struck from behind by another car. For the first 8 months, she received treatment at an outside facility. Information regarding this treatment was obtained from the patient and from a copy of the complete medical record. A complete physical examination 4 weeks after the inciting event was notable for pain at the right sciatic notch increased in extension, normal deep tendon reflexes, normal motor and sensory findings, and negative bilateral straight-leg raise. The initial radiologic evaluation included normal plain films and normal magnetic resonance imaging (MRI). She was referred to a pain clinic where treatment was initiated with a 5-day methylprednisolone taper and physical therapy without improvement. She then received an L5-S1 interlaminar epidural corticosteroid injection, repeated 2 weeks later, followed by a right sacroiliac joint injection. Again, she experienced no change in her pain.

Five months after the MVC, she received bilateral L3 and L4 medial branch blocks along with bilateral L5 dorsal ramus blocks with excellent temporary pain relief. She then underwent bilateral L3 and L4 medial branch and bilateral L5 dorsal ramus RFN. According to the procedure note, electrode location was confirmed by sensory stimulation at 50Hz and motor stimulation at 2Hz, to a maximum of 1V each. No symptoms or muscle activity in the limbs were observed, but twitching of the multifidus muscle was observed. Then, a 5-mm active tip electrode was used to create a single lesion at 80°C for 120 seconds. After recovering from sedation, she noted resolution of her left back pain. Her right back pain had not improved. More important, she had new right lower-extremity pain with paresthesias extending to the dorsum of her right foot. These new symptoms were unresponsive to rofecoxib, valdecoxib, tramadol, cyclobenzaprine, metaxalone, hydrocodone and acetaminophen, and baclofen. She had minimal relief with morphine and gabapentin. She reported 70% improvement with the use of a transcutanous electric nerve stimulator unit, but eventually developed second-degree burns over the right lumbar region due to its near-continuous high-intensity use. Because she never received a diagnosis or explanation for the new leg pain, she decided to pursue treatment elsewhere.

She presented to our spine center with this history, 8 months after the MVC and 3 months after the right leg symptoms began. She was involved in litigation against the driver of the
other car and the insurance company. She was considering litigation against the anesthesiologist who performed the RFN.

Her physical examination revealed guarding and diffuse pain-limited motor effort in the right lower extremity. Reflexes were 2/4 at the patellar and Achilles’ tendons bilaterally. She had hypoesthesia to light touch in the right L5 dermatome and to pinprick in the right L3-S1 dermatomes. Her right great toe proprioception was diminished but present. Straight-leg raise was negative bilaterally. We gave a clinical diagnosis of right L5 radiculopathy and initiated further workup with contrast-enhanced lumbosacral MRI and electromyography. Electromyography included sural sensory and peroneal motor nerve conduction studies along with needle examination of the right leg and bilateral lumbar paraspinal muscles at the L5-S1 level. Both the MR image and electromyogram were normal.

Because conservative management had failed, and there was no surgically treatable cause of the radiculopathy, we recommended evaluation for a spinal cord stimulator. She had a successful trial and underwent surgical placement with a Pi-ceans-Quad Compact lead and Synergy Versitrel generator. Postoperatively, she had 90% relief of her right lower-extremity pain and was subsequently able to discontinue all analgesics. Five months postoperatively, her right leg pain worsened. Spine imaging showed stimulator lead migration. This lead was removed and replaced with a Resume lead placed by a T10-11 laminotomy. Now, more than 1 year after the revision, she has had no further complications and continues to have excellent leg pain relief.

**DISCUSSION**

Although the post-RFN right lower-extremity electromyogram showed no evidence of radiculopathy, her history is most consistent with injury to the L5 nerve sustained during dorsal ramus RFN. The dorsal root ganglion of L5 lies in close proximity to the target site for L5 dorsal ramus neurotomy. Anterior misplacement of the electrode into the posterior neuroforamen would place the active tip of the electrode near the dorsal sensory portion of nerve root (fig 1). This is the most likely explanation for this patient’s symptoms. The geometry of lesions created by radiofrequency electrodes makes it possible to create a focal lesion to the dorsal root without injury to the anterior motor portion of the nerve. The normal right lower-extremity electromyogram, the normal motor exam, and the sensory deficits on exam led to a diagnosis of a pure sensory radiculopathy in this patient.

Well-documented pure sensory radiculopathies are rare. A Medline search of the term revealed only 2 applicable case reports. Both relate to unusual focal trauma to the dorsal Medline search of the term revealed only 2 applicable case reports. Both relate to unusual focal trauma to the dorsal...
responsive patient can describe this to reveal incorrect electrode placement. The procedural report states that intravenous conscious sedation was used, but does not specify the sedatives and dosages. The patient reported heavy sedation and complete amnesia of the actual procedure, so it is unlikely she was able to give adequate feedback during the procedure. The L5 nerve injury might have been averted with judicious use of sedation prior to sensory testing.

Sensory testing requires an alert patient, but motor stimulation does not. Motor stimulation is expected to produce level-associated multifidus contraction from L5 cephalad.1,12 With incorrect placement near a spinal nerve, motor stimulation produces contraction of the muscles in the myotome innervated by that spinal nerve. In this case, preneurotomy motor stimulation should have resulted in contraction of the ipsilateral L5-innervated muscles, thus indicating proximity to the L5 nerve root. Although the procedure note indicates motor stimulation evoked no response in the buttock or leg, the maximum voltage was recorded as less than 1V. It is possible that this was not adequate stimulation, because electrodes placed in the posterior foramen may require more than 1V to stimulate the more anterior motor portion of the spinal nerve. It is also possible that light stimulation of the L5 motor fibers did occur but the motor twitching was not identified by the treating physician. When done properly, motor stimulation by an electrode misplaced anteriorly into the neuroforamen results in contractions of muscles in the spinal nerve myotome. Thus, motor stimulation is recommended to verify proper catheter placement, even at levels where multifidus contraction is not expected.

**CONCLUSIONS**

Although rare, serious complications can occur during radiofrequency neurotomy of the medial branches and dorsal rami. The complication reported here can be avoided with meticulous needle placement under fluoroscopic guidance, confirmatory electric stimulation, and judicious use of conscious sedation.

**References**


**Supplier**

a. Medtronic Inc, 710 Medtronic Pkwy, Minneapolis, MN 55432-5604.

Baastrup’s disease has been identified as a source of axial low back pain. There has been debate as to the etiology of pain in patients with Baastrup’s disease. It has been theorized that the pain may originate from degenerative disk disease and spinal stenosis associated with the disease, whereas some have identified the neoarthrosis between joints and accompanying reactive eburnation as the source of pain. We present a simple case report of an 89-year-old woman with symptomatic Baastrup’s disease. The patient underwent a fluoroscopically guided interspinous process injection of 20mg of triamcinolone acetate with local anesthetic. The patient remained pain free for 3 months. The neoarthrosis in Baastrup’s disease may be the primary pain generator in cases of Baastrup’s disease without significant central canal stenosis.

Key Words: Back pain; Case report; Injections; Rehabilitation; Steroids.

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BAASTRUP’S DISEASE was initially characterized by Mayer in 1825.1 Interestingly, Mayer had found the disorder to be most prevalent in old soldiers. The disorder was subsequently described as the “kissing spinous process” disorder to be most prevalent in old soldiers. The disorder was subsequently described as the “kissing spinous process” disease2 and finally fully characterized by Baastrup3 in 1932. At the time, it was described as neoarthrosis between adjacent spinous processes in the lumbar spine; it is most common between L3-4. When found in the lumbar spine, Baastrup’s disease is usually characterized by axial low back pain (LBP), which is exacerbated by lumbar extension.4

The source of the pain in Baastrup’s disease has not fully been identified and has been the source of some debate. Pain associated with Baastrup’s disease is generally thought to be mechanical in nature and secondary to the hypertrophic spinous processes coming into contact with each other. An alternative explanation has been that the pain is actually secondary to degenerative disk disease, which often accompanies Baastrup’s, and not from the spinous processes.5 Interspinous bursal fluid collections have been associated with Baastrup’s disease; these collections have been shown to extend through the ligamentum flavum and lead to central canal stenosis, which may be yet another pain generator.6,7 To our knowledge, there have been no reports of nonsurgical management for Baastrup’s disease. We present a case of Baastrup’s disease being successfully treated with fluoroscopically guided interspinous steroid injections.

CASE DESCRIPTION

An 89-year-old woman with a history of Baastrup’s disease, heart disease, bleeding peptic ulcer, and osteoporosis presented with a chronic history of axial LBP in the setting of lumbar spondylolisthesis and T12-L1 vertebral body compression fracture. She had been treated with a variety of pain interventions including T12-L1 vertebroplasty, lumbar epidural steroid injection, lumbar facet intra-articular steroid injection, radiofrequency lesioning of the lumbar medial branch nerves, and nucleoplasty without any significant long lasting relief. The patient managed the pain with 10mg of hydrocodone and 325mg tablets of acetaminophen orally every 6 hours as needed which gave her minimal relief.

The pain was described as located in the low back without radiation. The quality was described as a sharp, stabbing sensation. The pain intensity was a 10/10 on a visual analog scale (VAS). Provocative factors included prolonged sitting and especially lumbar extension. Palliative factors included forward flexion. The patient added that, because of the intensity of her pain, she had been bedridden for several months.

On physical examination, there was focal tenderness over the L4 and L5 spinous processes but no tenderness with palpation of the lumbar facet joints. Pain was worsened with lumbar extension. The patient was able to toe and heel walk without difficulty. Manual muscle testing revealed 5/5 strength in all lower-extremity myotomes, and sensation was intact to fine touch in all lower-extremity dermatomal distributions. Active root tension signs including straight-leg raise and femoral stretch sign were negative bilaterally. There was no significant tenderness with palpation of the lumbar extensor muscles, hip abductors, greater trochanteric bursa, sacroiliac joint, or piriformis muscles. The patient had a negative Babinski sign bilaterally.

Radiographs (fig 1) were reviewed and showed articulation of the spinous process of L4 with L5 consistent with Baastrup’s disease. In addition, the patient had multilevel degenerative disk disease with associated facet joint osteoarthritis. There was a mild grade I retrolithesis of L3 on L4 and L1 on L2. Magnetic resonance imaging (MRI) (fig 2) of the lumbar spine was also obtained but did not reveal any significant central canal or foraminal stenosis.

The patient was scheduled for a fluoroscopically guided L4-L5 interspinous process steroid injection. After identification of the L4-L5 region on the anteroposterior view, the skin was prepped and draped in a sterile fashion. The region over the L4-L5 area was anesthetized with 1mL of 1% lidocaine. A 9.9-cm (3.5-in) 25-gauge spinal needle was then advanced with...
fluoroscopic guidance between the L4 and L5 spinous processes (fig 3). The latter part of the advancement was performed with the fluoroscope in the lateral view. The spinal needle was advanced until it made contact with the articulation of the L4 and L5 spinous processes. After negative aspiration, a 1-mL solution containing 0.5mL of 1% lidocaine and 0.5mL of 40mg/mL of triamcinolone acetate was injected in slow increments. The stylet was reinserted, and the needle was removed. There were no adverse effects or complications from the treatment.

The VAS score on the procedure on the day of the injection was 10/10. Postprocedure, the VAS score decreased to 0/10; the VAS score remained a 0/10 with the patient supine, seated, and in maximal lumbar extension.

The patient was able to fully wean off all of her narcotic medication use, increase her ambulation distance, and also tolerate physical therapy. The patient remained pain free for 3 months.

DISCUSSION

The differential diagnosis for axial LBP includes lumbar strain, lumbar facet joint arthropathy, central canal stenosis, diskogenic pain, spondylolithesis, paracentral disk herniation, lumbar spondylolisthesis, vertebral compression fracture, and Baastrup’s disease. Our patient may have had a component of lumbar strain; however, she did not have any tenderness with deep palpation of the lumbar extensor mus-

![Fig 1. Lateral view of the lumbar spine: Baastrup’s disease most prominent at L4-5.](image)

![Fig 2. MRI of the lumbar spine: T2-weighted sagittal image of patient with Baastrup’s disease.](image)
over the spinous processes and lumbar extension. Furthermore, she did not have any relief after her nucleoplasty procedure.

The patient had already received trials of lumbar facet steroid injections, epidurals, and intradiskal procedures without success when she presented to our institution. The rationale for attempting interspinous ligament injections was based on the patients’ clinical examination and radiographs. She appeared to have maximal tenderness with palpation of the low lumbar spinous processes. Pain correlated with the neoarthrosis between adjacent spinous processes identified on her radiograph and MRI. Because she did not have any clinical evidence of facet joint tenderness, worsening of pain with flexion, motor or sensory deficits, or active roots tension signs, the decision was made to manage the neoarthrosis between adjacent spinous processes similarly to joint arthropathies (ie, with interspinous steroid injection between the neoarthrosis).

The prevalence of Baasstrup’s disease ranges between 6.2% and 22.1% based on autopsy studies examining bursal index (sum of the heights of the interspinal spaces divided by the total height of the spine), with spines with a lower bursal index being identified as being more predisposed to developing Baasstrup’s disease. The etiology of pain in Baasstrup’s disease is thought to be mechanical in nature and secondary to adjacent spinous processes coming into contact with one another. Caudaveric studies have shown pseudojoints and bony erosions in patients with Baasstrup’s disease; it has been theorized that the pain may be secondary to these processes. Degenerative disk disease and spinal stenosis have also been identified as other potential pain generators. Fatty replacement of paraspinal musculature with denervation has been reported in patients with Baasstrup’s disease.

Interestingly, past surgical excision of affected spinous processes have revealed mixed results. Early studies reported modest benefits; Franck reported the improvement of pain and symptoms in 10 patients who underwent surgical excision of affected spinous processes. By contrast, a subsequent study of 64 patients with total or partial spinous process resection did not show significant improvement in pain intensity.

CONCLUSIONS

Our case suggests that the pain generator in Baasstrup’s disease was in fact the neoarthrosis between adjacent spinous processes. Reactive eburnation and abnormal uptake have been shown in patients with Baasstrup’s on single photon-emission computed tomography bone scintigraphy and would explain the significant pain relief experienced by our patient after steroid injection. This case, however, may not be representative of all Baasstrup’s disease patients because some have been reported to have significant central canal stenosis. A placebo effect may have also been possible but seemed less likely because she had numerous previous interventions without any relief.

When symptomatic patients with Baasstrup’s disease are identified in the absence of central canal stenosis, our case suggests that simple fluoroscopically guided intraspinous ligament steroid injection may be a reasonable first approach. We recommend the use of fluoroscopy because accurate identification of the neoarthrosis between adjacent spinous processes may be difficult from clinical examination alone, especially in patients with complex spinal pathology. Potential risks of the proposed injection include infection, allergic reaction, bleeding, and inadvertent epidural steroid injection.

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References
Acute Bacterial Sacroiliitis in an Adult: A Case Report and Review of the Literature

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Bacterial septic sacroiliitis is an uncommon diagnosis that occurs most frequently in children and young adults. Non-specific physical examination findings often make it difficult to diagnose the condition, thus delaying appropriate treatment. We review the case of a middle-aged woman with sacroiliac joint (SIJ) pain after a torsional injury. Radiographic films showed the pelvis and left lower extremity to be normal. Despite anti-inflammatory medications, analgesics, a corticosteroid injection, and physical therapy, her pain persisted. Laboratory data showed an elevated erythrocyte sedimentation rate and C-reactive protein; otherwise, tests were normal, including negative blood cultures. Magnetic resonance imaging (MRI) revealed a left posteroinferior SIJ effusion and computed tomography (CT) showed an effusion and irregularity in the left SIJ. An SIJ biopsy revealed inflammation suggestive of osteomyelitis. After a course of intravenous antibiotics, the symptoms completely resolved, thus supporting our diagnosis of bacterial sacroiliitis. Repeat MRI and CT confirmed the complete resolution of the sacroiliitis.

Key Words: Case report; Rehabilitation; Sacroiliac joint.

TYPICALLY, SACROILIAC joint (SIJ) pain is caused by trauma resulting from such activities as heavy lifting or prolonged bending and lifting, or as the result of a rear-end motor vehicle collision.1 Fortunately, most symptoms will resolve with appropriate treatment that includes activity modification, medication, physical therapy, and/or injections. Prolonged SIJ pain, however, should prompt a physician to look for other potential etiologies.

Although it represents less than 2% of all nontuberculous septic arthropathies,2-4 bacterial septic sacroiliitis is typically seen in children and young adults. It is less common in middle-aged and elderly people,5 unless there is a history of intravenous drug use, skin and respiratory infections, or genitourinary tract infections.5 Unfortunately, septic sacroiliitis has been difficult to diagnose secondary to nonspecific physical examination findings and poorly localized presenting symptoms.6,7 This often leads to an initial misdiagnosis that ultimately delays effective treatment. We report the case of a middle-aged patient who presented with signs, symptoms, and radiologic evidence of unilateral bacterial sacroiliitis that resolved with antibiotic treatment.

CASE DESCRIPTION

A 40-year-old woman without significant medical history presented to our clinic with a 2-week history of pain in the left gluteal region. She said her pain began after she lurched forward while carrying her luggage at the airport. The pain was sharp and progressed over the next several hours while she was on the aircraft, prompting her to seek an evaluation in the emergency department. Radiographs showed no abnormalities in the pelvis and hip. The patient was treated for a muscle strain and was given narcotic and anti-inflammatory medications on her discharge from the emergency department. Several days later she visited a local physician because of worsening gluteal pain and associated lower back pain. Subsequent magnetic resonance imaging (MRI) of the lumbar spine revealed a right-sided disk protrusion at L2-3, a mild annular disk bulge at both L4-5, and a posterior annular disk tear at L5-S1. She was diagnosed with a piriformis muscle strain and treated with a cortisone injection into the left gluteal region near the SIJ. In addition, she was prescribed an oral steroid, a cyclo-oxygenase-2 inhibitor, and physical therapy.

Two weeks later, she presented to our clinic with continued sharp left gluteal pain that was extremely painful when she engaged in any weight-bearing activity. The pain was aggravated with sitting, standing, and lying down for prolonged periods of time. She noted no exacerbation with coughing or sneezing, or radiation of the pain down the leg, or paresthesias distally in the left lower extremity. Sensation and reflexes were within normative limits. The Patrick and Stinchfield tests were both positive for pain in the SIJ and gluteal areas on the left side. Radiographs of the left hip and pelvis did not reveal any bony abnormalities.

We did a further diagnostic work-up because of the patient’s continued extreme pain in the left gluteal region and new constitutional symptoms (low-grade fever, chills, and fatigue). Laboratory serologies revealed an elevated erythrocyte sedimentation rate (ESR) of 69mm/h, an elevated C-reactive protein (CRP) of 7.5mg/dL, negative Lyme immunoglobulin G and M antibodies, negative antinuclear antibody screen, and negative human leukocyte antibody B-27. She had a normal white blood cell count of 5730/mm³. Blood cultures were also negative. MRI of the pelvis suggested a sacroiliitis rather than...
ACUTE BACTERIAL SACROILIITIS, Bindal

DISCUSSION

Bacterial septic sacroiliitis is more typically seen in children and young adults than in middle-aged or elderly persons. In adults, there is often a history of intravenous drug use, skin and respiratory infections, or genitourinary tract infections. It is thought that the majority of septic sacroiliitis cases occur through hematogenous seeding from a preexisting infection from a distant site. Others have suggested it is the result of local spreading of infection from a spinal or pelvic infection, or direct implantation during trauma or invasive procedures. In our case, the patient’s only trauma was lifting a suitcase and receiving a corticosteroid injection to the SI region while placed on oral steroids. Although it is unclear, perhaps these potential immune-suppressing interventions contributed to her SIJ infection.

Septic sacroiliitis often presents with a triad of fever, an antalgic gait, and buttock pain that may be acute or chronic at its onset. Almost 75% of cases present with an acute onset of fever and severe low back pain that is exacerbated by motion or weight bearing. The remaining 25% have symptoms that emerge gradually with less pain and low-grade or absent fever. Unfortunately, the physical examination is often unreliable in reaching a diagnosis. Such tests as Gaenslen and FABERE (flexion, abduction, external rotation, and extension) may localize the pain to the SIJ, but they are inadequate for differentiating pyogenic sacroiliitis from muscular pain, pelvic fracture, disk disease, or an intra-abdominal process. Other studies show a poor interrater reliability in identifying positive findings on some of the tests used to localize pain to the SIJ. Overall, such maneuvers suggest only that such examination techniques can simply enter SIJ pain into the differential diagnosis.

Several tests may be used to diagnose sacroiliitis. Although abnormalities may not be seen for several weeks after the onset of infection, plain radiographs may show widening of the joint space and blurring of the subchondral plate. Ultrasound has not been helpful except to exclude hip-joint effusions. Bone scans can be positive as early as 3 days after onset of symptoms, but are not specific for bacterial septic sacroiliitis.

MRI and CT appear to be the most useful in evaluating for SIJ pathology. CT is useful in identifying bony pathology and guiding aspiration or biopsy. MRI can delineate fluid in the sacroiliac joint, bone marrow edema, and soft tissue abscesses that may extend into the pelvic cavity, although it has been shown to have a diagnostic sensitivity of 54% for sacroiliitis. MRI is better than CT for evaluating cartilage integrity and detecting osseous erosions in patients with inflammatory and infectious sacroiliitis. As in our case, unilateral disease and edema in the soft tissue and marrow adjacent to the SIJ helps to distinguish infectious from noninfectious sacroiliitis (ie, some seronegative spondyloarthropathies). Laboratory data may be helpful in diagnosing bacterial sacroiliitis, but they do have their limitations. ESR and CRP may be elevated in the majority of cases, but while they are sensitive, they may not be specific. Cultures of SIJ fluid from either surgical exploration or percutaneous arthrocentesis with CT guidance are only positive in 50% to 88% of cases. Positive blood cultures have been reported in 23% to 67% of cases.

Fig 1. CT of the pelvis illustrating widening of the left SIJ with noted effusion and irregularity of the left SIJ, with a loss of cortex on the ilial surface of the joint.

Fig 2. Biopsy of the SIJ shows bone and fibrous tissue with inflamed marrow suggestive of osteomyelitis. NOTE. Hematoxylin and eosin stain, original magnification 100 times.
cases. Despite the best attempts at diagnosis, 40% of reported cases have no identified primary source of infection. In our case, the patient had positive ESR and CRP, but negative sacroiliac joint fluid and blood cultures.

Given the above laboratory limitations, several organisms can be seen in sacroiliitis. Greater than 80% of reported cases are caused by gram-positive bacteria, with Staphylococcus aureus being the most common. Seventeen percent are caused by the gram-negative organism Pseudomonas aeruginosa, most notably in association with intravenous drug use, primary or secondary immunodeficiency, underlying chronic diseases, prior prolonged broad spectrum antibiotic use, or in people with genitourinary or other invasive procedures. Escherichia coli was cited in 8 cases in 1 study, usually in conjunction with urinary tract infections. Other strains of Staphylococcus, Streptococcus, salmonella, Klebsiella, Neisseria gonorrhoeae, gram-negative enteric organisms, and anaerobes have also been reported in the literature.

Treatment of septic sacroiliitis includes 4 to 8 weeks of parenteral antibiotic therapy, occasionally followed by a course of oral antibiotics to prevent recurrence. Antibiotics result in resolution of symptoms in 1 to 2 weeks, with few long-term sequelae. Delayed diagnosis and treatment of septic sacroiliitis increases the risk of the formation of abscesses, septicemia, and hematogenous or seeding of infection to distant sites, especially in patients with total arthroplasties. Fortunately, distant metastasis via hematogenous spread is rare, with 2 reported cases of septic spread to the glenohumeral joint and 1 case of meningitis. Surgical intervention is warranted, especially in those patients with abscess formation, evidence of contiguous osteomyelitis, sequestrum of necrotic bone, and failure to respond to antibiotic therapy. In our case, the patient’s clinical symptoms, low-grade fever, and imaging findings, we elected to proceed with antibiotic treatment and surgery. Too often, these findings are ignored and the pain is treated with nonsteroidal anti-inflammatory drugs, therapy, or an injection. We believe the dramatic and rapid improvement of our patient’s symptoms after antibiotic therapy was initiated strongly supports the diagnosis of bacterial septic sacroiliitis. Physicians must be aware of the possibility of an SIJ infection early on and proceed with the appropriate laboratory and imaging studies before initiating treatment.

CONCLUSIONS

Infectious SIJ disease can be difficult to diagnose, given the nonspecific symptoms and physical examination findings. Clinicians should be aware of the diagnosis, however, even in the acute setting or in unilateral cases. With appropriate laboratory and imaging workup, the appropriate treatment can be initiated without delay and without any long-term complications. As was true for our patient, the proper identification of bacterial septic sacroiliitis frequently leads to a positive outcome.

References

Further Validation of the Orientation and Cognitive Logs: Their Relationship to the Mini-Mental State Examination

Suzanne Penna, PhD, Thomas A. Novack, PhD, ABPP


Objective: To further evaluate the construct validity of bedside screening measures of orientation (Orientation Log [O-Log]) and cognition (Cognitive-Log [Cog-Log]) by examining the relationship between these measures and the Mini-Mental State Examination (MMSE).

Design: Correlational analysis used to assess the degree of overlapping variance among the O-Log, Cog-Log, and MMSE. Qualitative item analysis used to assess strengths and weaknesses of the measures.

Setting: Inpatient rehabilitation center affiliated with a large university medical school.

Participants: Participants were 45 inpatients receiving neurorehabilitation.

Interventions: Not applicable.

Main Outcome Measures: The O-Log, Cog-Log, and MMSE.

Results: The MMSE correlated significantly with both measures (O-Log, r=.65, P<.001; Cog-Log, r=.75, P<.001). The O-Log and C-Log were significantly related to each other (r=.75, P<.001).

Conclusions: The results indicated good construct validity of the O-Log and Cog-Log. These measures may be better suited for a population with moderate to severe brain injury in a rehabilitation setting, compared with the MMSE, because scales were developed to give partial credit based on partially correct answers. Further, the O-Log and C-Log do not have a written component, allowing administration for persons with hemiparesis.

Key Words: Brain injuries; Cognition; Orientation; Rehabilitation; Reliability and validity.

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THE ORIENTATION LOG (O-Log)1 and Cognition Log (Cog-Log)2 were developed as brief, bedside instruments to assess cognition during recovery from neurologic disorders. The reliability1 and validity3,4 of the O-Log has been confirmed. It compares favorably with the Galveston Orientation and Amnesia Test, an established measure of orientation. The O-Log also is predictive of cognitive outcome at discharge from an inpatient rehabilitation setting.5,6 The Cog-Log has exhibited good interrater reliability2 as well as significant correlations with neuropsychologic measures of memory, language, attention, and reasoning.2 Scores on the Cog-Log are predictive of neuropsychologic outcome 1 year after brain injury.7

Neither the O-Log nor the Cog-Log has been compared with established instruments that briefly assess mental status. There is hesitancy to use the O-Log and Cog-Log in the medical community without such a comparison being available, as reflected in questions to the authors about the scales. The purpose of the current study was to further establish construct validity of the O-Log and Cog-Log by comparing them with the Mini-Mental State Examination (MMSE),3,5 the most widely used mental status screening instrument.8 It is hypothesized that the O-Log and Cog-Log will be highly correlated with the MMSE.

METHODS

Participants

Our patient sample included 45 consecutively admitted inpatients receiving treatment at an acute rehabilitation hospital. To approximate a clinical situation with maximum generalizability, we included patients with known or suspected cognitive impairment of varying etiology. The sample consisted of 68% with traumatic brain injury (TBI), 27% with vascular accident, and 4% with brain tumor. Of the patients with TBI, 61% were severely brain injured (Glasgow Coma Scale [GCS] score <9), and 13% were moderately brain injured (GCS score range, 9–12). Ages ranged from 17 to 81 years (mean age ± standard deviation [SD], 39.7±18.5y). There were 26 (60%) men and 18 (40%) women. The majority of the sample was white (80%), with 18% African American, and 2.3% Asian/Pacific Islander. The majority (71%) of the sample had a high school education or less. No participant withdrew from the study.

Measures

Orientation Log. The O-Log is a 10-item bedside instrument with questions clustered into 3 domains: place, time, and situation. Each item is scored between 0 and 3 on the basis of the response, with cueing provided after incorrect responses. The range of scores is 0 to 30, with higher scores representing better orientation.

Cognitive Log. The Cog-Log is a 10-item scale that serves as a bedside screening of cognition. It includes items assessing verbal learning and recall, attention, working memory, motor sequencing, time estimation, and response inhibition. Each item is scored from 0 to 3, taking into account errors in responding.

Mini-Mental State Examination. The MMSE5 is an 11-item test designed to screen for cognitive impairment. Scores...
range from 0 to 30, with higher scores indicating better performance. Items focus on orientation questions, attention and concentration, language, constructional ability, and immediate and delayed recall. Interrater reliability is over .65.8

Procedure

The study was approved by the university institutional review board. Data collection took place as a routine part of patient care provided by the primary author (SP). Data were gathered at 2 time points during the day. The O-Log and Cog-Log were administered in 1 sitting. The MMSE was administered at a different time on the same day to minimize practice effects. The administration of the measures was counterbalanced.

We used correlation coefficients to assess the degree of overlapping variance among the 3 measures. Assuming a large effect size for a correlation coefficient, and a sample size of 45 at an α level of .05, power is over .80.10

RESULTS

The range of scores on the O-Log was 14 to 30 (mean ± SD, 4.8±4.6). The range of scores on the Cog-Log was 3 to 30 (mean, 19.8±6.4). The range of scores on the MMSE was 10 to 30 (mean, 22.2±4.8).

Using Pearson correlation coefficients, the MMSE total score correlated significantly with both the O-Log (r=.65, P<.001) and the Cog-Log total scores (r=.75, P<.001). The O-Log and Cog-Log total scores correlated significantly (r=.75, P<.001). Individual items from the measures were examined to provide a detailed picture of the relationship between the measures. The orientation questions relating to time (eg. What is the date?) did not correlate significantly between the MMSE and the O-Log and Cog-Log. Orientation questions based on place (eg. What city are you in?) were significantly related (r=.74, P<.001). There was a significant relationship between working memory items on the Cog-Log and MMSE (r=.39, P<.01) and between items assessing delayed recall of new information on the Cog-Log and MMSE (r=.391, P<.01).

DISCUSSION

The results support the validity of the O-Log and Cog-Log in relationship to the MMSE. As hypothesized, the O-Log and Cog-Log correlated highly with the MMSE. This finding is consistent with expectation given that the measures studied are designed to provide brief estimates of orientation and cognitive functioning. This is consistent with prior research showing the efficacy of the Cog-Log as a measure that captures cognitive skills in a general sense,7 and the O-Log as a measure that captures orientation in a general sense5; along with the MMSE, which combines the two.8

Individual item analysis revealed significant correlations between items assessing orientation to place, working memory, and delayed recall for new information. It was surprising that items assessing orientation to time were not significantly related. Further inspection of the data suggests that this was likely due to the difference in the scoring of the measures. The O-Log and Cog-Log provide greater variability in scoring on individual items than the MMSE, which scores items dichotomously (right or wrong). Participants who could not directly answer orientation questions may have received some credit on the O-Log and Cog-Log items while receiving no credit on the MMSE. Variable scoring of items on the O-Log and Cog-Log is considered a benefit because it allows the clinician to observe the response to logical cues, particularly in situations when verbal output may be limited.

The O-Log and Cog-Log also have an advantage over the MMSE in that no materials are needed to administer either measure. The MMSE requires the manipulation of a writing implement for a visuospatial task and a task of written language. The use of a writing implement may be difficult or impossible with brain injured patients who are hemiparetic or unable to use their hands due to peripheral injury.

Study Limitations

There were some study limitations. Primary among them was the increased likelihood of type I error due to the number of statistical analyses. Also, it is possible that the positive relationship among the measures was due to the method of administration (eg, verbal questioning or by the fact that a single individual administered the questionnaires), rather than the content of the questions asked. A multitrait, multimethod approach would address this potential confounding variable, and so it is an area for future research. Another possible limitation of the study was the inclusion of a heterogeneous sample; however, this was done to maximize the generalizability to everyday clinical situations. Future research could include a study replication using other brain compromised populations, particularly dementia.

CONCLUSIONS

The study provides support for the O-Log and Cog-Log as valid measures of cognitive functioning relative to the MMSE, an established measure of mental status. The O-Log and Cog-Log have advantages in administration over the MMSE including the use of partial credit, no materials to manipulate, and the inclusion of items that assess a person’s awareness of their situation.

References

BRIEF REPORT

Ultrasound-Guided Blockade of the Lateral Femoral Cutaneous Nerve: Technical Description and Review of 10 Cases

Mark F. Hurdle, MD, Toby N. Weingarten, MD, Ralph A. Crisostomo, MD, Christina Psimos, BS, Jay Smith, MD


Blockade of the lateral femoral cutaneous nerve (LFCN) is performed for therapeutic management of meralgia paresthetica and as a regional anesthetic technique. The conventional technique is associated with high failure rates secondary to variable LFCN anatomy. We describe a technique for blockade of the LFCN using ultrasound guidance. A cross-sectional view of the LFCN was obtained by identifying the anterior superior iliac spine, then moving a 14- to 7-MHz linear array ultrasound probe in a medial caudal direction until the nerve was encountered. The needle was advanced to the LFCN under ultrasound guidance via a lateral to medial approach. Injection using dynamic ultrasound demonstrated excellent perineural spread. Ten subjects underwent successful blockade of the LFCN with this technique. Five subjects were obese. Use of ultrasound for precise needle placement allowed low injection volumes to be utilized. Thereof were no complications. Ultrasound guidance can facilitate blockade of the LFCN for diagnostic and therapeutic purposes and may be particularly beneficial with patients with challenging surface anatomic landmarks, or when low volume injections are desired.

Key Words: Femoral nerve; Nerve block; Rehabilitation; Ultrasound.

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Regional Blockade of the lateral femoral cutaneous nerve (LFCN) with local anesthetic is performed as a regional anesthetic technique for surgical procedures and for the diagnosis and treatment of meralgia paresthetica.1–3 Blockade of the LFCN is classically described as using anatomic landmarks,4 but anatomic variability leads to failure rates as high as 60%.5 Regional anesthetic techniques utilizing ultrasound guidance to visualize target nerves are gaining popularity.6–10 Ultrasound guidance is particularly suited for injection of a structure such as the LFCN because of its anatomic variability.11–14 We present here a technical description of the performance of ultrasound-guided LFCN blocks. We also provide a case series of patients who were sent to our clinic with the working diagnosis of meralgia paresthetica or lateral thigh pain for a LFCN block under ultrasound guidance. We feel that this technique can overcome the anatomic variability common to the course of this nerve.

TECHNICAL DESCRIPTION

The patient is placed in the supine position. Use of a high-frequency (>10MHz) linear array transducer is suggested. For our case series, we utilized a 14- to 7-MHz linear array transducer. The anterior superior iliac spine (ASIS) is palpated and visualized with the ultrasound probe as a hyperechoic structure with posterior acoustic shadowing. The lateral end of the linear probe is placed on the ASIS and the medial end extends medially in an anatomic transverse plane. With the probe in this position, the medial part of the probe is angled slightly in a caudal direction so the transducer is parallel with the inguinal ligament. The transducer is gently moved in a medial-caudal direction while the operator searches for the echo signature of the LFCN. Using this approach, the LFCN will appear in cross-section as an oval hyperechoic structure containing several circular hyperechoic fascicles. This appearance has been likened to a honeycomb (fig 1). The nerve is visualized beneath the fascia lata. After identifying the LFCN, the operator continues the sweep medially until the neurovascular bundle of the femoral nerve, artery, and vein are visualized in a transverse view. After the position of the neurovascular bundle is noted, the operator once again moves laterally to identify the LFCN. Even an experienced ultrasonographer may take several sweeps to visualize the LFCN.

Several anatomic variations in the course of the LFCN at the ASIS have been described.11–14 Therefore, if the LFCN is not identified using the technique above, the operator should scan anterior and lateral to the ASIS. Once the LFCN is visualized in a transverse plane, the nerve should be traced proximally and distally to confirm its appropriate course toward the lateral thigh. The nerve is then visualized in a longitudinal plane for confirmation as well.

Injections are performed with strict adherence to sterile techniques with appropriate skin preparation, and sterile ultrasound probe covers, sterile ultrasound gel. After confirming the location of the LFCN, the operator advances the needle under direct ultrasound visualization to the LFCN while maintaining a short axis (transverse) view of the nerve. The needle is advanced in a longitudinal view relative to the transducer to ensure visualization of the entire needle. Injection of local anesthetic results in perineural spread that is visualized on ultrasound (fig 2).
CASE DESCRIPTION

With approval from our institutional review board, the charts of our first 10 patients who underwent ultrasound-guided LFCN blocks were reviewed. Table 1 lists patient and injection characteristics. Four men and 6 women underwent injections, with a patient mean age of 55 years (range, 19–79y) and a mean body mass index (BMI) of 31.0kg/m² (range, 19.8–43.6kg/m²). A single operator (MFH) performed all injections, using a 14-to-7MHz linear array transducer. Needle placement was performed as described above. Injection resulted in perineural spread in all cases. No paresthesias were observed. The initial 2 injections were performed with a volume of 7 to 8mL of solution containing local anesthetic and triamcinolone ace-tonide for possible therapeutic affect. Subsequent injections were performed with smaller volumes of 1 to 2mL.

Assessment of the block was by sensory testing with pin-prick and light touch 30 minutes after the injection. All patients developed hypoesthesia in locations concordant with LFCN distribution. There were no sensory changes in the femoral and obturator nerve distributions and no changes in motor function.

DISCUSSION

The literature from 1950 to the present was reviewed using OVID Medline; to our knowledge, this is the first description of an ultrasound-guided LFCN block technique based on a case series. Traditionally, this injection is performed by inserting a needle medial and caudal to the ASIS and injecting local anesthetic in a fan-like fashion as a field block technique.4 The success rate using this technique has been reported to be as low as 40%.5 This low rate is, in part, secondary to the lack of a predictable relationship of the LFCN to a palpable vascular structure or close proximity to a bony landmark. Another explanation for the poor success of this blockade is the wide anatomic variability in the course of the LFCN. The nerve courses from the pelvis to the thigh by passing under the inguinal ligament medial to the ASIS. Anatomic studies have demonstrated that the distance from the LFCN at the inguinal ligament to the ASIS can range from 3mm to 7.3cm11-13 and the LFCN has even been described as being lateral to the ASIS.14 Shannon et al5 described 100% success in blocking the LFCN by using a nerve stimulator to achieve a paresthesia. Anatomic variability can limit the usefulness of such a technique, however, and Shannon5 reported that the nerve stimulator technique took almost twice as long as the fan technique to block the LFCN. Nerve stimulation can also be uncomfortable for the patient. The time required to perform this technique was not recorded, but it was our perception that the procedure time was substantially decreased with greater experience with the technique.

Ultrasound-guided peripheral nerve blocks allow real-time visualization of relevant anatomy and needle positioning under live guidance. Ultrasound-guided nerve blocks have been shown to be superior to conventional blocks of the brachial plexus and ilioinguinal and iliohypogastric nerves.6,7 In this series, ultrasound imaging identified the LFCN in all cases. Successful imaging was achieved even with obese patients (n=5). In all of our cases, we were able to visualize the LFCN with a 14-to-7MHz transducer with a central frequency of 12MHz. Very obese patients could conceivably require lower frequency imaging, which would sacrifice resolution and possibly compromise an operator’s ability to accurately identify the LFCN with ultrasound. The BMI threshold at which the

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (y)</th>
<th>Sex</th>
<th>BMI (kg/m²)</th>
<th>Side</th>
<th>Volume (mL)</th>
<th>Injectate*</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>42</td>
<td>Female</td>
<td>30.6</td>
<td>Left</td>
<td>8</td>
<td>Bupivacaine (.25%)</td>
</tr>
<tr>
<td>2</td>
<td>74</td>
<td>Female</td>
<td>43.6</td>
<td>Right</td>
<td>7</td>
<td>Bupivacaine (.25%)</td>
</tr>
<tr>
<td>3</td>
<td>56</td>
<td>Male</td>
<td>34.6</td>
<td>Right</td>
<td>2</td>
<td>Lidocaine (1%)</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>Female</td>
<td>40.3</td>
<td>Left</td>
<td>2</td>
<td>Lidocaine (1%)</td>
</tr>
<tr>
<td>5</td>
<td>71</td>
<td>Male</td>
<td>24.0</td>
<td>Right</td>
<td>2</td>
<td>Lidocaine (1%)</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>Male</td>
<td>25.5</td>
<td>Right</td>
<td>2</td>
<td>Lidocaine (1%)</td>
</tr>
<tr>
<td>7</td>
<td>61</td>
<td>Female</td>
<td>29.6</td>
<td>Right</td>
<td>1</td>
<td>Bupivacaine (.25%)</td>
</tr>
<tr>
<td>8</td>
<td>39</td>
<td>Male</td>
<td>36.9</td>
<td>Right</td>
<td>2</td>
<td>Lidocaine (1%)</td>
</tr>
<tr>
<td>9</td>
<td>51</td>
<td>Male</td>
<td>24.7</td>
<td>Left</td>
<td>2</td>
<td>Lidocaine (1%)</td>
</tr>
<tr>
<td>10</td>
<td>79</td>
<td>Female</td>
<td>19.8</td>
<td>Right</td>
<td>2</td>
<td>Lidocaine (1%)</td>
</tr>
</tbody>
</table>

*The injectate contains local anesthetic and triamcinolone acetone.
ultrasound-guided LFCN block becomes problematic remains indeterminate and requires further investigation. We successfully used ultrasound to block patients with BMIs as high as 43kg/m² (see table 1). Using ultrasound guidance for needle placement, we achieved sensory blockade of the LFCN in all patients. In comparison, failure rates with blind injection of the LFCN have been reported to be as high as 60%.9 As noted by Marhofer and Chan,10 however, smaller (<1cm) nerves in deeper locations are more challenging to image and block and consequently ultrasound-guided blocks will occasionally fail.

Inadvertent blockade of the femoral and obturator nerves has been described as a complication of LFCN injections, presumably because of the higher volumes used to inject this structure without image guidance.15,16 Injection volumes of 10 to 15mL have been advocated.4 Because ultrasound guidance allowed for close proximity of the needle to the LFCN, we were successful in blocking the LFCN with very small volumes of anesthetic agents. There were no complications such as a blockade of nearby nerves.

The ability to guide the needle into close proximity of the LFCN under direct visualization adds a theoretical degree of safety. Blind field block injections could theoretically result in needle trauma of the target neural structure. In this series, no patient reported a paresthesia during injection, which suggests that our needle did not come in direct contact with the LFCN. Also by direct visualization of the needle tip, inadvertent placement of the needle into the peritoneal cavity can be avoided.

CONCLUSIONS

Ultrasound-guided injections of the LFCN allow for consistent blockade of the nerve with minimal volumes. We feel this technique is superior to the traditional approach to blocking the LFCN. Randomized controlled studies should be performed to directly compare the different techniques.

References


Suppliers
a. Toshiba Nemio, 20 Ultrasound Unit, Toshiba, Tokyo, Japan.
b. Betadine; Purdue Pharma, 1 Stamford Forum, 201 Tresser Blvd, Stamford, CT 06901-3431.
c. Chlorhexidine; Enturia Inc, 11400 Tomahawk Creek Pkwy, Ste 310, Leawood, KS 66211.

Correction

In figure 1 on page 958 of English CK, Hillier SL, Stiller KR, Warden-Flood A. Circuit class therapy versus individual physiotherapy sessions during inpatient stroke rehabilitation: a controlled trial. Arch Phys Med Rehabil 2007;88:955-63, the data on eligible participants excluded from the trial (Excluded n=146; Refused informed consent n=8; Circuit class had maximum participants at time of admission n=4) should be replaced with: Excluded n=79.
ARTICLE OBJECTIVES:

Article One: **Comparison of a Functional Restoration Program With Active Individual Physical Therapy for Patients With Chronic Low Back Pain: A Randomized Controlled Trial**

Learning Objective: After completing this article and with appropriate self-study, the participant will be able to:

a) Compare the components of an active individual therapy program and a functional restoration program for patients with chronic low back pain.
b) List 3 measures where there was no significant difference in outcome between the 2 treatment groups.
c) Discuss the relevance of the areas where there was a significant difference between the 2 treatment groups.

Article Two: **The Effect of Hippotherapy on Spasticity and on Mental Well-Being of Persons With Spinal Cord Injury**

Learning Objective: After completing this article and with appropriate self-study, the participant will be able to:

a) List 3 methods employed to decrease spasticity.
b) Recall the effect on spasticity due to the interventions based on clinical assessment and self-report.
c) Discuss the immediate and long-term effect of hippotherapy on mental well-being.

Article Three: **Musculoskeletal Disorders in Referrals for Suspected Cervical Radiculopathy**

Learning Objective: After completing this article and with appropriate self-study, the participant will be able to:

a) List 3 musculoskeletal disorders that can be mistaken for a cervical radiculopathy.
b) Recall the cervical nerve root or roots associated with these disorders.
c) Discuss the prevalence of musculoskeletal disorders in patients with and without electromyographic evidence of cervical radiculopathy.

**INDICATE THE DEGREE TO WHICH YOU AGREE OR DISAGREE WITH EACH STATEMENT**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Not Certain</th>
<th>Agree</th>
<th>Strongly Agree</th>
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</thead>
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<td>D</td>
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<td>A</td>
<td>SA</td>
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<tr>
<td>2. Objectives for article two were met.</td>
<td>SD</td>
<td>D</td>
<td>NC</td>
<td>A</td>
<td>SA</td>
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<tr>
<td>3. Objectives for article three were met.</td>
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<td>D</td>
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<td>A</td>
<td>SA</td>
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<tr>
<td>4. I learned a new skill or patient management approach</td>
<td>SD</td>
<td>D</td>
<td>NC</td>
<td>A</td>
<td>SA</td>
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<tr>
<td>5. This material will enhance my professional effectiveness</td>
<td>SD</td>
<td>D</td>
<td>NC</td>
<td>A</td>
<td>SA</td>
</tr>
<tr>
<td>6. I plan to implement a change(s) to my practice as a result of this material.</td>
<td>SD</td>
<td>D</td>
<td>NC</td>
<td>A</td>
<td>SA</td>
</tr>
</tbody>
</table>

If you circled “Agree” or “Strongly Agree,” please give one example:

___________________________________________________________________________

7. In what ways did/will you utilize the information from these articles in your medical practice? I have used/will use it to:

- [ ] Confirm previous knowledge and reinforce clinical practice
- [ ] Study for recertification examination
- [ ] Serve as initial resource for clinical problems
- [ ] Apply new techniques/procedures to the care of my patients
- [ ] Use the information to train staff
- [ ] Share the information with colleagues
- [ ] Help develop new policy and procedures
- [ ] Other (please specify):

8. The material was fair, objective, and unbiased toward any product or program. Yes ......No

9. Please share any general comments, recommendations, or an elaboration of any item on this form:

___________________________________________________________________________

___________________________________________________________________________

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*Archives of Physical Medicine and Rehabilitation*  
Volume 87, Issue 11, Pages 1509-1515 (November 2006)

Cindy B. Ivanhoe, MD, Gerard E. Francisco, MD  
John R. McGuire, MD, Thyagarajan Subramanian, MD, Samuel P. Grissom, MD

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Co-Director, Brain Injury Research Center, Memorial Hermann/TIRR

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The 2007 presentation is scheduled for 4:00 PM, October 5, 2007 at the ACRM-ASNR Joint Educational Conference in Washington, DC.

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The International Committee of Medical Journal Editors (ICMJE) and the Council of Science Editors support the registration of prospective clinical trials that involve human subjects “to study the cause-and-effect relationship between a medical intervention and a health outcome.” Archives’s editors have adopted in principle the spirit of the requirement to register clinical trials, at or prior to subject enrollment. At this time, however, it is not a requirement of submission that authors whose studies meet the ICMJE criteria (criteria available at: http://www.archives-pmr.org) register their trials or, if they do, comply fully with the Minimal Registration Data Set. In the future and by prior notice, Archives’s editors may make registration and compliance mandatory, that is, a condition prior to peer review. Authors who have registered their trials should provide the trial registration number in the cover letter to their submissions. Registration numbers will appear in all content published in the journal.

IRB and Animal Care Committee Approval

Research submitted to Archives must comply with accepted ethical standards for human and animal research. When submitting work to Archives, authors must certify (1) that their institution or the appropriate regional institution approved the protocol for any investigation involving humans or animals (or that the research complied with the Declaration of Helsinki) and (2) that the conduct of all investigation conformed to the protocol and the ethical and humane principles of research.
Case Reports and Single-Case Studies

With the implementation of the US Health Insurance Portability and Accountability Act (HIPAA), federal regulations now govern the privacy of patient data in the United States. To comply with HIPAA without compromising important clinical detail, authors submitting case reports (category Clinical Notes) or single-case studies (category Articles) are required to assure the anonymity of patients (including names, uniquely identifying personal descriptors, detailed family trees, and geographic location). Authors need to deidentify subjects in the manuscript and photographs OR obtain from each patient a written consent to publish the manuscript and photographs (a form is available at: http://www.archives-pmr.org). If patient consent for publication is obtained, a copy of that document must accompany the manuscript submission. All manuscripts submitted to Archives, whether from domestic or international authors, must comply with this standard at submission.

Patients’ Rights to Privacy

Patients and research subjects have a right to privacy that should not be infringed without informed consent. Identifying information will not be published in written descriptions, photographs, and pedigrees unless the information is essential for scientific explanation and the patient (or legal proxy) gives written informed consent for publication. Informed consent for this purpose requires that the patient or proxy be shown the manuscript to be published.

Identifying details should be omitted if they are not essential, but patient data should not be altered or falsified to attain anonymity. Complete anonymity is difficult to achieve, and informed consent should be obtained when doubt exists. For example, masking the eye region in photographs of patients is inadequate protection of anonymity.

MANUSCRIPT PREPARATION

Authors should prepare manuscripts according to the “Uniform Requirements for Manuscripts Submitted to Biomedical Journals,” as developed by the International Committee of Medical Journal Editors. A copy of the Requirements is available at http://www.icmje.org.

Manuscripts must be double-spaced throughout, including title page, abstract, text, acknowledgments, references, individual tables, and legends. Use only standard 12-point type and spacing. Unjustified, flush-left margins and letter-quality printing. Number pages consecutively, beginning with the title page. Put the page number in the upper or lower right-hand corner of each page. **Number each line on each page to facilitate peer review.**

Title Page

The title page should include:

1. a short running head of no more than 40 characters (count letters and spaces)
2. the article title (informative but concise);
3. first name, middle initial, and last name of each author, with highest academic degree(s);
4. all authors’ institutional affiliations (department, institution, city, state/province);
5. disclaimers, if any;
6. if all or part of the material in the manuscript was presented at a meeting, report the organization, city, and date of presentation
7. the source(s) of support in the form of grants, equipment, drugs, or all of these;
8. the authors’ financial disclosure (as selected in the Disclosure Statements & Copyright Assignment form) and description of authors’ conflicts of interest
9. complete name, address, telephone number, fax number, and e-mail address of the designated corresponding author to whom all communications and reprint requests should be addressed; and
10. a statement if reprints will not be available from the authors.

Abstract

For Articles reporting original data (Article; Brief Reports; Prosthetics, Orthotics, Devices; Clinical Management Reviews; Clinical Implications of Basic Research) and Review Articles (including Meta-Analyses), see the Instructions for Structured Abstracts. For other manuscripts (eg, Clinical Notes, Commentaries, Special Communications), include a conventional, unstructured abstract of no more than 275 words.

Accompanying all abstracts, authors must provide 3 to 5 Key Words. Key words must be selected from the US National Library of Medicine’s (NLM) Permitted Medical Subject Headings, which is available at http://www.nlm.nih.gov/mesh/MBrowser.html.

Text (see Instructions for Structured Abstracts)

The text of observational and experimental articles is usually divided into sections with the headings Introduction, Methods, Results, Discussion, and Conclusions. Longer articles may need subsection headings to clarify their content, especially the Results and Discussion sections.

Clinical Notes are usually divided into sections with the headings Introduction, Case Description, Discussion, and Conclusions.

Clinical Management Reviews should have the following sections: Introduction, Summary of Pertinent Research, Therapeutic Approach, and Conclusions.

Other types of articles such as Commentaries and Special Communications do not require this format.

**Introduction:** State the purpose of the article. Summarize the rationale for the study or observation. Give only pertinent references, and do not review the subject extensively. Do not include data or conclusions from the work being reported.

**Methods:** Describe the selection of the observational or experimental subjects (patients or experimental animals, including controls) clearly. Discuss eligibility of experimental subjects. Give details about randomization. Describe the methods, including statistical methods (see below); provide very brief descriptions for methods that have been published but are not well known; describe new or substantially modified methods, give reasons for using them, and evaluate their limitations. Identify precisely all drugs and chemicals used, including generic name(s), dose(s), and route(s) of administration.

**Archives** will accept only studies that have strictly observed a sufficient length of time for follow-up. For a surgical procedure, the recommended minimum follow-up period is 2 years. For a nonsurgical modality, a 1-year follow-up period is recommended. Longer-term follow-ups are important and encouraged. All follow-up studies must be evaluated by an unbiased observer. Follow-up studies based solely on chart material are not acceptable.

When reporting experiments on human subjects, indicate whether the procedures followed accord with the ethical standards of the responsible institutional review board or with the Helsinki Declaration of 1975, as revised in 1983. Do not use patients’ names, initials, or hospital numbers, especially in any
illustrative material. When reporting experiments on animals, indicate whether the procedures followed accord with the institution’s committee on animal experimentation or with the National Research Council’s guide on the care and use of laboratory animals. Archives may require authors to verify the above procedures.

Describe statistical methods in enough detail to enable knowledgeable readers with access to the original data to verify the reported results. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (eg, confidence intervals [CIs]). Avoid sole reliance on statistical hypothesis testing, such as P values, which fails to convey important quantitative information. Researchers should report and identify the specific statistical test used and the obtained statistical value. Researchers should supplement the results of any statistical value. Researchers should supplement the results of any statistical significance test with the use of effect size values or CIs. Measures of effect size or CIs should be routinely included in quantitative clinical trials reported in rehabilitation research. The statistical power values and the corresponding type II error probability should always be reported for statistically nonsignificant results. The investigator should ensure that there is sufficient power to detect, as statistically significant, a clinically meaningful treatment effect of an a priori specified size. References for study design and statistical methods should be to standard works (with pages stated) rather than to papers in which designs or methods were originally reported. Specify any general use computer programs used. Avoid non-technical uses of technical terms in statistics, such as “random” (which implies a randomizing device), “normal,” “significant,” “correlation,” or “sample.” Define statistical terms, abbreviations, and symbols. The Editorial Board has adopted the CONSORT (Consolidated Standards for Reporting Trials) statement, which applies to randomized controlled trials (RCTs). When submitting manuscripts on RCTs, authors must include the CONSORT flow diagram outlining the progress of subjects through the various phases of the RCT. The flow diagram and explanation can be accessed at http://www.consort-statement.org/Downloads/flowchart.doc.

Results: When data are summarized in the Results section, specify the statistical methods used to analyze them. Describe the success of any blinding of observations. Report treatment complications. Give numbers of observations. Report losses to observation (ie, dropouts from a clinical trial). Present results in logical sequence in the text, tables, and illustrations. Restrict tables and figures to those needed to explain arguments and to assess their support. Use graphs as an alternative to tables with many entries; do not duplicate data in graphs and tables. Do not repeat in the text all the data in the tables, illustrations, or both; emphasize or summarize only important observations.

Discussion: Emphasize the new and important aspects of the study and the conclusions that follow from them. Do not repeat in detail data or other material given in the Introduction or the Results section. Include in the Discussion section the implications of the findings, including implications for future research. Authors should address the issue of effect magnitude, in terms of both the statistics reported and the implications of the research. Relate the observations to other relevant studies. Authors must include in the Discussion section a subsection, Study Limitations, to discuss the limitations of the study.

Conclusions: Link the conclusions with the study’s goals but avoid unqualified statements not completely supported by the data. Avoid claiming priority and alluding to work that is incomplete. State new hypotheses when warranted, but clearly label them as such. Recommendations, when appropriate, may be included.

Acknowledgments

One or more statements should specify: (1) contributions that do not justify authorship (ie, third-party statistical analysis, writing/editing); and (2) acknowledgments of technical help.

Persons who have contributed intellectually to the manuscript but whose contributions do not justify authorship must be named and their function or contribution described, eg, “scientific advisor,” “critical review of study proposal,” “data collection,” or “participation in clinical trial.” Such persons must give permission to be named. Authors are responsible for obtaining written permission from persons acknowledged by name because readers may infer their endorsement of the data and conclusions.

Clerical, administrative, and laboratory staff should not be acknowledged, unless they have contributed significantly to the research, writing, or intellectual quality of the article.

Acknowledge financial and material support and financial relationships that may pose a conflict of interest on the title page (see Manuscript Preparation and Disclosure Statements & Copyright Assignment).

References

References in manuscripts accepted by Archives shall include only material that is retrievable through standard literature searches. Number references consecutively in the order in which they first appear in the text. Identify references in text, tables, and legends by superscript Arabic numerals. References cited only in tables or in legends to figures should be numbered in accordance with a sequence established by the first identification in the text of the particular table or figure.

Reference style is based on the formats used by the NLM in Index Medicus. Consult List of Serials Indexed in Index Medicus, which is available from the NLM and at http://www.nlm.nih.gov/tsd/serials/issiou.html. Examples of correct forms of references are available at: http://www.archives-pmr.org.

Try to avoid using abstracts as references; “unpublished observations” and “personal communications” may not be used as references, although references to written, not oral, communications may be inserted (in parentheses) in the text. Avoid “personal communication” unless it provides essential information not available from a public source. In this case, cite the name of the person and date of communication in parentheses in the text. For scientific articles, authors should obtain written permission and confirmation of accuracy from the source of personal communication.

Include among the references those papers accepted but not yet published; designate the journal and add “In press.” Authors must obtain written permission to cite such papers as well as verification that they have been accepted for publication. Editors will request from the author(s) a copy of the letter from the journal accepting the “In press” article if the manuscript in which it is cited is accepted by Archives. Information from manuscripts submitted but not yet accepted should be cited in the text as “(unpublished observations)” with written permission from the source.

The references must be verified by the author(s) against the original documents. List all authors and/or editors for each reference. Do not insert “et al.”

Suppliers

Names and addresses of the manufacturers and/or suppliers of equipment and/or materials used in a study must be identi-
fied. Identify equipment and/or materials in text, tables, and legends by superscript lower case. List suppliers consecutively in the order they are mentioned in the text.

Tables
Submit each table as a separate file. Number tables consecutively in the order of their first citation in the text and supply a brief title for each. Give each column and row a short or abbreviated heading. Place explanatory matter in footnotes, not in the heading. Explain in footnotes all nonstandard abbreviations that are used in each table. For footnotes, use the following symbols, in this sequence: *, †, ‡, §, ¶, ‖, #, **, ††, . . .

Identify statistical measures of variations such as standard deviation and standard error of the mean. Do not use internal horizontal and vertical rules. Be sure that each table is cited in the text in order. Using too many tables in relation to the length of the text may produce typesetting difficulties.

Data from another published or unpublished source may only be used with permission and must be acknowledged fully. It is the author’s responsibility to obtain such permission.

Figures, Images, and Photographs
Figures should be numbered consecutively in the order they are first cited in the text. If a figure has been published, acknowledge the original source and submit written permission from the copyright holder to reproduce the material. Permission is required, irrespective of authorship or publisher, except for documents in the public domain.

Letters, numbers, and symbols should be clear and consistent throughout, and of sufficient size that when reduced for publication each item will still be legible. Titles and detailed explanations belong in the legends for figures, not on the figures themselves.

Consistency in size within the article is strongly preferred. Any special instructions regarding sizing should be clearly noted.

Photomicrographs must have internal scale markers. Symbols, arrows, or letters used in the photomicrographs should contrast with the background.

If photographs of persons are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photographs.

The Editorial Board reserves the right to determine which figures are appropriate for publication. Color figures will be published without charge when color reproduction is essential to understanding of the material presented. There is no charge for publication of noncolor illustrations.

Units of Measurement
Metric units are required. Blood pressures in millimeters of mercury (mmHg) and all hematologic and clinical chemistry measurements using the International System of Units (SI).

Abbreviations and Symbols
Avoid excessive use of abbreviations in a manuscript. Never use abbreviations in the article’s title. Use only standard abbreviations in the text; write out the full term for which an abbreviation stands when it is first used in the text.

MANUSCRIPT SUBMISSION
Manuscripts must be submitted through the journal’s online system (http://ees.elsevier.com/archives-pmr/). Archives uses a double-blind review process, thus authors must “mask” their manuscripts to prevent reviewers from knowing the authors’ identities.

To mask copies, remove any words or phrases in the abstract, main text, references, tables, and figures that could reveal the author’s identity. Examples include:
- the name (or revealing description) of the institution where the research was conducted,
- any comments that refer to the author’s school, hospital, or other institution,
- the acknowledgments section, and
- any obvious clues from context that could disclose the author(s) identity these will most likely be in the introduction, discussion, and reference sections.

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Include in the cover letter accompanying a submission the names and addresses of 3 potential manuscript reviewers. The editors may seek reviews from others. Authors should not recommend as potential reviewers current members or associate members of Archives’s Editorial Board, or people who are affiliated with the authors’ institutions. Authors may suggest people to whom they think their study should not be sent.

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Authors are responsible for obtaining written permission from persons acknowledged by name because readers may infer their endorsement of the data and conclusions. The corresponding author must include the following statement in the cover letter: “I have obtained written permission from all persons named in the Acknowledgment.”

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The Editorial Office requires electronic source files of text in Microsoft Word or WordPerfect software in PC format. Figures and graphics files may be uploaded in: Word, Excel, PowerPoint, and PDF. A complete list of acceptable file formats is available at: http://authors.elsevier.com/ArtworkInstructions.html?dc=AI2.

INSTRUCTIONS FOR STRUCTURED ABSTRACTS
All manuscripts that are (1) reports of original data (Article; Brief Reports; Prosthetics, Orthotics, Devices; Clinical Management Reviews; Clinical Implications of Basic Research), or (2) reviews (including meta-analyses), should be submitted with structured abstracts as described below.

Reports of Original Data
Manuscripts reporting original data require an abstract of no more than 275 words under the following headings: Objective, Design, Setting, Participants, Interventions (if any), Main Outcome Measure(s), Results, Conclusions, and Key Words. The content following each heading should be as follows.
Objective: Begin with a clear statement of the precise objective or question addressed in the report. If more than 1 objective is addressed, the main objective should be indicated and only key secondary objectives stated. If an a priori hypothesis was tested, it should be stated.

Design: Describe the basic study design. State the duration of follow-up, if any. As many of the following terms as apply should be used:

1. Intervention studies: randomized controlled trial (see Glossary for definitions and other technical terms); non-randomized controlled trial; double-blind; placebo control; crossover trial; and/or before-after trial.

2. For studies of screening and diagnostic tests: criterion standard (ie, a widely accepted standard with which a new or alternative test is being compared; this term is preferred to gold standard); and/or blinded or masked comparison.

3. For studies of prognosis: inception cohort (subjects assembled at a similar and early time in the course of the disorder and followed thereafter); cohort (subjects followed forward in time, but not necessarily from a common starting point); and/or validation cohort or validation sample of the study involves the modeling of clinical predictions.

4. For studies of causation: randomized controlled trial; cohort; case control; and/or survey (preferred to “cross-sectional study”).

5. For descriptions of the clinical features of medical disorders: survey; and/or case series.

6. For studies that include a formal economic evaluation: cost-effectiveness analysis; cost-utility analysis; and/or cost-benefit analysis. For new analyses of existing data sets, the data set should be named and the basic study design disclosed.

Setting: Describe the study setting(s). Of particular import is whether the setting is the general community, a primary care or referral center, private or institutional practice, or ambulatory or hospitalized care.

Participants (or Animals, Specimens, Cadavers): Subjects include, but are not limited to, controls, laboratory animals, etc. State clinical disorders, important eligibility criteria, and key sociodemographic features. Provide the numbers of participants and how they were selected (see below), including the number of otherwise eligible subjects who were approached but refused. If matching is used for comparison groups, specify characteristics that are matched. In follow-up studies, indicate the proportion of participants who completed the study. In intervention studies, give the number of patients who withdrew due to adverse effects.

For selection procedures, use the following terms, if appropriate: random sample (where “random” refers to a formal, randomized selection in which all eligible subjects have a fixed and usually equal chance of selection); population-based sample; referred sample; consecutive sample; volunteer sample; or convenience sample. These terms help readers determine an important element of study generalizability. They also supplement (rather than duplicate) the terms used by indexing services.

Intervention(s): Describe the essential features of all interventions, including their method and duration of administration. The intervention should be identified by its most common clinical name (eg, the generic term chlorthalidone). Common synonyms should be given as well to facilitate electronic text-word searching. This includes the brand name of a drug if a specific product was studied. NOTE: If the study does not contain any interventions, then the following form should be used: Interventions: Not applicable.

Main Outcome Measure(s): Indicate the primary study outcome measurement(s) as planned before data collection began. If the study does not emphasize the main planned outcomes of a study, state this fact and indicate the reason. If the hypothesis being reported was formulated during or after data collection, state this information clearly.

Results: Provide the main study results. Define measurements requiring explanation for the expected audience of the article. Indicate whether observers were blinded to patient groupings, particularly for subjective measurements. Results must be given in narrative rather than tabular form. If possible, the results should be accompanied by CIs (eg, 95%) and the exact level of statistical significance. For comparative studies, CIs should relate to the differences between groups. For non-significant differences for the major study outcome measure(s), state the clinically important difference sought and give the CI for the difference between the groups. When risk changes or effect sizes are given, indicate absolute values so that readers can determine the absolute as well as relative impact of the finding. Approaches such as number needed to treat to achieve a unit of benefit are encouraged when appropriate; reporting of relative differences alone is usually inappropriate. If appropriate, studies of screening and diagnostic tests should use the terms sensitivity, specificity, and likelihood ratio. If predictive values or accuracy are given, give prevalence or pretest likelihood as well. Report no data in the abstract that do not appear in the article.

Conclusions: Conclusions must be directly supported by the evidence reported. Avoid speculation and overgeneralization, and indicate whether additional study is required before the information should be used in usual clinical settings.

Key Words: Authors must include in the abstract 3 to 5 key words from NLM’s Permed Medical Subject Headings (MeSH) (http://www.nlm.nih.gov/mesh/MBrowser.html).

To permit quick and selective scanning, the headings outlined above must be included in the abstract. For brevity, parts of the abstract may be written in phrases rather than complete sentences. (For example: “Design: Double-blind randomized trial.” rather than “Design: The study was conducted as a double-blind, randomized trial.”)

Review Articles (Including Meta-Analyses)

Review articles and meta-analyses require an abstract of no more than 250 to 300 words under the following headings: Objective, Data Sources, Study Selection, Data Extraction, Data Synthesis, Conclusions, and Key Words. The content following each heading should be as follows.

Objective: Begin with a precise statement of the primary objective of the review. The focus should be guided by whether the review emphasizes factors such as cause and diagnosis, prognosis, therapy, or prevention. It should include information about the specific population, intervention or exposure, and test or outcome being reviewed.

Data Sources: Succinctly summarize data sources, including any time restrictions. Potential sources include experts or research institutions active in the field, computerized databases and published indexes, registries, abstract booklets, conference proceedings, references identified from bibliographies of pertinent articles and books, and companies or manufacturers of tests or agents being reviewed. If a bibliographic database is used, state the exact indexing terms used for article retrieval, including any constraints (eg, English language or human).
Study Selection: Describe the criteria used to select studies for detailed review from among studies identified as relevant to the topic. Details of selection should include particular populations, interventions, outcomes, or methodologic designs. Specify the method used to apply these criteria (eg, blind review, consensus, or multiple reviewers). State the proportion of initially identified studies that met selection criteria.

Data Extraction: Describe the guidelines used for abstracting data and assessing data quality and validity (eg, criteria for causal inference). State the method by which the guidelines were applied (eg, independent extraction by multiple observers).

Data Synthesis: State the main results of the review, whether qualitative or quantitative. Outline the methods used to obtain these results. Meta-analyses should state the major outcomes that were pooled and include odds ratios or effect sizes, and, if possible, sensitivity analyses. Numerical results should be accompanied by CIs, if applicable, and exact levels of statistical significance. Evaluations of screening and diagnostic tests should address issues of sensitivity, specificity, likelihood ratios, receiver operating characteristic curves, and predictive values. Assessments of prognosis could include summaries of survival characteristics and related variables. State the major identified sources of variation between studies, for example, differences in treatment protocols, concomitant treatments, confounders, outcome measures, length of follow-up, and drop-out rates.

Conclusions: State the conclusions and their applications clearly, limiting generalization to the domain of the review. Suggest directions for new studies.

Key Words: See above under Reports of Original Data.

References

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SOFTWARE: Microsoft Word or WordPerfect are recommended (in PC format). Tables may be submitted in either WordPerfect or Microsoft Word. Figures and graphics may be uploaded online.

Document Formatting:
The publisher handles typographical formatting. This includes design specifications for the final printed product (column widths, page depths, type styles).

Authors should format electronic files for specific attributes such as italics, superscripts/subscripts, and Greek letters. The coding scheme for each such element must be consistent throughout the file.

Text Style:
- Format text flush left in upper/lowercase letters as appropriate.
- Enter only 1 space between words and sentences.
- For line breaks within a paragraph, use the automatic soft return feature in your word processor; do not use hard return.
- Use 2 returns at the end of each paragraph (ie, 1 blank line between paragraphs).
- Use 2 returns between headings and text.
- Do not use word processors’ indenting or margin-setting features. (These will be handled during typesetting.)

CHECKLIST

To be completed prior to submission of manuscripts.
Incomplete submissions will not be put into peer review until requirements are met.

A more complete description of each item that must be checked is provided under the appropriate heading in the Information for Authors.

General
- The cover letter with essential information, including statement of information on corresponding author and statement signed by corresponding author that written permission has been obtained from all persons named in the Acknowledgments.
- All elements of the manuscript are printed in English and double-spaced with 1-inch margins at top, bottom, and sides. Right margins are unjustified.
- All pages are numbered in the following order: title page, structured or standard abstract, body of the text, acknowledgments, references, legends, and tables.
- The text is consecutively line numbered.
- If this is a randomized controlled trial, provide the CONSORT flow diagram (http://www.consort-statement.org/Downloads/Flowchart.doc).
- The Disclosure Statements & Copyright Assignment form signed by the guarantor at original submission. If a resubmission, then all authors must submit the Disclosure Statements & Copyright Assignment form. In either case, the author uploading the submission must insert the selected financial disclosure into the title page of the manuscript.
- Human experimentation has been approved by the local institutional review board or conforms to Helsinki Declaration as stated in the section Manuscript Preparation, Methods.
- Guidelines for the care use of nonhuman animals or other species approved by the institution have been followed as indicated in the Methods. The species is named in the title, abstract, and Methods section.
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It is recommended that a professional editor or a colleague fluent in English edit before submission manuscripts by authors whose first language is not English.

When resubmitting a manuscript for further consideration, provide an itemized accounting of how the manuscript was changed in response to the original set of evaluations.

Similar Publication

Attached is a reprint of each article and/or abstract the author and/or coauthors have previously published or is “in press,” and each manuscript the author and/or coauthors have submitted for possible publication or have in manuscript form dealing with the same patients, animals, laboratory experiment, or data, in part or in full, as those reported in the submitted manuscript. Further explanation of the circumstances is included. Similarities and differences are explained in the cover letter.

Title Page

These elements are in the following sequence, and are type double spaced.

- Running head of no more than 40 character spaces.
- Title.
- Author(s) full name(s) and highest academic degree(s) are included.
- The name(s) of the institution(s), section(s), division(s), and department(s) where the study was performed are provided and the institutional affiliation(s) of the author(s) at the time of the study is indicated.
- Acknowledgment of any presentations of this material, to whom, when, and where.
- Acknowledgment of financial support.
- Requisite financial disclosure as selected from the Disclosure Statements & Copyright Assignment form and an explanation of any conflicts of interest.
- Name, address, business and home telephone numbers, fax number, and e-mail address of corresponding author and author from whom reprints can be obtained.
- If reprints are not available, this is stated on the title page.
- Clinical trial registration number.

Abstract

- A structured abstract (eg, Articles, Review Articles) with Key Words is on page 2 and is headed by the title.
- A standard abstract of 200 words or fewer (eg, Clinical Notes) with Key Words is on page 2 and is headed by the title.

References

- All references have been checked for accuracy and completeness.
- Are numbered consecutively in the order they are cited in the text; all listed references have been cited in the text.
- The format prescribed by the “Uniform Requirements for Manuscripts Submitted to Biomedical Journals” has been followed. Examples provided under Manuscript Preparation have been followed.
- For any reference cited as “in press,” a copy of the article is uploaded.
- Personal communications and unpublished observations are not used as numbered references but are mentioned in the text with the written approval of the person being quoted. Author must produce a copy of the approval if so required by the editors.

Figures

- Each is numbered with an Arabic numeral and cited in numeric sequence in the text.
- Photographs of recognizable persons should be accompanied by a signed release from the patient or legal guardian authorizing publication. Masking eyes to hide identity is not sufficient.

Figure Legends

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- Are numbered and presented together in numeric order following Reference page(s).

Tables

Each table is headed by a title and numbered in Arabic numerals on a separate page.
Tables are cited in numeric sequence in the text.

Credits & Permissions

- In addition to the notice of informed consent and releases to publish photographs of recognizable persons, submit with the manuscript written permission to use nonoriginal material (quotations exceeding 100 words, any table or illustration) from both author and publisher of the original. No article will be accepted as a submission to Archives without all required permissions. Credit the source in a text or table footnote or in a legend.

Reviewers

- Submit the names of 3 potential reviewers and their addresses, telephone numbers, and email address (if known). Do not submit names of people affiliated with your institution.
2007 ACRM Annual Conference Abstracts

Provided here are the abstracts of scientific papers and posters presented at the joint 84th Annual Meeting of the American Congress of Rehabilitation Medicine (ACRM) and the 14th Annual Meeting of the American Society of Neurorehabilitation (ASNR), in Washington, DC, October 3–7, 2007. Papers and posters were chosen by the joint ACRM—ASNR program committee. The abstracts have not been subjected to formal peer review by the Editorial Board of the Archives of Physical Medicine and Rehabilitation. Abstracts from the 2007 ACRM—ASNR Joint Conference are published in both society journals: Archives of Physical Medicine and Rehabilitation 2007;88(10):E1-27, and Neurorehabilitation and Neural Repair 2007;21(6).

Paper Presentations

Article 1
A Practical Clinical Trial of Holistic Neuropsychologic Rehabilitation After Traumatic Brain Injury. Keith Cicero (JFK-Johnson Rehabilitation Institute, United States), Tasha Mott, Joanne Azulay, Mary Sharlow-Galella, Wendy Ellmo, John Friel, Susan Paradise.
Disclosure: None declared.

Objective: To evaluate the effectiveness of intensive-holistic cognitive rehabilitation (ICRP) and “standard” neurorehabilitation (SRP) for traumatic brain injury. Design: Randomized controlled trial with 6-month follow-up. Setting: Outpatient brain injury rehabilitation program. Participants: 68 participants randomly assigned to ICRP (n=34) or SRP (n=34). Interventions: ICRP consisted of individual and group interventions emphasizing self-regulation, interpersonal communication, functional problem solving, and self-efficacy for management of symptoms. SRP primarily consisted of individual physical therapy, occupational therapy, speech therapy, and neuropsychologic treatment. Both interventions lasted 17 weeks. Main Outcome Measures: Primary outcomes were community integration (Community Integration Questionnaire [CIQ]) and perceived quality of life (QOL). Neuropsychologic functioning was assessed before and after treatment. Results: Neuropsychologic functioning improved equally in both groups (P<.001). CIQ exhibited a significant improvement of treatment conditions with significant improvement after ICRP (P=.004), while SRP did not change. Perceived QOL showed a significant main effect (P=.011) and interaction on perceived QOL due to improvement of ICRP (P=.004) with no benefit of SRP. Benefits were maintained at 6-month follow-up. Conclusions: There are significant benefits from ICRP in community integration and life satisfaction compared with standard neurorehabilitation for traumatic brain injury. Key Words: Brain injuries; Rehabilitation.

Article 2
The Psychologic Effects of Employment Following Traumatic Brain Injury: Objective and Subjective Indicators. Theodore Tsayouides (Mount Sinai School of Medicine, United States), Teresa Ashman, Colette Seter.
Disclosure: Supported by NIDRR (grant no. H133b040033).

Objective: To examine the differential effects of objective and subjective indicators of employment on psychologic well-being, quality of life (QOL), and depression following traumatic brain injury (TBI). Design: Quasi-experimental. Setting: Research and training center on TBI interventions, in a school of medicine, in New York City. Participants: 437 individuals with TBI (age range, 18–65y) living in the community independently. Interventions: Not applicable. Main Outcome Measures: Bigelow’s Psychological Well-Being Scale, Life—3, and Beck Depression Inventory—II. The objective indicator of employment included level of employment (no employment, part-time, full-time) and the subjective indicator included work discrepancy, which was defined as the discrepancy between the perceived importance of work and the degree to which work needs are met. Results: A substantial percentage of subjects with TBI reported large negative changes in level of employment. Psychologic well-being was not significantly related to any predictor variables. QOL was significantly related to level of employment (.15), work discrepancy (−.29), and income (.23). Depression was significantly related to education (−.10), income (−.14), level of employment (−.17), and work discrepancy (.19). Hierarchical multiple regression showed that work discrepancy contributed significantly to QOL and depression variance above and beyond all other predictors. Conclusions: The results of this study highlight the importance of including subjective indicators of employment when assessing QOL and depression in persons with TBI. The benefits of TBI rehabilitation could be optimized when traditional goals of rehabilitation (ie, return to work) are combined with more subjective and personally meaningful goals. Understanding the importance ascribed to work and identifying appropriate ways to help people fulfill their employment needs is likely to contribute further to QOL and improved mood. Key Words: Brain injuries; Employment; Quality of life; Rehabilitation.

Article 3
Responsiveness of the Utrecht Scale for Evaluation of Rehabilitation. Marcel Post (De Hoogstraat, Netherlands), Rebecca Baines, Ingrid van de Port, Renee Peeters, Steven Berdenis van Berlekom.
Disclosure: None declared.

Objective: To examine the validity and responsiveness of the Utrecht Scale for Evaluation of Rehabilitation (USER), a generic measure covering mobility, self-care, cognition, pain, fatigue, and mood. Design: Longitudinal study with measurements at admission and at discharge from clinical rehabilitation, with a maximum period between measurements of 4 months. Setting: 3 rehabilitation facilities in The Netherlands. Participants: Rehabilitation inpatients with different diagnoses (N=319). Interventions: Not applicable. Main Outcome Measures: Effect sizes of the USER were compared with those of the Barthel Index, FIM instrument, and 36-Item Short-Form Health Survey (SF-36). Results: Strong correlations were found between the motor scores of USER, Barthel Index, and FIM (range, .91–.96), and the cognitive scores of USER and FIM (.88). Correlations between USER mood scores and SF-36 mental health scores were .67 to .69. Effect sizes of the motor scores were .97 (USER), .90 (Barthel Index), and .83 (FIM). In patients with spinal cord injuries (n=44), effect sizes of the
motor scores were 1.35 (USER), 1.28 (FIM), 1.24 (Barthel Index), and 1.21 (Spinal Cord Independence Measure). In patients with brain lesions (n=108), effect sizes of the cognitive scores were .27 (USER) and .14 (FIM). Finally, effect sizes of the mood scores were .42 (SF-36 mental health) and .35 (USER). Conclusions: USER shows favorable responsiveness compared with other functional status measures. Key Words: Outcomes research; Rehabilitation; Reproducibility of results.

Article 4
Team Training and Stroke Rehabilitation Outcomes: A Cluster Randomized Trial. Dale Strasser (Emory University–Atlanta VAMC, United States), Judith Falconer, Alan Stevens, Jay Uomoto, Jeph Herrin, Susan Bowen, Andrea Burridge.
Disclosure: None declared.
Objective: To test whether a team training intervention is associated with improved patient outcomes. Design: Cluster randomized trial of 31 rehabilitation units comparing stroke outcomes between intervention and control groups. Setting: 31 Veterans Affairs hospitals. Participants: 237 clinical staff on 16 control teams and 227 staff on 15 intervention teams. 487 stroke patients were treated before and after the intervention. Intervention: A 6-month, multiphase staff training program. Control and intervention teams received site-specific team profiles. Main Outcome Measures: 3 patient outcomes: change in FIM instrument motor score, community discharge, and length of stay (LOS). Results: For both the primary (stroke only) and secondary analyses (all patients), there was a significant difference in improvement in functional outcome between the 2 groups, with the percentage of stroke patients gaining more than a median FIM gain of 23 points, increasing significantly more in the intervention group (difference in increase, 13.6%; P= .032). There was no significant difference in LOS or rates of community discharge. Conclusions: Stroke patients treated by staff who participated in a team training program were more likely to make functional gains than those treated by staff who received information only. Key Words: Clinical trials; Rehabilitation; Stroke; Treatment outcome.

Article 5
Controlled Study of Affect Recognition Training for Persons With Traumatic Brain Injury. Dawn Neumann, MA (University at Buffalo, United States), Barbra Zupan, Barry Willer.
Disclosure: None declared.
Objective: To compare the effects of 2 interventions for persons with emotion recognition problems subsequent to traumatic brain injury (TBI): (1) facial affect recognition (FAR) and (2) stories of emotional inference (SEI). Design: Randomized controlled study with repeated measures. Setting: Western New York hospital and Canadian university. Participants: 30 participants with TBI with impaired facial affect recognition were randomly assigned to FAR (n=15) or SEI (n=15). Interventions: FAR taught participants to determine emotions by identifying facial features and emotional self-awareness. SEI taught participants to infer emotions in short stories by associating information to emotions. Main Outcome Measures: Facial affect recognition, vocal affect recognition, video vignettes, emotional awareness, and social-behavioral functioning. Results: Repeated-measures analysis of variance (α=.05) was used for analysis. FAR participants demonstrated better facial affect recognition. There was a trend toward better recognition of emotions in videos. SEI participants also showed improvements for facial affect recognition. Behavior and community integration for participants in both groups improved. Conclusions: Interventions aimed at improving affect recognition are effective and have a positive impact on interpersonal relations for persons with TBI. Future research needs to assess the impact of various cognitive impairments on the program’s effectiveness. Key Words: Brain injuries; Expressed emotion; Rehabilitation.

Article 6
Treatment of Upper-Limb Paresis by Transcutaneous Electric Nerve Stimulation and Task-Related Training During Chronic Stroke: A Randomized Placebo-Controlled Trial. Bi Sheng (The Hong Kong Polytechnic University, China), Christina W. Hui-Chan.
Disclosure: None declared.
Objective: To investigate the effectiveness of combining transcutaneous electric nerve stimulation (TENS) with task-related training (TRT) in promoting motor recovery in the upper limb of stroke patients. Design: Randomized placebo-controlled trial. Setting: A university rehabilitation research laboratory. Participants: 77 adults with chronic stroke. Interventions: Patients were randomly assigned to 4 groups: TENS+TRT (n=18), placebo-TENS+TRT (n=20), TENS alone (n=20), and control without treatment (n=19), to receive treatment daily, 5 days a week, for 8 weeks. Main Outcome Measures: The functional level and time scores of the Wolf Motor Function Test (WMFT). Repeated-measure analysis of variance (ANOVA) followed by 1-way ANOVA compared the 4 groups at baseline and the percentage gain. Results: No significant difference in the baseline values was found among the 4 groups. After 8 weeks of treatment, there was a significant improvement in the percentage of time scores of the WMFT in TENS+TRT (P=.007), a marginal change in placebo TENS+TRT (P=.013), and an insignificant change in the TENS group (P=.821), when compared with that of the control group. Conclusions: Combining TENS with TRT was more superior to TENS alone, and probably placebo-TENS with TRT in improving upper-limb motor function of patients with chronic stroke. Key Words: Randomized controlled trials; Rehabilitation; Stroke.

Article 7
An International Comparison of the Characteristics of Inpatient Stroke Rehabilitation: Are We Talking About the Same Thing? Koen Putman (National Rehabilitation Hospital, United States), Harry McNaughton, Randy Smout, Susan Horn, Mark Leys, Gerben De Jong.
Disclosure: None declared.
Objective: To compare inpatient rehabilitation following stroke. Design: Secondary analyses on the pooled dataset from 2 prospective cohort studies, one in Europe (Collaborative Evaluation of Rehabilitation In Stroke across Europe) and one in the United States (Post-Stoke Rehabilitation Outcomes Project). Setting: 6 inpatient rehabilitation facilities (IRFs) in the United States, 1 IRF in New Zealand, and 4 IRFs in Europe. Participants: 1214 patients suffering first ever-stroke (U.S.: n=622; N.Z.: n=60; E.U.: n=532). Interventions: Not applicable. Results: Median age was the highest in the N.Z. group and the lowest in the U.S. (75y, 67y, respectively; P<.001). Time between stroke onset and admission to the IRF varied significantly (median: U.S.: 7d; N.Z.: 9d; E.U.: 16d; P<.001). Functional status on admission was significantly lower in the U.S. group compared with the E.U. group (median Barthel Index score, 7 and 11, respectively; P<.001). Additionally, length of stay showed large differences (median values: U.S.: 16d; N.Z.: 24d; E.U., 50d). Functional status at discharge was significantly higher in the E.U. group compared with the U.S. group (median Barthel Index score, 17 and 13, respectively; P<.001). Conclusions: Significant differences in case mix and processes of care were observed among the 3 regions. These differences provide a good basis for evaluating the effectiveness of different rehabilitation programs. Key Words: Health services research; Inpatients; Rehabilitation; Stroke.
Article 8
A Comparative Study of Admission Criteria to Stroke Rehabilitation Unit in 4 European Centers. Mark Leys (Vrije Universiteit Brussel, Belgium), Koen Putman.
Disclosure: None declared.
Objective: To explore the clinical and nonclinical factors involved in decision-making concerning admission to European stroke rehabilitation units (SRUs). Design: Observational study of case mix at admission combined with questionnaires and semi-structured interviews with the medical consultants of each SRU. Setting: United Kingdom, Belgium, Germany, and Switzerland. Participants: Clinical data gathered on 532 first-ever stroke patients. Medical consultants of 6 SRUs in 4 European countries (United Kingdom, Belgium, Germany, Switzerland). Interventions: Not applicable. Results: Case mix of stroke patients differed significantly between SRUs. Clinical criteria for admission were seldom explicit and were evaluated differently among the SRUs. In the British SRUs, diagnosis of stroke was the only criterion for admission to SRU. In the Belgian, German, and Swiss SRUs, premorbid conditions were taken into account in admission decisions. The likelihood of discharge home was considered highly important in the Swiss SRU. Conclusions: Case-mix differences at intake could be linked to different appraisals of clinical and nonclinical factors of stroke patients. The findings suggest the need to be more explicit about decision-making processes at admission in order to provide a more comprehensive insight into the interplay between context and process of care. Key Words: Decision making; Patient admission; Rehabilitation; Stroke.

Article 9
Influence of Virtual Reality Environment on the Recovery After Stroke. Jerome Gnanaraj (Madurai Medical College, India), Hatim Chowdry, Satish Kumar.
Disclosure: None declared.
Objective: To determine the influence of virtual reality environment on the effect of recovery of activities of daily living after stroke. Design: Randomized, single-blinded, prospective, case-controlled study. Setting: Traditional stroke care unit and a special virtual environment simulating a health resort. Participants: 23 stroke patients who had sustained hemiparesis within 90 days. Interventions: Control group of 20 patients received stroke rehabilitation, including medical, social, educational, and vocational measures in a traditional stroke care unit. The other group of 13 patients received the same treatment in an environment, which almost stimulated the conditions they face in everyday life. They were encouraged to interact with each other, perform activities like walking, gardening, cooking, and accounting as far as possible under the supervision and the support of experienced therapists. Main Outcome Measure: Improvement in the activities of daily living (ADLs) as measured by Barthel Index. Results: We found a statistically significant improvement in ADLs in the group that received interventions in the special environment when compared with patients treated in the traditional stroke care unit. The mean Barthel Index score increased from 34 to 78 at 6 months in the patients treated in the virtual reality environment whereas in the other control group the score increased from 31 to 62, which was statistically significant ($P<.001$). Also, the prevalence of depression was significantly lower in the intervention group than in the control group (28% vs 45%). Conclusions: We conclude that the environment plays a major role in the recovery of stroke patients. A multidimensional approach, including a virtual reality environment tailored to the specific needs of each patient, will increase their chance of recovering to their maximal functional capability. Key Words: Activities of daily living; Hemiparesis; Rehabilitation.

Article 10
Modified Constraint-Induced Movement Therapy in Chronic Stroke: Results of a Single-Blinded, Randomized, Controlled Trial. Stephen Page (University of Cincinnati Academic Medical Center, United States), Peter Levine, Anthony Leonard.
Disclosure: None declared.
Objective: To compare efficacy of modified constraint-induced movement therapy (mCIMT) (0.5-hour therapy sessions with less affected arm restriction 5d/wk for 5 hours, both during a 10-wk period), with a time-matched affected arm exercise program or a no treatment control regimen. Design: Pre-post, randomized, placebo-controlled trial. Setting: Outpatient rehabilitation hospital. Participants: 35 subjects with chronic stroke, exhibiting stable hemiparesis and affected arm nonuse. Interventions: 35 subjects with chronic stroke were administered either: (1) mCIMT, consisting of structured therapy emphasizing more affected arm use in valued activities 3 days a week for 10 weeks, and less affected arm restraint 5 days a week for 5 hours; (2) 30 sessions of a time-matched, affected arm rehabilitation program, which included affected limb manual dexterity exercises and stretching, as well as compensatory strategies with the unaffected limb; or (3) no treatment (control). Main Outcome Measures: The Action Research Arm Test (ARAT), Fugl-Meyer Assessment, and Motor Activity Log (MAL), administered twice before intervention and once after intervention. Results: After intervention, we observed significant differences on the ARAT ($F_{2,31}=13.1, P<.001$) and MAL amount of use ($F=49.1, P<.01$) and quality of movement ($F=63.1, P<.01$) scales, all in favor of the mCIMT group. Conclusions: Data affirm previous findings suggesting that this reimbursable, outpatient protocol increases more affected arm use and function. Magnitude of changes was consistent with those reported in more intense protocols, such as constraint-induced movement therapy. Key Words: Hemiplegia; Physical therapy techniques; Rehabilitation; Stroke.

Article 11
Relationship of Ambulation and Independence in Locomotion With Long-Term Outcomes After Spinal Cord Injury. James Krause (Medical University of South Carolina, United States), Sandra Brotherton, Karla Swanygin.
Disclosure: None declared.
Objective: To identify the association of mode of locomotion (ambulation vs wheelchair use) and independence in locomotion (independent of assistance vs partial or complete dependence) with health, participation, and subjective well-being. Design: Secondary analysis of survey data. Setting: Data were collected from 2 rehabilitation hospitals in the Midwest and a specialty hospital in the Southeast. Participants: 1493 adults with traumatic spinal cord injury of at least 1 year in duration. Interventions: Not applicable. Main Outcome Measures: Health outcomes included general ratings and number of hospitalizations and treatments. Participation was measured by the Craig Handicap Assessment Reporting Technique. Subjective well-being was measured with the Life Situation Questionnaire and the Older Adult Health and Mood Questionnaire. Results: Multivariate analysis of variance indicated significant main effects and an interaction effect. Independence in locomotion was favorably related to every outcome, whereas a mixed pattern was observed for mode of locomotion. Ambulation was associated with higher levels of participation and some aspects of subjective well-being, but also a greater number of depressive symptoms, more pain interference, and more poor health days. Among the participants who were dependent on help from others in order to ambulate, nonwheelchair users and those who were at least partially dependent in wheelchair use reported substantially poorer outcomes than those who were independent in wheelchair use. Conclusions: We must balance our zeal for interventions designed to...
Artic. 12
Botulinum Neurotoxin Type A Versus Oral Tizanidine in the Treatment of Upper-Limb Spasticity: A Double-Blind, Placebo-Controlled, Multicenter Trial. Jean-Michel Gracies (Mount Sinai School of Medicine, United States), David Simpson, Stuart Yablon, Richard Barbano, Allison Brashear.

Disclosure: None declared.

Objective: To compare the efficacy and safety of intramuscular botulinum neurotoxin type A (BTX-A) (Botox) with tizanidine and placebo for treatment of upper-limb (UL) spasticity. Design: Randomized, double-blind, placebo-controlled, multicenter trial. Setting: Outpatient clinics in 10 centers. Participants: 60 subjects with UL spasticity (wrist flexor Modified Ashworth Score [MAS] score ≥3) after stroke or traumatic brain injury. Interventions: Intramuscular injection of ≤500U of BTX-A divided into spastic UL muscles versus oral tizanidine, titrated to ≤36mg/d, or placebo. Wrist flexors were systematically injected at a fixed dose (50U/muscle); other UL muscles were injected as per investigator judgment. Participants were randomly assigned into groups: (1) intramuscular BTX-A plus oral placebo; (2) oral tizanidine plus intramuscular placebo; and (3) intramuscular placebo plus oral placebo. Main Outcome Measures: Change from baseline in the MAS wrist flexor between groups. Other outcome measures included MAS in other muscles, Disability Assessment Scale (DAS), and adverse events (AEs). Results: BTX-A produced greater tone reduction in finger flexor and wrist flexors at week 3 (P<.03 vs tizanidine; P<.02 vs placebo) and week 6 (P<.02 vs tizanidine; P=.08 vs placebo), and greater improvement in the DAS disfigurement domain at week 6 (P=.01). AEs were more frequent with tizanidine than with BTX-A (P<.01) or placebo (P=.001). Conclusions: BTX-A is safer and more effective than tizanidine in reducing tone and disfigurement in UL spasticity. Key Words: Botulinum toxin type A; Muscle spasticity; Rehabilitation.

Artic. 13
The Effect of Repeated Treatment of Botulinum Toxin Type A on Poststroke, Spasticity-Related Pain: A Subgroup Analysis of Patients in a 12-Month Trial. Elie Elovic (Kessler Medical Rehabilitation Research and Education Corp, United States), Allison Brashear, Darryl Kaelin, Susan Abu-Shakra, Amanda VanDenburgh, Catherine C. Turkel, Frederick Beddington III.

Disclosure: Susan Abu-Shakra, Amanda Van Denburgh, Catherine C. Turkel, Frederick Beddington III are employees of Allergan Inc.

Objective: To evaluate the efficacy and safety of repeated botulinum toxin type A (BTX-A) (Botox) treatment of focal upper-limb poststroke spasticity in reducing pain frequency and intensity. Design: Open-label, repeated-dose study. Setting: 35 clinical centers. Participants: Of 279 upper-limb poststroke spasticity patients from a 12-month study, a subanalysis was performed on 73 (mean age, 56.8y; 56.2% female) who scored ≥2 on the 4-point Disability Assessment Scale (DAS) pain domain (range, 0 [no pain] to 3 [severe pain]) at baseline. Interventions: Up to 5 treatments of 200 to 400U of BTX-A in the affected limb; successive treatments were administered at least 12 weeks after the previous injection. Patients were assessed every 6 weeks for 12 months. Main Outcome Measures: Change from baseline in pain frequency (range, 0 [none of the time] to 4 [all of the time]), intensity (range, 0 [no pain] to 10 [pain as bad as it can be]), and DAS (pain). Results: BTX-A treatment significantly reduced pain frequency and DAS at all time points (P<.05); pain intensity reduction was significant at all time points (P<.05), except at week 54. Mild-to-moderate treatment-related adverse events were reported in 6.8% (5/73 patients). Conclusions: Repeated BTX-A treatment was well tolerated and significantly decreased pain frequency and intensity in spastic upper limbs. Key Words: Botulinum toxins; Pain; Rehabilitation.

Artic. 14
Traumatic Spinal Cord Injury and Co-Occurring Brain Injury: A Prospective Analysis of Incidence and Outcomes. Stephen Maciocchi (Shepherd Center, United States), Ronald Seel, Nicole Thompson, Rashida Byams, Brock Bowman.

Disclosure: Supported by NIDRR.

Objective: To identify the incidence of persons with a dual diagnosis of traumatic brain injury (TBI) and spinal cord injury (SCI) and to examine whether persons with TBI and SCI have different outcomes than persons with SCI only. Design: Prospective cohort survey with comparison control group collected. Correlation, analyses of variance, tree modeling, and regression analyses were calculated. Setting: Single-center, acute SCI rehabilitation unit. Participants: Demographically diverse sample of 199 persons assessed at acute rehabilitation admission, discharge, and 1-year follow-up. Interventions: Not applicable. Main Outcome Measures: Acute rehabilitation length of stay (LOS), and FIM instrument motor and cognitive scores. Results: The incidence of TBI in persons with SCI was 57%; about 17% had moderate or severe TBI. Persons with dual diagnosis had lower FIM motor and cognitive subscale scores and longer rehabilitation LOS. Persons with moderate and severe TBI and SCI had significantly worse long-term outcomes than persons with SCI only. Conclusions: Persons with traumatic SCI and co-occurring moderate and severe TBI are at greater risk for poor short- and long-term outcomes. Key Words: Brain injuries; Dual diagnosis, psychiatric; Rehabilitation; Spinal cord injuries; Treatment outcomes.

Artic. 15
Comparing Verbal Rating Scale and Numeric Rating Scale Ratings of Pain. Marcel Dijkers (Mount Sinai School of Medicine, United States), Adam Stein.

Disclosure: None declared.

Objective: To assess the comparability of reports of pain intensity using a verbal rating scale (VRS) and a numeric rating scale (NRS). Design: Longitudinal observational study with multiple reports on multiple pains. Setting: Inpatient rehabilitation unit. Participants: 185 persons with new traumatic spinal cord injury admitted for inpatient rehabilitation. Interventions: Not applicable. Main Outcome Measures: VRS and NRS. Results: For 1110 ratings of pain, VRS and corresponding NRS correlated weakly (η²=.15). For each VRS level except “mild,” the standard deviation of the corresponding NRS score was high. Mean NRS ratings by VRS adjectives were disordered: supposedly higher adjectives received a lower mean NRS rating. Conclusions: Not only are there considerable differences between people as to how NRS and VRS are used, but there also seem to be people who understand the meaning of these adjectives completely differently than was intended by the creators of VRS. Both VRS and NRS data have to be used with extreme caution. Key Words: Pain; Rehabilitation; Spinal cord injuries.
National Institute on Disability and Rehabilitation Research Presentations

Presentation 1
Review of Walk-Test Methodology on Overall Performance and Variability of Performance. James E. Graham (University of Texas Medical Branch–Galveston, United States).

Disclosure: None declared.

Objectives: To describe differences in walk-test methodology in the health care literature and to assess whether these differences affect performance and/or variability of performance. Design: Systematic literature review and pooled analysis. Setting: Walk-test literature from various clinical and laboratory settings. Participants: Patient (and control) groups from numerous diagnostic and age categories (N=23,631). Interventions: Not applicable. Main Outcome Measures: Mean walking velocity and velocity coefficient of variation (CV) relative to instructions for pace, testing protocol, and distance timed. Results: The most frequent distance utilized was 10m. Nearly 50% of studies did not describe test protocol or instructed pace. Analysis of covariance yielded significant main effects of age and pace for walking velocity, but not CV. No significant differences were observed between 10-m and 4- to 6-m walks for either outcome. Conclusions: Walk-test data are not measured or reported uniformly. Pace is the single most important methodologic factor influencing velocity. More important, it appears that test protocol may affect clinical interpretation. Additional study is necessary to verify the results of this comprehensive review and analysis. In the interim, a common protocol (ie, static start) of practical distance (ie, 4–6m) should be promoted, with pace being determined by the underlying objective of the assessment and intervention. Key Words: Gait; Methods; Outcome assessment (health care); Rehabilitation; Review article.

Presentation 2
Thigh Intermuscular Fat and Its Relation to Insulin Resistance in Young Black Women With Different Body Mass Indexes. Ashraf S. Gorgey (University of Michigan, United States), Billy Hawkins, Gary A. Dudley.

Disclosure: None declared.

Objective: To test whether intermuscular fat (IMF) contributes to insulin resistance in young black women with different body mass indexes (BMIs). Design: Cross-sectional design. Setting: University-based setting. Participants: 26 young black women were classified, according to their BMIs, into 4 groups; the first was less than 22.5kg/m²; the second, 22.5 to less than 25kg/m²; the third, 25 to less than 30kg/m²; and the fourth, greater than 30kg/m². Interventions: Not applicable. Main Outcome Measures: Magnetic resonance imaging was used to measure thigh IMF; plasma glucose and plasma insulin were also determined after an oral glucose tolerance test. Results: Increasing BMI did not result in a subsequent increase in IMF. The 4 groups showed normal homeostasis model assessment index (P=.22). Plasma glucose increased in the 4 groups at 60 and 90 minutes after oral glucose ingestion. Plasma insulin was 11±1, 91±10, 78±10, and 61±7.5µU/mL after fasting, 60, 90, and 120 minutes (P<.001), respectively. IMF explained 60%, 92%, 88%, and 99% of the variance in fasting, 60, 90, and 120 minutes in the obese group, respectively. Conclusions: IMF did not increase with increasing BMI. However, it was a strong predictor for developing insulin resistance in overweight and young obese black women. Key Words: Female; Magnetic resonance imaging; Rehabilitation.

Presentation 3
Attachment, Disability, and Romantic Relationships. Karen Hwang (Kessler Medical Rehabilitation Research and Education Corp, United States).

Disclosure: None declared.

Objective: To examine the relationship between physical disability, attachment in intimate relationships, and psychologic adjustment in persons with physical disabilities. Design: Cross-sectional survey comparing subjects with spinal cord injuries (SCIs) with subjects with congenital disabilities on attachment style, dyadic adjustment, self-esteem, and life satisfaction. Setting: General community. Participants: Volunteer sample of 50 adults with SCI acquired after age 16 and 50 adults with congenital disabilities recruited from the general community. All participants were age 20 to 50 years and all subjects with SCI were at least 2 years postinjury. People with progressive conditions or significant cognitive impairments were excluded. Interventions: Not applicable. Main Outcome Measures: Adult attachment style, romantic relationship status, dyadic adjustment, general social relationships, self-esteem, and life satisfaction. Results: Differences in attachment security between disability groups were nonsignificant, and both samples reported attachment style distributions comparable with the general population. Overall, the SCI sample reported greater dyadic adjustment (F1,56 =7.456, P =.008). Secure subjects in both disability groups had higher self-esteem scores relative to insecure subjects (F3,55 =8.126, P <.001). Life satisfaction was predicted by greater physical independence (F1 =11.174, P =.001) and secure attachment style (F1 =5.694, P =.001), and both had a combined effect size of .270. Conclusions: Adult attachment style has a significant influence on romantic adjustment, self-esteem, and life satisfaction. Results underscore the importance of secure, intimate relationships to individual quality of life for people with disabilities and draw clinical attention to this area. Key Words: Disabled persons; Quality of life; Rehabilitation; Spinal cord injuries.

Presentation 4
Foot and Ankle Kinematics in Patients With Posterior Tibial Tendon Dysfunction. Mary Ellen Ness (Olin Engineering Center, United States), Richard Marks, Jason Long, Mike Khazzam, Gerald Harris.

Disclosure: None declared.

Objectives: To quantitatively characterize the 3-dimensional kinematics of patients with posterior tibial tendon dysfunction (PTTD) and to compare the results with those of a control population. Design: Case series. Setting: Outpatient area of teaching hospital. Participants: 34 patients with PTTD. Interventions: Not applicable. Main Outcome Measures: Temporospatial and kinematic gait parameters. Results: Significant alterations in temporospatial and kinematic parameters occur in patients with PTTD. Stride length, cadence, and walking speed were all significantly diminished, while stance duration was significantly prolonged compared with controls. Significant kinematic findings included: (1) diminished dorsiflexion and increased eversion.

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of the hindfoot; (2) decreased plantarflexion and abduction shift with loss of varus thrust in the forefoot; and (3) decreased range of motion with diminished dorsiflexion of the hallux. Results were considered to be statistically significant at the $P$ less than .01 level. **Conclusions:** Our study of 34 patients demonstrates that significant alterations in kinematics and temporospatial parameters occur in the gait of patients with PTTD when compared with a control population. **Key Words:** Gait; Rehabilitation.

**Presentation 5**

**Racial and Ethnic Differences in Activity of Daily Living Disability Among Older Adults: The Case of Spanish Speakers.** Manasi Tirodkar (Institute for Healthcare Studies, Northwestern University Feinberg School of Medicine, United States), Jing Song, Rowland W. Chang, Dorothy D. Dunlop, Huan J. Chang.

Disclosure: None declared.

**Objective:** To compare incident disability patterns across racial and ethnic groups. **Design:** Prospective cohort study with a 6-year (1998–2004) follow-up. **Setting:** National probability sample. **Participants:** 1998 Health and Retirement Study sample of 12,288 non-Hispanic whites, 1952 African Americans, 575 Hispanics interviewed in Spanish (Hispanic/English), and 518 Hispanics interviewed in English (Hispanic/English), with age greater than 65 years and free of disability at baseline. **Interventions:** Not applicable. **Main Outcome Measure:** Disability in activities of daily living (ADL) tasks (walking, dressing, transferring, bathing, toileting, feeding). **Results:** Although Hispanic/English reported lower-extremity dysfunction more frequently than other groups (27.53% vs Hispanic/English [15.22%), African American [17.65%], white [11.52%]), they developed walking disability at lower rates (7.9% vs Hispanic/English [15.39%), African American [16.42%], white [11.80%]). Across the 6 ADL tasks, the development of walking disability was most frequent among Hispanic/English, African American, and whites. By contrast, Hispanic/Spanish reported dressing as the most frequent ADL task disability while walking was fourth. **Conclusions:** Aggregating all Hispanics, regardless of interview language, may be inappropriate. To contribute to National Institute on Disability and Rehabilitation Research’s long-range goal of exploring cultural factors among minority and underserved populations at risk of developing disability, future research on linguistic group differences in self-reported health outcomes is necessary to provide appropriate health status measures for diverse racial and ethnic groups. **Key Words:** Activities of daily living; Hispanic Americans; Language; Rehabilitation.
Poster Presentations

Interventions

Poster 1
Disclosure: None declared.

Objective: To examine the efficacy of low-load prolonged stretching with dynamic splinting on patients’ passive range of motion (PROM) in ankle dorsiflexion. Design: Controlled, crossover, cohort study, lasting 6 months. Setting: Multiple physical medicine and physical therapy clinics across the United States. Participants: 40 volunteer patients participated (25 with cerebrovascular accident, 15 with traumatic brain injury); all patients had unresolved plantarflexion contracture. Intervention: Ankle dorsiflexion D纳斯plint for low-load, prolonged-stretch. Main Outcome Measure: Maximal ankle dorsiflexion measured in PROM. Results: There was a significant change for all crossover groups (P ≤ .001). Conclusions: Excessive plantarflexion tone and contracture can be reduced with dynamic splinting. Key Words: Ankle; Brain injuries; Contracture; Rehabilitation; Stroke.

Poster 2
Effect of Neurodevelopmental Therapy in Chronic Stroke Patients. Eugene Kang (Bobath Memorial Hospital, Republic of Korea), Soon-yong Kwon, Seong-gon Son, Soo-yeol Park, Seok Bum Ko.
Disclosure: None declared.

Objective: To evaluate the effect of neurodevelopmental therapy (NDT) in patients with chronic stroke (>6mo) as measured by the FIM instrument and Mini-Mental State Examination (MMSE). Design: Retrospective chart analysis. Setting: Inpatient stroke rehabilitation ward of a hospital. Participants: Consecutive patients (N = 109) presenting with chronic stroke. Interventions: Not applicable. Main Outcome Measures: Functional outcome was measured by the FIM and MMSE instruments at admission and discharge. The difference in scores of FIM and MMSE at admission and discharge was defined as the gain and the gain divided by period of hospitalization was defined as the efficiency. Results: The scores of FIM, motor FIM, and cognitive FIM at discharge were higher than those at admission (78.67 vs 73.13; 52.00 vs 47.72; 26.67 vs 25.41, respectively; P < .05). The MMSE score at discharge was also higher than that at admission (22.60 vs 21.47, respectively; P = .13). Conclusions: This study showed that the stroke patients, even in the chronic stage, had motor and cognitive functional potential that was improved by NDT. The speech problem, depression, shoulder pain, and osteoarthritis might be limited factors in rehabilitation in patients with chronic stroke. Key Words: Rehabilitation; Stroke.

Poster 3
Examining the Effects of Treatment Intensity and Constraint-Induced Language Therapy for Persons With Stroke-Induced Aphasia: Findings of an Evidence-Based Systematic Review. Anastasia Raymer (Old Dominion University, United States), Janet Patterson, Leora Cherney, Rob Mullen, Tracy Schooling, Tobi Frymark.
Disclosure: None declared.

Objective: To synthesize evidence for intensity of treatment and constraint-induced language treatment (CILT) for aphasia. Data Sources: We conducted a systematic search of 17 literature databases (eg, PubMed, CINAHL). Study Selection: We included English peer reviewed studies addressing 1 of 10 clinical questions in adults with stroke-induced aphasia. We excluded studies if subjects had other medical diagnoses or received pharmacologic intervention for aphasia. Of 447 citations, 36 addressed intensity of aphasia treatment or CILT. We excluded 26 that did not provide direct evidence or contain original data. Data Synthesis: The remaining 10 studies were evaluated based on the American Speech-Language-Hearing Association’s levels of evidence scheme for methodologic quality using 9 criteria (eg, study design, blinding). Studies were characterized by research stage and effect sizes were calculated. Conclusions: Overall, we found modest evidence for the effects of CILT and intensive treatment in chronic aphasia. No studies evaluated CILT in acute aphasia and 1 evaluated intensity. Of 4 studies reported as discovery research, 3 were minimally influential and 1 was influential in their quality. 5 studies fell in the domain of treatment efficacy research, all of which were influential. One study of treatment effectiveness was considered minimally influential. Key Words: Aphasia; Language therapy; Rehabilitation.

Poster 4
Effect of Botulinum Toxin Type A on Walking Speed in Poststroke Patients: A Subgroup Analysis of Patients in a 2-Part, 32-Week, Multicenter Study. Fiona Napier-Flood (Allergan Australia, Australia), John Olver, John Rogers, Jane Deane.
Disclosure: Fiona Napier-Flood, John Rogers, Jane Deane are employees of Allergan Australia Pty Ltd, Australia.

Objective: To investigate whether botulinum toxin type A (BTX-A) (Botox) treatment increases walking speed in poststroke patients. Design: Part I was an 18- to 20-week, double-blind, placebo-controlled study; part II was a 12-week, open-label follow-up. Setting: 7 clinical sites. Participants: Of 85 original study poststroke patients, the subanalysis included 47 with spastic equinovarus deformity (baseline: Ashworth Scale score, 2–3; walking speed, <10m per 13s). Interventions: Part I patients were randomized to either 200 or 300U of BTX-A or placebo; patients entered part II and received up to 300U of BTX-A at least 12 weeks after the first injection if their Ashworth scores returned to baseline. Patients were assessed at 4-week intervals after each injection. Main Outcome Measure: Percentage of change from baseline in walking speed (calculated as time taken to walk 10m). Results: BTX-A significantly increased walking speed by 18.8%, 14.4%, and 25.8% (P ≤ .028) after first injection and by 25.9%, 38.8%, and 39.3% (P ≤ .005) after second injection at 4, 8, and 12 weeks, respectively. Placebo subjects showed a significant increase of 19.8% (P = .026) at 4 weeks; patients receiving first BTX-A injection in part II showed significant increase of 35.5% (P = .04) at 12 weeks. BTX-A was safe and well-tolerated. Conclusions: BTX-A significantly improved walking speed in poststroke patients. Key Words: Botulinum toxin type A; Rehabilitation; Walking.
Poster 5
Paradoxical Facilitatory Effect of Cathodal Transcranial Direct Current Stimulation on Poststroke Aphasia. Eun Kyong Kang (National University Bundang Hospital, Republic of Korea), Hae Min Sohn, Min-Kyun Oh, Byung-Mo Oh, Jae Yong Jeon, Dae-Yul Kim, Nam-Jong Paik.
Disclosure: None declared.
Objective: To test whether cathodal transcranial direct current stimulation (tDCS) applied to the contralesional cortex (F8 on 10-20 system) during speech training would enhance picture naming ability relative to speech training alone. Design: Double-blind, sham-controlled, crossover design. Setting: University hospital. Participants: 5 stroke patients with anomic or motor aphasia. Interventions: Patients received 5 days of standardized speech training coupled with real tDCS (2mA for 20min) or sham stimulation. Improvement in percentage of correct responses and reaction time (in milliseconds) relative to baseline on computerized Boston naming test (60 items) for each intervention. Results: Patients showed more improvement on picture naming with real stimulation than on sham stimulation (mean ± SD, Δ12.3% ±14.5%, vs Δ−0.6% ±9.8%; t=1.66; 2-tailed, P=.18). Patients showed significantly reduced reaction time to name pictures with real stimulation than with sham stimulation (mean ± SD, Δ810.8±2180.0ms vs Δ428.5±612.8ms; t=−2.7; 2-tailed, P=.03). 4 of 5 patients showed more improvement in number of picture namings with real stimulation than with sham stimulation. Conclusions: Noninvasive down-regulatory cortical stimulation on the contralesional Broca’s area enhanced speech training effects relative to speech training alone, suggesting a potential role for noninvasive cortical interventions as adjuvant strategies in speech rehabilitation. Key Words: Aphasia; Brain; Rehabilitation; Stroke.

Poster 6
Mental Practice as a “Gateway” to Modified Constraint-Induced Movement Therapy: A Promising Combination to Improve Function. Stephen Page (University of Cincinnati Academic Medical Center, United States), Peter Levine.
Disclosure: None declared.
Objective: To determine the efficacy of a program of mental practice that preceded a modified constraint-induced movement therapy program (mCIMT) in improving more affected arm function in 4 patients with stroke. Design: Pre-post case series. Setting: Outpatient rehabilitation clinic. Participants: 4 subjects with chronic stroke (>1y poststroke) exhibiting stable, moderate hemiparesis. Interventions: Half-hour therapy sessions emphasizing activities of daily living (ADLs) were administered 2 days a week for 6 weeks, immediately followed by 30-minute mental practice sessions requiring mental practice of the ADLs being practiced. A week after completing mental practice, and after readministering outcome measures, patients participated in mCIMT, consisting of structured therapy emphasizing more affected arm use in ADLs 3 times a week for 10 weeks. Their less affected arms were also restrained 5 days a week for 5 hours. Main Outcome Measures: The Fugl-Meyer Assessment (FMA) for arm impairment and the Action Research Arm Test (ARAT). Results: After mental practice, patients exhibited marked changes on the ARAT (mean change, +4.9) and the FMA (mean change, +3.8), and increased active wrist and finger extension, qualifying them for mCIMT. After mCIMT, participants exhibited additional ARAT and FMA changes (mean change, +9.9 and 8.7, respectively) sustained 3 months later. Conclusions: Data suggest that mental practice provides a pathway whereby patients can participate in mCIMT, realize additional gains, and again perform valued ADLs. Key Words: Hemiplegia; Physical therapy techniques; Rehabilitation; Stroke.

Poster 7
Bilateral, Reciprocal Locomotor Training in Chronic Stroke: A Randomized, Controlled Crossover Study. Stephen Page (University of Cincinnati Academic Medical Center, United States), Peter Levine.
Disclosure: None declared.
Objective: To determine the efficacy of a bilateral reciprocal training regimen on affected leg impairment and dynamic balance. Design: Randomized, controlled, single-blinded crossover study. Setting: Outpatient rehabilitation hospital. Participants: 7 patients who experienced stroke more than 1 year prior to study entry exhibiting affected leg weakness. Intervention: Subjects were randomly assigned to receive either: (1) use of a bilateral, recumbent locomotor training device, called the NuStep, occurring 3 days a week in 30-minute increments during an 8-week period, followed by an 8-week home exercise program (HEP) (n=4); or (2) an 8-week home exercise program followed by participation in the bilateral locomotor training program 3 days a week in 30-minute increments during an 8-week period (n=3). Main Outcome Measures: Outcomes were evaluated by a blinded rater using the lower-extremity scale of the Fugl-Meyer Assessment (FMA) and the Berg Balance Scale (BBS). Results: After HEP participation, subjects showed nominal or no changes on the outcome measures. After NuStep participation, patients showed improvement reductions as shown by the FMA, and increased balance as shown by the BBS. Conclusion: Use of this modality produced increased isolated movement in joints that conveys improved balance. Key Words: Exercise; Rehabilitation; Stroke.

Poster 8
The Effects of Intensive Activity-Based Restorative Therapy on Function in Chronic Spinal Cord Injury (American Spinal Injury Association Grade D). Katie Dickelman (Kennedy Krieger Institute, United States).
Disclosure: None declared.
Objective: To demonstrate the impact of intensive activity-based restorative therapies on functional limitations in a highly functioning patient with chronic American Spinal Injury Association (ASIA) grade D spinal cord injury (SCI). Design: Single case study. Setting: Outpatient SCI rehabilitation program. Participant: The subject was an employed 26-year-old who sustained an SCI as a child and had not participated in formal rehabilitation for the past 20 years. He ambulated in the community with Lofstrand crutches, demonstrated decreased activity tolerance, and had limited participation in strenuous activities. Interventions: A 6-month program of clinical-based therapy and home exercise program with an activity log was prescribed, with treatment including: partial body weight-supported gait training, strengthening, electric stimulation, and manual stretching. Main Outcome Measures: Standardized measures include: Timed Up & Go (TUG), Berg Balance Scale (BBS), timed single-leg stance, six-minute walk test (6MWT), Biodex isokinetic knee and ankle strength measurements, spatiotemporal gait parameters (GAITRite mapping), Spinal Cord Independence Measure, version III (SCIM III), ASIA scores, manual muscle testing (MMT), and 36-Item Short-Form Health Survey (SF-36). Measurements were taken at initial evaluation and repeated monthly throughout a 6-month intensive physical therapy bout, with the exception of Biodex scores, ASIA, and SF-36, which were taken at initial evaluation and at discharge. Results: Preliminary results showed an improvement from baseline by 8 points in BBS, 33% increase in 6MWT, 1 MMT score in hip and knee muscles bilaterally, 22% increase in velocity, and 8% increase in cadence on 10m walk for time, and 5 points on SCIM III after 5 months of therapy. The study is ongoing; select measures were chosen for long-term follow-up and will be presented. Conclusions: Intense, individualized activity-based restorative therapy can produce a meaningful increase.
Poster 9
Treatments Used for Spinal Cord Injury Pain: Results of a Systematic Review. Jeanne M. Zanca (Mount Sinai School of Medicine, United States), Marcel P. Dijkers.
Disclosure: None declared.
**Objectives:** To identify treatments used for chronic pain after spinal cord injury (SCI) and to gather information on treatment effectiveness.
**Data Sources:** Searches of Medline, CINAHL, EMBASE, and other databases; review of reference lists; and manual searches of SCI journals. Search terms included pain, spinal cord injury, paraplegia, quadriplegia, and tetraplegia.
**Study Selection:** 15 articles describing 16 studies met criteria for inclusion. They were original survey studies of chronic pain treatments in persons with traumatic SCI or SCI of unspecified etiology, published in English.
**Data Extraction:** Data on study characteristics, sample, treatments, and treatment effectiveness were abstracted and entered into a database. Treatment data were tabulated by treatment type.
**Data Synthesis:** Nonsteroidal anti-inflammatories (reported in 8 studies), opioids, and acetaminophen (7 studies each) were frequently reported pharmacologic treatments. Massage, acupuncture, and physical therapy (9, 8, and 7 studies, respectively) were frequently reported nonpharmacologic treatments. Surgical treatments included cordotomy, rhizotomy (3 studies each), and corpectomy (2 studies). Marijuana use was reported in 6 studies. Methods of describing effectiveness varied widely among the 12 studies reporting these data. Pharmacologic agents, chiropractic treatment, massage, exercise, cordectomy, rhizotomy, and marijuana use were among those treatments with favorable effectiveness reports.
**Conclusions:** A variety of treatments are used for post-SCI pain, and reports of effectiveness vary widely. **Key Words:** Pain; Rehabilitation; Spinal cord injuries; Treatment effectiveness; Treatment outcome.

Poster 10
Assessment of the Effects of a Hip Flexion Assist Orthosis With 3-Dimensional Gait Analysis in Multiple Sclerosis Patients. Darlene Stough (Cleveland Clinic, United States), Matthew Sutliff, Brian Davis, Brandy Reynolds, Francois Bethoux.
Disclosure: None declared.
**Objective:** To compare long-term effect of a hip flexion assist orthosis (HFAO) on clinical gait tests with immediate changes in 3-dimensional gait analysis parameters.
**Design:** Prospective 12-week uncontrolled trial of HFAO, followed by cross-sectional 3-dimensional gait analysis.
**Setting:** Outpatient multiple sclerosis (MS) center in a biomedical engineering lab.
**Participants:** Ambulatory patients with MS and severe hip flexor weakness.
**Intervention:** Use of a customized HFAO.
**Main Outcome Measures:** For the longitudinal study, the timed 25-foot walk test (25FWT), six-minute walk test (6MWT), and Mellen Center Gait Test (MCGT). For gait analysis, step width, walking speed, step length, and toe clearance.
**Results:** 5 subjects were included. There were trends for improvement of the 25FWT and MCGT, but no significant difference in step width with HFAO wear (effect size, 1.2; \( P = .043 \)). There was a statistically significant decrease in step width with HFAO wear (effect size, 1.2; \( P = .068 \)).
**Conclusions:** Significant improvement in gait tests at 8 and 12 weeks was previously demonstrated on a larger sample. The significant decrease in step width suggests an improvement in gait stability, but there were no other significant immediate changes in gait parameters. This suggests that the long-term clinical benefits result not only from immediate biomechanic changes, but also from the training effects of daily use.
**Key Words:** Gait; Orthosis; Rehabilitation.

Poster 11
Progressive Multiple Sclerosis Improves With Constraint-Induced Movement Therapy. Victor Mark (University of Alabama at Birmingham, United States), Edward Taub, Gitendra Uswatte, Khurram Bashir, Adriana Delgado, Mary Bowman, Camille Bryson, Staci McKay.
Disclosure: None declared.
**Objective:** To evaluate the responsiveness of chronic hemiparetic multiple sclerosis (MS) to constraint-induced movement therapy (CIMT).
**Design:** Pre-post prospective treatment comparison.
**Setting:** Outpatient neurorehabilitation program.
**Participants:** 5 patients with either primary or secondary progressive MS associated with chronic hemiparesis who were relapse-free at least 3 months and showed clinical evidence of unilateral upper-extremity (UE) nonuse with retained ability to undergo training tasks.
**Interventions:** CIMT for chronic UE hemiparesis was administered for a total of 35 hours, distributed over 2 to 10 weeks, based on the preference of each patient.
**Main Outcome Measure:** Change in self-reported 30-item mean Motor Activity Log (MAL) score from pre- to post-treatment. The MAL has an established reliability and validity; scores can range from 0 to 5. Clinically meaningful change is \( \geq 0.5 \) points.
**Results:** The mean pre-post change in mean MAL score \( \pm SD \) was 1.8 \( \pm 1.0 \) points.
**Conclusions:** This is the first study to demonstrate that a progressive neurologic disorder can improve in its limb nonuse following CIMT. The treatment response of MS is similar to that of other stroke, suggesting that the disorders share a common mechanism involving limb nonuse, despite differences in etiology and pathology. Follow-up evaluations are planned.
**Key Words:** Motor activity; Multiple sclerosis; Rehabilitation.

**Physiologic Studies**

Poster 12
Somatosensory Evoked Potentials Monitoring During Restoration Functions of Spinal Cord and Peripheral Nerves. Sergey Lytaev (State Pediatric Medical Academy, Russian Federation), Andrei Trapenikov, Olga Timkina.
Disclosure: None declared.
**Objective:** To study the dynamics of rehabilitation, after trauma to the spinal cord and nerves, on somatosensory evoked potential (SEP) data.
**Design:** Clinical diagnostics study.
**Setting:** Course of rehabilitation after surgery.
**Participants:** 23 patients with vertebral trauma (at the lumbosacral level) and 32 patients with posttraumatic neuropathies.
**Intervention:** Electric signals were obtained for the following nerves—sciatic, peroneal, and tibial.
**Main Outcome Measure:** SEPs in 19 monopolar sites using standard technique.
**Results:** We found full break of neural conductivity pathways of the central nervous system, but only during full compression or hypoxia. At partial compression or hypoxia of the pathways, SEPs were absent in the parietal cortex; however, SEPs were formed in associated areas. If the SEP is found in more than 50% of the sites, rehabilitation is possible. If more than 60% of the points are silent, then rehabilitation is not possible.
**Conclusions:** The SEP pattern in vertebral trauma is similar to that of violations of peripheral nerves. In both cases, conducting change of spatial maps have acts: information flow, reflected in the multicomponent pattern of the evoked potential, did not register in whole regions of the brain. An absence of SEP points at tested sites is a function of the functional status (not the anatomic) of somatosensory systems.
**Key Words:** Evoked potentials, somatosensory; Rehabilitation; Trauma.
Poster 13
Repetitive Transcranial Magnetic Stimulation, Stem Cells, and Synaptic Plasticity. Rosalia Crupi (CUNY School of Medicine, United States), Hoan-Yan Wang, M. Felice Ghilardi, René Hen, Fortunato Battaglia.
Disclosure: None declared.
Objectives: To investigate the effects of repetitive transcranial magnetic stimulation (rTMS) on neuronal plasticity and stem cell proliferation in rodents. Design: Not provided. Setting: Laboratory. Animals: 129 SvEv age-matched adult male mice (age, 12–25wk). Intervention: 5-day rTMS treatment (15-Hz stimulation at 50% stimulator output intensity with a rodent coil) or sham stimulation. Main Outcome Measures: Neocortical and hippocampal long-term potentiation (LTP) (dentate gyrus, the Shaffer collateral-CA1 pathway, prefrontal cortex, motor cortex), dentate gyrus stem cell proliferation and glutamate N-methyl-D-aspartate (NMDA) receptor composition, and signaling in the brain from stimulated- and sham-treated mice. Results: rTMS treatment induced an increase in the amount of LTP in all the tested brain areas, an increase in the number of new-generated neurons, and an increase of NMDA/glycine-induced NMDA receptor activation without affect on receptor assembly and interaction with postsynaptic density protein 95. Conclusions: Chronic rTMS treatment in rodents stimulates proliferation of newly generated neurons in the dentate gyrus and induces an increase of LTP in neonurogenic and non-neurogenic areas. Biochemical evidence supports an enhanced NMDA receptor function that may underlie these plastic changes. These results have important implications for neurorehabilitation and regenerative strategies. Key Words: Long-term potential; Neuronal plasticity; Rehabilitation; Stem cells.

Poster 14
Disturbance of Cerebellar Blood Flow on Postural Sway in Patients With Cerebrovascular Attack. Shin-Tsu Chang (Tri-Service General Hospital, Taiwan).
Disclosure: None declared.
Objective: To study the relationship between postural sway and contralateral cerebellar diaschisis (CCD) in patients with chronic cerebrovascular attack using single-photon emission computed tomography (SPECT). Design: Case-control study. Setting: A medical center. Participants: A total of 42 patients (34 men, 8 women; mean age, 56y) with duration of more than 6 months. Patients with left-side and right-side CCD and patients with CCD naive were allocated to SPECT based on results. Interventions: Not applicable. Main Outcome Measures: Comparison of upright posture was obtained from the sway intensity and sway velocity, which were recorded via a force platform. Results: Generalized estimating equations were adopted for statistics. After adjusting for age and sex, the relationship between sway intensity and velocity and patient groups was found to vary with the CCD. The values obtained with open eyes had 1.62 lower (P=.000) sway intensity and 2.78 lower (P<.000) sway velocity, when compared with those values obtained with closed eyes. Obtained from statistical comparison of the sway profiles, the group differences between right-side CCD and CCD naive were not significant in sway intensity (Δ=6.6, P=.675) or in sway velocity (Δ=1.4, P=.961); however, there were significant differences between left-side CCD and CCD naive in sway intensity (Δ=2.70, P=.005) and in sway velocity (Δ=8.18, P=.001), respectively. Conclusions: This study supports the hypothesis that postural sway abnormality correlates strongly with left-side CCD. Key Words: Gait; Posture; Rehabilitation.
Objective: To study the influence of a multifaceted treatment approach on movement and cognitive functions in the early period of acute disturbance of cerebral blood flow. Design: Not provided. Setting: Not provided. Participants: Patients with acute stroke who had stable neurologic symptomatology and relative stability in hemodynamic indices. In the main group (n=387) with ischemic stroke, rehabilitation started at 1 to 2 days; with hemorrhagic, at 2 to 4 days. In the control group (n=350), at 5 to 7 days and at 7 to 10 days in accordance. Interventions: Not applicable. Main Outcome Measures: The diagnostic standard was neurologic examination: neurovisual methods (eg, computed tomography [CT], CT angiography, duplex vessel scan); neurofunctional methods (eg, transcranial magnetic stimulation, evoked potentials of brain of different modalities, electromyography, electromyography, stabilitometry); neuropsychologic observation (qualification of the defect, revelation of the syndrome of the disturbed psychic functions and emotional-motivation sphere); and assessment scales (eg, Lindmark Scale, Ashworth Scale, Rankin Scale, social activity, individual typologic questioner). The program to influence proprioception and cognitive disorders included the following: gymnastics (breathing, passive, passive and active); prime stages of verticalization; laser therapy of the neck vertebrae and sinocarotid zone (80Hz, at 4–5W, at 6 points per minute); Bemer therapy (basic 8-minute program 3+ locally on the collar zone – 12-min program P2); correction of swallowing disorders (Vocastim-electrostimulation from 0.4–15mA; impulse duration, up to 1000mc; length of treatment, 7–20min); selective vibrostimulation of feet in the regime of cyclogram of walking, vibrostimulation 64Hz for 5min; 128Hz for 7min; 60–80 steps/min; programmed electrostimulation (low frequency current, up to 100mA; duration, up to 15min); and helio-oxygen inhalations (70% of helium temperatures up to 80°C; duration, 15min 2 times a day). Results: When we compared disability 6 months poststroke (Rankin Scale), the results of the treatment group were better than those of the main group. Conclusions: Early treatment of proprioception and cognitive disorders allows for greater restoration of disturbed neurologic functions, normalized social status, improved adaptation to changed circumstances, and improved quality of life. Key Words: Cognitive disorders; Rehabilitation.

Poster 18
Influence of Temporal Targets and Object Weight on Smoothness of Forearm and Wrist Motion in Focal Dystonia: A Case Study. Timothy Reistetter (East Carolina University, United States), Howard William, Julie Nagelson, Erwin Manalo, Monica Carrion-Jones, Cindy Ivanhoe.

Disclosure: None declared.

Objective: To explore the effects of object weight and movement rates on the smoothness of forearm and wrist motions in focal dystonia. Design: Case study. Setting: Upper-extremity motion analysis laboratory. Participants: A 65-year-old man with dystonia. Interventions: 5 reaching movements: (1) an empty cup at the participant’s self-selected rate; (2) without weight as fast as possible (WO-F); (3) without weight as slow as possible (WO-S); (4) with weight as fast as possible (WW-F); and (5) with weight as slow as possible. Main Outcome Measures: Motion data from a 6-camera Qualysis system was used to calculate smoothness of pronation and supination, wrist flexion and extension, and ulnar and radial deviation. Using the third derivative of position, the primary outcome was the raw unfiltered peak change in angular acceleration over time. Results: As indicated by the range across all trials, the smoothest motions were pronation and supination. Within pronation and supination, the smoothest trial was WO-F. For flexion and extension, the smoothest trial was WW-F. For ulna and radial deviation, the smoothest trial was WO-S. Conclusions: These data indicate that smoothness depends on the motion performed and that different temporal and object parameters influence smoothness, thus supporting the need to match the subject’s capacity to the task being performed. Key Words: Dystonia; Motion; Rehabilitation.

Poster 19
Asymmetries in Weight Bearing Measured in Healthy Persons. Nitin Moholkar (Kessler Medical Rehabilitation Research and Education Center, United States), Venkata Gade, David Tung, Thomas Edwards.

Disclosure: None declared.

Objective: To determine the degree of weight-bearing asymmetry in healthy control subjects, who are often used for comparisons in rehabilitation research. Design: Subjects were tested on an oscillating platform. Setting: Balance rehabilitation research laboratory. Participants: 12 healthy subjects with no balance disorder. Intervention: 3 oscillation trials at 1.25Hz with a 6-cm peak amplitude and eyes open. Main Outcome Measures: Vertical ground reaction force under each foot. Asymmetry index, which was used to assess degree of uneven weight distribution on the feet. Results: More than a third of the trials (39%) showed an uneven weight distribution (asymmetry index<−0.1) between feet. Some subjects averaged nearly 100N more weight on 1 side than the other. This would lead to under- or overestimation of joint forces and moments, and therefore incorrect baseline values for comparison with injured populations. Conclusions: While not as asymmetric as stroke patients, healthy controls demonstrated a significant amount of asymmetry in weight bearing. This finding seems important to consider when interpreting rehabilitation weight-bearing activities. Key Words: Balance; Kinetics; Rehabilitation.

Poster 20
The Relationships Between Grip Strength, Perceived Hand Ability, and a Standardized Hand Function Assessment. Christine Chen (New York University, United States), Celina Rallan.

Disclosure: None declared.

Objective: To examine the relationships between perceived manual ability and standardized hand function assessments (strength, functional rating of simulated hand tasks) among patients with hand injuries or pathologies. Design: Cross-sectional cohort. Setting: Outpatient hand rehabilitation. Participants: Patients receiving hand rehabilitation services due to orthopedic or neurologic diagnoses. Interventions: Not applicable. Main Outcome Measures: Manual Ability Measure (MAM), grip strengths, the TEMPA (Upper Extremity Performance Test for the Elderly) functional ratings. Results: Moderate associations were found between the MAM (ie, perceived manual ability) and the TEMPA; correlations between MAM and bilateral functional rating and combined functional rating were higher (Spearman ρ range, .58–.66) than those between MAM and functional rating for the right or left hands (Spearman ρ range, .36–.59). Conclusions: Perceived manual ability seems to be associated more with bilateral or total (ie, combined) hand function assessed by the TEMPA than with grip strength or TEMPA functional ratings of the separate hands. Moreover, perceived hand ability can only be partially explained by impairment components or function of the separate hands. Key Words: Hand; Patient outcome assessment; Rehabilitation.

Disability Epidemiology
Poster 21
Associations Between Neurobehavior and Disability After Stroke. Elizabeth Skidmore (University of Pittsburgh, United States), Joan Rogers, Lynn Chandler, Margo Holm.

Disclosure: None declared.
Objective: To test 2 hypotheses: (1) that domains of neurobehavioral impairment (cognitive, motor, affective) interact to influence activities of daily living (ADLs) for Medicare beneficiaries who reside in the community in the year after suffering a stroke. Design: Prospective cohort study. Setting: Medicare Current Beneficiary Survey (MCBS) between 1992 and 2000. Participants: 1062 participants in the MCBS who suffered a stroke between 1992 and 2000. Interventions: Not applicable. Main Outcome Measures: Frequency of self-reported ADL difficulty (in walking, transferring, bathing, toileting, dressing, eating) at 3 time points: prior to diagnosis of stroke, interview following stroke, and next yearly interview. Results: More ADL difficulties were reported over time, with the percentage reporting the highest number of ADL difficulties (5 or 6), increasing from 10.3% prestroke to 16.4% after onset of stroke, to 18.5% 1 year later. At least 41% of participants had no difficulties at all time points (n=330). Reporting more ADL difficulties after onset of stroke was associated with prestroke ADL difficulty and older age (both P<.000), but not hospital length of stay or other demographic variables. Conclusions: Frequency of ADL difficulties increased after stroke and over time in this cohort of Medicare beneficiaries living in the community. The increase in ADL difficulties appears to be related to ongoing difficulties and increasing age. Key Words: Activities of daily living; Medicare; Rehabilitation; Stroke.

Poster 24
Effect of Time to Rehabilitation Admission on Stroke Rehabilitation Outcomes. Hua Wang (Kaiser Foundation Rehabilitation Center, United States), Michelle Camicia, Mary Elizabeth Sandel. Disclosure: None declared.

Objective: To examine the association between stroke onset days and rehabilitation outcomes. Design: Retrospective study. Setting: An inpatient rehabilitation facility (IRF) in northern California. Participants: 2037 stroke patients admitted for initial inpatient rehabilitation between 2002 and 2006. Interventions: Not applicable. Main Outcome Measures: Discharge FIM scores (total, motor, cognition), rehabilitation length of stay (LOS), LOS efficiency measured by total FIM gain divided by LOS, and rehabilitation discharge disposition. Results: After controlling for age at admission, sex, race, relative weight of case-mix group, LOS, as well as corresponding admission FIM scores, earlier IRF admission was significantly and linearly associated with higher discharge FIM scores, greater total FIM gain, and higher LOS efficiency (P<.001). Patients admitted to IRF early tended to have a shorter LOS and higher percentage discharge disposition to a community setting. Associations of age at admission, sex, race, and patients’ pre-hospital setting were also observed in relation to rehabilitation outcomes. Conclusions: Early admission to IRF was positively associated with motor and cognitive functional improvement in this stroke population, indicating the importance of availability and prompt access of postacute inpatient rehabilitation services. Key Words: Rehabilitation; Stroke; Treatment outcomes.

Poster 25
Occupation Classification (Professional, Skilled, and Manual) and Employment After Spinal Cord Injury. Jerry Wright (Santa Clara Valley Medical Center, United States), Tamara Bushnik. Disclosure: None declared.

Objective: To examine the relationship between preinjury work classifications (professional, skilled, manual) and employment at 1 year post spinal cord injury (SCI). Design: Prospective longitudinal database. Setting: 15 National Institute on Disability and Rehabilitation Research Model Spinal Cord Injury Systems. Participants: 1759 persons with SCI, between ages 18 and 62 years. Interventions: Not applicable. Main Outcome Measure: Employment at 1 year post-SCI. Results: People were coded as being in 1 of 4 occupation classifications, depending on
their preinjury occupation: professional (n=269), skilled (n=678), manual (n=281), and not employed (n=531). People with a preinjury classification of professional had the highest percentage return to competitive employment (34.6%) at 1 year postinjury, followed by skilled (17.5%), manual (7.1%), and not employed (4.9%). A multiple logistic regression showed that beyond preinjury classification, education status, marital status, sex, days in rehabilitation, and FIM motor discharge also played a role in predicting employment status at 1 year. Neurologic category, age, race and ethnicity, and English-language capability were not predictive in this model. Subjects who were preinjury professionals had a 7.5 times greater chance of being employed at 1 year postinjury. Conclusions: People who were previously employed prior to an SCI had much higher rates of employment at 1 year postinjury (19% vs 5%) than those that were unemployed. Among the group that was previously employed, people who had professional positions had the highest percentage of employment (34.6%) at 1 year postinjury. Preinjury occupation classifications are useful in predicting postinjury employment after SCI. Key Words: Employment; Rehabilitation; Spinal cord injuries.

Poster 26
Disclosure: Supported in part by the National Institute on Disability and Rehabilitation Research.
Objective: To evaluate predictors of loss to follow-up in persons with spinal cord injury (SCI). Design: Multicenter longitudinal study. Setting: 4 Model Spinal Cord Injury Systems (MSCIS) throughout the United States with complete data sets between 1979 and 2006. Participants: 7219 patients who received initial hospital care from the MSCIS, were injured at age 15 years or older, and had clinically discernible neurologic deficit at discharge and follow-up. Interventions: Not applicable. Main Outcome Measures: Loss to follow-up was defined as no research information obtained from patients who were eligible for follow-up. Results: Loss to follow-up rate was 15%, 36%, and 51% for postinjury years 1, 5, and 10, respectively. Generalized estimating equation model showed that, after controlling for MSCIS and postinjury years, patients who were retired or unemployed, were self-responsible for medical expenses, and had less severe neurologic deficit were more likely to be lost to follow-up. In contrast, patients who received support from the state vocational rehabilitation program or worker’s compensation were less likely to be lost. There is no significant association between loss to follow-up and age, race, sex, education, and marital status. Conclusions: The study findings could help examine the potential bias in SCI outcomes studies because of loss to follow-up. Key Words: Rehabilitation; Spinal cord injuries.

Poster 27
Disclosure: None declared.
Objective: To explore the relationship between physiologic and quality of life (QOL) benefits of pushrim-activated power-assist wheelchair (PAPAW) use. Design: Quantitative and qualitative methods, A-B-A design, and descriptive analyses. Qualitative investigator was blinded. Setting: Wheelchair users’ natural environment and biomechanics laboratory. Participants: 12 full-time manual wheelchairs users. Interventions: A: own manual wheelchair (4wk); B: PAPAW (8wk); and A: return to own wheels (4wk). Main Outcome Measures: Effort (heart rate elevation), rate of perceived exertion (RPE), and completion time associated with propulsion tasks; and QOL (qualitative structured interviews). Results: Significant decreases in change in heart rate elevation and RPE were observed when going from manual wheelchairs to PAPAWs (P≤.001). The 5 of 12 participants who reported an overall positive experience with the PAPAW tended to take longer to complete propulsion tasks, own a lift and/or ramp to their car, were older, and were more years postinjury. The likelihood, however, of having a positive experience and a relatively high physiologic benefit hovered around chance. Conclusions: While physiologic benefit was documented in 10 of 12 participants, only 5 of the 12 reported a positive experience; level of disability and environmental resources were also important factors. Key Words: Effort; Exertion; Quality of life; Rehabilitation; Wheelchairs.

Poster 28
Patterns of Stress Appraisal and Coping Effort as Revealed in the Narratives of White and African-American Caregivers of Persons With Spinal Cord Injuries. Colette Duggan (Rehabilitation Institute of Michigan, United States), Tara Jeji.
Disclosure: None declared.
Objective: To describe patterns of stress appraisal and coping effort as revealed in the narratives by white and African-American caregivers to people with spinal cord injury (SCI). Design: Ongoing mixed-method (qualitative and quantitative) study. Setting: Community-based. Participants: 40 caregivers. Interventions: Not applicable. Main Outcome Measures: Themes of stress appraisal and coping effort embedded in the narratives. Results: Preliminary analysis of the narrative data suggests that caregivers were flexible in their appraisals of caregiver stress. They were, however, more likely to report stressors as threats than as challenges or losses. Participants used a variety of coping styles to manage perceived stress but were more likely to report using emotion-focused coping than other styles of coping (problem-solving and social support—focused and meaning-focused). To a certain extent, type of stressor was associated with the choice of strategy. Thus problem-solving coping was used more frequently to manage stressors perceived as a challenge. Emotion-focused coping was used more frequently to manage stressors perceived as threats and, to a lesser extent, as losses. This analysis also focuses on racial and ethnic differences in patterns of stress appraisal and coping effort associated with SCI caregiving. Conclusions: Attention to racial and ethnic differences in the stress-coping process should help clinicians deliver SCI caregiver services. Key Words: Caregivers; Rehabilitation; Spinal cord injuries; Stress.

Poster 29
The Prevalence of Chronic Pain in Community Residents With Spinal Cord Injury. Marcel Dijkers (Mount Sinai School of Medicine, United States), Fay Rim.
Disclosure: None declared.
Objectives: To determine the prevalence of chronic pain among persons with (traumatic) spinal cord injury (SCI), based on a quantitative summary of published studies. Data Sources: Searches of Medline, CINAHL, PsycINFO, and other bibliographic databases; ancestor search; and manual search of selected journals. Study Selection: Pain prevalence rate reported for a sample of at least 30 subjects with certain or likely traumatic SCI, published since 1980, in any language. Data Extraction: Data on sample makeup, study quality indicators, pain prevalence, and year of publication.
publication were abstracted using a form and extensive syllabus. **Data Synthesis:** 44 studies reported chronic pain prevalence rates ranging from 20% to 91%, with a fairly even spread between these extremes. The rate reported did not appear to be related to study quality. Prevalence of pain in the combined samples did not differ much between men and women, those with complete and incomplete SCI, those with paraplegia and tetraplegia. **Conclusions:** There is too much heterogeneity in reported chronic pain estimates to calculate a pain prevalence estimate using meta-analytic methods. Further research is needed to determine whether rates are related to sample make-up (eg, percentage complete injury) or specific research methods (eg, telephone interview versus self-report instruments; definition of “chronic”). The methodologic quality of the literature requires improvement. **Key Words:** Pain; Rehabilitation; Spinal cord injuries.

**Poster 30**

**Romantic Involvement, Sexuality, and Quality of Life in Persons With Traumatic Brain Injury.** Karen Murphy (Mount Sinai School of Medicine, United States), Sara Howard, Teresa Ashman, Joshua Cantor.

Disclosure: None declared.

**Objective:** To explore the relationship between romantic involvement, sexuality, and quality of life (QOL) in adults living in the community with traumatic brain injury (TBI). **Design:** Observational. **Setting:** Community-based research center. **Participants:** 185 persons with TBI up to 7 years postinjury and 55 age-matched controls. **Interventions:** Not applicable. **Main Outcome Measures:** Items from the Living Life After TBI and Life-3. **Results:** Participants with TBI who reported being romantically involved reported a better QOL (P<.01) and more sexual activity (P<.01), and rated sexual activity as more important (P<.01) than participants with TBI who denied involvement in a romantic relationship. However, participants with TBI, including those who were romantically involved, reported decreases in the frequency of sexual activity after their brain injury, lower sexual activity levels (P<.01), and lower QOL ratings (P<.01) than control participants. **Conclusions:** Study findings suggest that sexuality is an important QOL issue that needs to be addressed in the treatment of both people and couples with TBI. **Key Words:** Brain injuries; Rehabilitation; Sexuality.

**Poster 31**

**Symptoms and Experiences of Persons With Mild Traumatic Brain Injury and Participation in Litigation.** Charles Filanovsky (Mount Sinai Medical School, United States), Teresa Ashman, Evelyn Segura.

Disclosure: None declared.

**Objective:** To explore the relationship between participation in litigation and demographics, etiology, symptoms, service access and utilization, functional limitations, and perceptions of current and future financial status in persons with mild traumatic brain injury (TBI). **Design:** Observational. **Setting:** Large urban hospital. **Participants:** 135 people (54 litigants, 81 nonlitigants) reporting mild TBI (ie, “dazed and confused” or loss of consciousness <20min) in a longitudinal study examining psychosocial functioning postinjury. **Interventions:** Not applicable. **Main Outcome Measures:** Living Life After TBI and Brain Injury Screening Questionnaire (BISQ). **Results:** Chi-square analyses after post hoc correction found minimal differences: etiology (car collision, P<.001; fainting, P<.002), perceived functional limitations (working for pay/being a student, P<.001), and limitations on socialization with friends and family (P<.004). No significant differences were found in demographic variables, pain, actual employment, welfare benefits, most etiologies, most functional limitations, insurance coverage, received rehabilitation services, perceptions of current and future income adequacy, and quality of life. A t test comparing symptom self-report (BISQ) found significant differences in cognitive (P<.006) and emotional (P<.008) but not physical symptoms. **Conclusions:** This study replicates the oft-reported findings that mild TBI litigants describe more symptoms than persons not in litigation. When placed in a larger context, however, the almost uniform similarity between groups in this sample suggests that litigation status is not associated with major differences between individuals. These results speak to the importance of examining the full context of a person rather than focusing solely on symptom self-report before drawing conclusions. **Key Words:** Pain; Rehabilitation; Spinal cord injuries.

**Poster 32**

**After the Crash: A Research-Based Theater Approach for Knowledge Translation on Traumatic Brain Injury.** Angela Colantionio (University of Toronto, Canada), Pia Kontos, Kate Rossiter, Julie Gilbert, Julia Gray, Michelle Keightley.

Disclosure: None declared.

**Objective:** To evaluate a research-based dramatic production for the purpose of translating knowledge about traumatic brain injury (TBI) for health care professionals, managers, and decision-makers. **Design:** A post-test design was implemented following 4 performances. **Setting:** Ontario, Canada. **Participants:** Primary health care professionals (N=291) with varying levels of knowledge about TBI. **Interventions:** Using the results of 6 focus group discussions with TBI survivors, their family members, and TBI health care professionals, a full-length play was produced that reflected the experiences of the focus group participants. Strategies to address challenges of TBI care were also included, based on the literature. **Main Outcome Measures:** Use of a 5-item Likert scale to evaluate knowledge gained (5, most positive) and potential impact on practice, and open-ended comments to elaborate ratings. **Results:** Participants with no prior knowledge of TBI reported enhanced understanding of TBI (mean score range, 4.3±0.7 to 4.6±0.9). Virtually all participants indicated that the knowledge gained from the play will affect their interaction with TBI survivors (mean score, 4.1±0.8), even though the majority of practitioners had prior experience with this population. Qualitative comments were also overwhelmingly supportive of this intervention. **Conclusions:** Findings support the short-term impact of the use of drama for knowledge translation and will be discussed in relation to theories of learning and future research. Research-based theater can be an innovative approach to address the gap between research and clinical care. **Key Words:** Brain injuries; Malingering; Rehabilitation.

**Poster 33**

**Perceived Mental Health Status Following Trauma With and Without Brain Injury.** Marie-Christine Ouellet (Centre de Recherche du Centre Hospitalier Affilieé Universitaire de Queébec [Site Hôpital de l’Enfant-Jésus], Canada), Marie-Josée Sirois, André Lavoie.

Disclosure: None declared.

**Objectives:** To compare the frequency of self-reported mental health problems in trauma survivors with and without brain injury, to compare needs in terms of mental health services and perceived access limitations, and to describe factors associated with low mental health. **Design:** Cross-sectional survey. **Setting:** Community. **Participants:** 405 trauma survivors (239 with brain injury; 166 without brain injury) interviewed 2 to 4 years postinjury. **Interventions:** Not applicable. **Main Outcome Measures:** A survey questionnaire measured mental health problems, per-
Poster 34
Racial and Sex Differences in Employment Outcomes After Traumatic Brain Injury. Juan Carlos Arango-Lasprilla (Virginia Commonwealth University, United States), Jeffrey Kreutzer, Paul Wehman, Kelli Williams, Carlos Marquez de la Plata, Therese O’Neil-Pirozzi, Amitabh Jha.
Disclosure: None declared.
Objective: To examine racial and sex differences in employment outcome 1 year after a traumatic brain injury (TBI). Design: Retrospective study. Setting: Longitudinal dataset of the Traumatic Brain Injury Model Systems (TBIMS) National Database. Participants: People with moderate to severe TBI (4538 whites vs 2205 minorities) hospitalized between 1989 and 2006 in a TBIMS center. Interventions: Not applicable. Main Outcome Measures: Employment status (competitively employed vs unemployed) 1 year postinjury. Results: 1-tailed chi-square tests conducted on persons in the database with data for employment status (N=4386) indicated main effects for race (P<.001) and sex (P<.05), with a race by sex interaction (P<.01), such that minorities and men were more likely to be unemployed, and minority men were 1.23 times more likely to be unemployed than white men. For persons unemployed pre-injury, there were main effects for race (P<.01) and sex (P<.05), with a race by sex interaction (P<.05), such that minority men were 1.36 times more likely to remain unemployed at 1 year postinjury than white men. There were no significant main effects for sex or race among persons who were employed preinjury. Conclusions: Race and sex, along with preinjury employment status, are important determinants of postinjury employment. Research is needed to help elaborate factors underlying employment disparities. Key Words: Brain injuries; Employment; Rehabilitation.

Poster 35
Psychologic Status Correlates of Caregiver Appraisals After Traumatic Brain Injury. Gina Evans (Baylor College of Medicine, United States), Angelle Sander, Margaret Struchen.
Disclosure: None declared.
Objective: To explore the relationship between psychologic function and caregiver appraisal after traumatic brain injury (TBI). Design: Correlational. Setting: Follow-up with patients from 3 inpatient rehabilitation facilities. Participants: 133 caregivers of persons with TBI. Interventions: Not applicable. Main Outcome Measures: Brief Symptom Inventory (BSI) and Modified Caregiver Appraisal Scale (MCAS) at 1 to 2 years postinjury. Results: The findings indicate 2 significant canonical roots. The first root (Wilks $\lambda=.55, F_{27,445}=3.71, P<.001; R^2=.34$) accounted for 34% of the overlapping variance. The root was characterized by positive loadings on 9 of 9 BSI scales and the MCAS perceived burden and caregiver satisfaction subscales. Individual loadings indicated an inverse relationship between caregiver satisfaction and psychologic distress and a parallel relationship between burden and distress. The second root (Wilks $\lambda=.83, F_{16,306}=1.9, P<.05; R^2=.11$) accounted for 11% of the overlapping variance. This root was characterized by small loadings on 4 BSI scales and on the MCAS caregiver ideology subscale. More traditional caregiver ideology was related to increased distress. Conclusions: Consistent with previous research, psychologic distress was associated with increased perceived burden. Additionally, distress was associated with decreased satisfaction and increased feelings of obligation among caregivers. Findings can be used to target interventions for caregivers. Key Words: Brain injuries; Caregivers; Rehabilitation.

Poster 36
Cognitive Functioning in Older Adults Over Time: Effect of Traumatic Brain Injury and APOE e4 Allele Status. Amanda Sacks (Mount Sinai School of Medicine, United States), Teresa Ashman, Joshua Cantor, Mathew Egan.
Disclosure: None declared.
Objective: To determine the relative contributions of traumatic brain injury (TBI) and APOE e4 allele status to cognitive functioning over time in people 55 years and older. Design: Observational. Setting: Research center at an urban medical center. Participants: 54 subjects with TBI and 41 participants with no history of TBI. Interventions: Not applicable. Main Outcome Measures: Factor scores measuring memory, processing speed, verbal fluency, and executive functioning derived from standardized neuropsychologic tests. Results: The neuropsychologic battery was administered twice postinjury, with a mean interval of 31.9±12 months between assessments. An initial analysis of covariance (ANCOVA), controlling for age and education, comparing the positive and negative APOE e4 status groups yielded no significant differences between groups at either time point for any of the factors. However, when the TBI and non-TBI groups were compared, a main effect for group was found on the processing speed factor, with the TBI group performing worse than the non-TBI group at both time points (P<.001). ANCOVAs comparing both the positive and negative APOE e4 status among TBI and non-TBI groups showed no significant between-group differences in cognitive functioning over time. Conclusions: In this study, older adults with TBI did not exhibit different rates of cognitive change over time from non-TBI counterparts and APOE e4 status did not contribute significantly to changes in cognitive function. However, older adults with TBI did have greater cognitive impairment than their non-TBI counterparts at both assessment points on a factor measuring processing speed. Key Words: Brain injuries; Elderly; Rehabilitation.

Poster 37
Correlates of Sexual Satisfaction for Persons With Traumatic Brain Injury. Angelle Sander (Baylor College of Medicine, United States), Allison Clark, Margaret Struchen, Mark Sherer.
Disclosure: None declared.
Objective: To investigate correlates of sexual activity and satisfaction with sexual functioning in persons with traumatic brain injury (TBI). Design: Correlational. Setting: Follow-up with patients discharged from an inpatient rehabilitation program. Participants: 243 caregivers of persons with mild to moderate and severe TBI, tested at 1 to 2 years following injury. Interventions: Not applicable. Main Outcome Measures: Sexual activity and sexual satisfaction questions; Community Integration Questionnaire social integration scale; Neurobehavioral Functioning Inventory depression scale; and Satisfaction With Life Scale. Results: 28% of participants reported dissatisfaction with their sexual functioning. Univariate analyses of variance revealed...
that more severely injured persons reported less sexual activity, but were not less satisfied. Men and younger persons reported greater sexual satisfaction. Persons who were dissatisfied with their sexual activity were less socially integrated and had lower satisfaction with life. Logistic regression showed that the model consisting of injury severity, age, sex, social integration, depression, satisfaction with life, and sexual activity correctly classified 89% of persons satisfied with their sexual functioning and 62% of those dissatisfied. Conclusions: Sexual satisfaction, but not activity, is related to younger age, sex, overall life satisfaction, and social integration. Results can guide treatments for sexuality after TBI, with specific focus on increasing satisfaction. **Key Words:** Brain injuries; Rehabilitation; Sexuality.

**Poster 38**

Employment Status, Perceived Employability, and Independence and Assertiveness: A View of Quality of Life and Community Participation After Traumatic Brain Injury. Adam Warshowsky (Mount Sinai School of Medicine, United States), Teresa Ashman, Joshua Cantor, Matthew Egan.

Disclosure: None declared.

**Objective:** To explore how employment status and employability are related to quality of life (QOL) and community participation among persons with traumatic brain injury (TBI). **Design:** Observational. **Setting:** Community-based research center. **Participants:** 427 persons with TBI. **Interventions:** Not applicable. **Main Outcome Measures:** Living Life After TBI items, Bigelow Quality of Life subscales, Craig Handicap Assessment and Reporting Technique social integration subscale, Flanagan Scale of Needs, and Life-3. **Results:** Chi-square analyses were conducted to identify demographic and injury-related variables related to employment. Variables that were significantly associated with employment (income, P<.001; education, P<.05) were included as covariates in later analyses with QOL and community participation variables (global QOL, social integration/interaction, participation in leisure and household activities). Multivariable analyses of variance, including employment, employability, and the covariates income and education, were conducted using each QOL and community participation construct as the dependent variables. Employment status was associated only with household activities (P<.05), while employability was associated with overall QOL (P<.001) and social interaction (P<.05). Perceived employability also predicted employment status (P<.05). **Conclusions:** In contrast to findings from previous research, employment status was not associated with overall QOL or social integration/interaction. Results indicated that employability instead acted as a moderator between employment status and these variables. Thus, how people with TBI perceive their employability, rather than their employment status alone, may be an important contributor to QOL. **Key Words:** Brain injuries; Quality of life; Rehabilitation.

**Poster 39**

Long-Term Community Integration in Minority Groups Following Traumatic Brain Injury. Guido Mascialino (Mount Sinai School of Medicine, United States), Matthew Egan, Joshua Cantor, Teresa Ashman.

Disclosure: None declared.

**Objective:** To determine whether the discrepancy, that 1 year after injury minority groups with traumatic brain injury (TBI) exhibit lower levels of community integration than whites, continues more than 1 year postinjury. **Design:** Retrospective analysis of archival data. **Setting:** Research center of a large urban medical center. **Participants:** 396 community-dwelling adults with TBI, including 30% from minority backgrounds. Mean time postinjury ± SD was 6.3±8.6 years. **Interventions:** Not applicable. **Main Outcome Measures:** Community Integration Questionnaire items embedded in the Living Life After TBI. **Results:** Multiple regression indicated that minority status predicted levels of community integration (P=.017) up to 1 year postinjury (n=44), but not beyond that period (n=265). Interestingly, whites had the lowest levels of community integration. **Conclusions:** Contrary to past research, these findings suggest community integration may be slightly better in minorities than whites. Sampling issues or protective factors common to minorities might account for this result. However, these discrepancies may not persist beyond 1 year postinjury. **Key Words:** Brain injuries; Minority groups; Rehabilitation.

**Poster 40**

Incident Injuries Among Community-Dwelling Adults With Mobility Limitations in the United States. Elizabeth Rasch (National Center for Health Statistics, CDC, United States), Lois Fingerhut, Leighton Chan.

Disclosure: None declared.

**Objective:** To compare the nature and incidence of injuries that occurred over a 2-year period in nationally representative groups of adults with mobility, nonmobility, and no limitations. **Design:** Data were collected prospectively from a probability subsample of households that represent the civilian, noninstitutionalization U.S. population. **Setting:** 5 rounds of household interviews. **Participants:** Data were analyzed for the same respondents from the 1996–1997 Medical Expenditure Panel Survey linked to the 1995 National Health Interview Survey Disability Supplement. Respondents were categorized into 3 groups for analysis. The analytic sample included 12,302 adults (≥18y). **Interventions:** Not applicable. **Main Outcome Measure:** 2-year incidence of self-reported injuries compared across groups. **Results:** After age-adjustment, significantly more adults with mobility limitations had incident fractures (5.1% vs 3.2%), sprains and strains (11.3% vs 7.0%), contusions (6.0% vs 3.1%), and unspecified injuries (6.3% vs 4.3%) over the 2-year period compared with adults without limitations. **Conclusions:** Determining factors that influence the occurrence of injuries among adults with mobility limitations is important for informing prevention strategies. **Key Words:** Chronic limitation of activity; Injuries; Rehabilitation.

**Poster 41**

The Patterns of Changes in Participation Following Rehabilitation. Nancy Latham (Boston University, United States), Pengsheng Ni, Alan Jette.

Disclosure: None declared.

**Objective:** To explore how the pattern of recovery differs across participation domains. **Design:** Prospective observational cohort study with 1-, 6-, and 12-month follow-up. **Setting:** Community. **Participants:** Adults who received inpatient rehabilitation for neurologic, lower-extremity musculoskeletal, or medically complex conditions (N=356). **Interventions:** Not applicable. **Main Outcome Measures:** The Participation Measure for Post-Acute Care, which assesses self-rated participation across 7 domains: mobility; role functioning; community, social, and civic life; communication; social relationships; home management; and personal finances. **Results:** The communication, personal finances, home management, and social relationships domains had no significant changes over the 3 time periods, while the role functioning, community life, and mobility domains increased significantly from 1 to 6 months (P<.05). Only role functioning and community life continued to improve from 6 to 12 months. **Conclusions:** Return to participation following rehabilitation is a complex process. The pattern of recovery differs enormously depending on the
domain of participation examined. It is therefore important when measuring changes in participation to explore the changes at the level of the individual domain. **Key Words:** Community networks; Rehabilitation; Treatment outcomes.

**Poster 42**

A Retrospective Investigation of Patient Characteristics in Rehabilitation Neuro-Optometry. Vaughn Cartwright (Kessler Medical Rehabilitation Research and Education Center, United States), Vincent Vicci, Anna Barrett.

**Disclosure:** None declared.

**Objectives:** To assess the frequency with which clients with spatial neglect and hemianopsia are seen in a general neuro-optometry practice and to describe demographic, diagnosis, and treatment characteristics of this patient group. **Design:** Retrospective record examination. **Setting:** We created a relational database of outpatient records from the practice of a clinical neuro-optometrist, collecting demographic and clinical data from optometric patient reports by means of a set of nominal and numeric variables. **Participants:** Retrospective record examination. We coded 500 reports—9.1% of 5461 neurorehabilitation consultations collected over 9 years, selected randomly by first letter of last name. **Interventions:** Not applicable. **Main Outcome Measures:** As per the objectives, we counted cases diagnosed with spatial neglect and hemianopsia and qualitatively examined demographic, diagnosis, and treatment characteristics of this patient group. **Results:** Of 500 records examined, there were 75 (15%) diagnosed with hemianopsia. There were 84 (16.8%) with spatial neglect, 53 due to stroke and 8 to traumatic brain injury (TBI). Patient age varied across the lifespan (44.4% women; age range, <5y to >65y; mean age ± SD, 51.4±24.7y). Stroke was the most frequent patient diagnosis (38.8% [194 patients]), followed by TBI (20.6% [103 patients]), 24 (4.8%) patients were diagnosed with brain tumor. As a result of consultation, subjects were prescribed, among other treatments, Fresnel prisms (44 stroke, TBI patients), and occupational therapy (112 stroke patients, 54 TBI patients). **Conclusions:** This limited record review suggests neuro-optometric assessment and treatment may offer patients with visual and visual attentional disorders access to treatments not frequently available in general rehabilitation settings, and re-referral to occupational therapy. Thus, neuro-optometric referral may be an appropriate part of a stroke or traumatic brain injury care plan for visual disorders. **Key Words:** Cognitive therapy; Hemianopsia; Hemispatial neglect; Rehabilitation; Stroke.

**Service Delivery**

**Poster 43**

Passive and Active Functional Tasks: Main Reasons for Treatment (or Referral for Treatment) of Upper-Limb Spasticity in Poststroke Patients Among Neurologists, Physiatrists, and Primary Care Physicians. Amanda VanDenburg (Allergan, United States), Susan Abu-Shakra, Mitchell Brin, Frederick Beddingfield III.

**Disclosures:** AM VanDenburg, S Abu-Shakra, MF Brin, and F Beddingfield III are employees of Allergan Inc, United States.

**Objective:** To determine major reasons for treatment (or referral) of poststroke upper-limb spasticity patients among 3 leading specialties. **Design:** Internet-based survey. **Setting:** Physicians in full-time practice. **Participants:** Of 523 physicians contacted, 50 neurologists, 50 physiatrists, and 300 primary care physicians (PCPs) fulfilled eligibility criteria and completed the survey. **Interventions:** Physician demographics and poststroke spasticity patient characteristics were collected. **Main Outcome Measures:** Average number per month of adult stroke patients treated and/or referred and with upper- and/or lower-limb poststroke spasticity; type of deformity; and treatment goals. **Results:** Adult stroke patients treated by neurologists and physiatrists and seen by PCPs per month were 23.8, 17.9, and 38.6, respectively, of which approximately half had spasticity in the upper and/or lower limb (10.3, 10.0, 12.5, respectively). Majority of upper-limb spasticity patients had severe finger or wrist spasticity. Main treatment goals in this population were to relieve pain or discomfort and improve access to the palm for hygiene (passive function) or improve the ability to grasp or hold objects (active function). **Conclusions:** Surveyed physicians evaluate and treat a significant number of poststroke spasticity patients suffering from passive and active functional consequences. Hand pain and discomfort and inability to access palm for hygiene or use the hand for grasping or holding were major reasons for treatment. **Key Words:** Muscle spasticity; Rehabilitation; Stroke.

**Poster 44**

Rehabilitation Hospital Versus Nursing Home Setting for Rehabilitation Following Stroke: A Case-Matched Controlled Study. Janet Herbold (Weill Medical College of Cornell University at Burke Rehabilitation Hospital, United States), Mary Beth Walsh, Michael Reding.

**Disclosure:** None declared.

**Objective:** To assess the first case-matched controlled study of stroke rehabilitation outcome for care provided in a rehabilitation hospital versus a nursing home setting. **Design:** Observational study of outcomes for case-matched pairs receiving stroke rehabilitation in a rehabilitation hospital versus nursing home setting. **Setting:** An inpatient acute rehabilitation hospital that is a free-standing, not-for-profit hospital that manages rehabilitation care at 4 independent skilled nursing facilities. **Participants:** Demographic features and selected FIM instrument scores were recorded at all 5 institutions. There were 73 sequential index cases admitted for stroke rehabilitation to the nursing homes. Matched controls were identified from 784 sequential patients admitted for stroke rehabilitation at the rehabilitation hospital. Cases were matched for sex, age (≥3y), FIM ambulation score (≥1), FIM stair transfer score (≥2), and FIM problem-solving plus FIM memory score (≥9). All selected FIM scores were available for 32 nursing home patients. The remaining 41 patients were matched for sex, age, and available FIM scores, as listed above. **Interventions:** Not applicable. **Main Outcome Measures:** Subscales of the FIM instrument and need for transfer back to acute care hospital or death were compared for the matched patient pairs. The Mann-Whitney U statistic was used for comparison of ordinal data and the chi-square statistic for categorical data. Linear data were analyzed using the Student t test. Variance are reported as ± SD. Statistical significance was inferred if the 2-tailed probability statistic was less than .05. **Results:** Matching was exact for sex, and did not differ significantly for age, FIM ambulation, or FIM chair transfer scores. FIM problem-solving plus memory scores were slightly lower (7.2±2.6 vs 8.5±3.7, P<.02) for rehabilitation hospital versus nursing home patients. The interval from stroke to admission was 9.5±6 days for both rehabilitation settings. Rehabilitation hospital patients had shorter lengths of stay (20±7d vs 28±24d, P<.003). Change in scores from admission to discharge for both groups, respectively, were: FIM ambulation, 2.1±1.6 versus 2.3±1.9 (P=.62); FIM stair, 2.6±1.7 versus 2.0±2.2 (P=.04); FIM chair transfer, 1.96±1.1 versus 1.34±0.9 (P=.002); and FIM memory plus problem-solving, 1.64±2.1 versus 0.25±2.3 (P<.001). Discharge to home was 47 versus 40. Need for transfer back to acute care hospital or death was 4 versus 13 (P<.02). **Conclusions:** Rehabilitation hospital care is associated with significantly greater improvement in self-care scores and a 3-fold reduction in need for return to acute care.
hospital or death. Key Words: Outcome assessment (health care); Rehabilitation; Stroke.

Poster 45
Discharge Disposition After Inpatient Stroke Rehabilitation: An International Comparison. Koen Putman (Center for Post-Acute Studies, National Rehabilitation Hospital, United States), Randy Smout, Susan Horn, Mark Leys, Gerben De Jong. Disclosure: None declared.
Objective: To compare discharge disposition after inpatient rehabilitation following stroke. Design: Secondary analyses on the pooled dataset from 2 prospective cohort studies, one in Europe (Collaborative Evaluation of Rehabilitation In Stroke across Europe [CERISE] study) and one in the United States (Post-Stroke Rehabilitation Outcomes Project [PSROP] study). Settings: 4 inpatient rehabilitation facilities (IRFs) in Europe and 6 IRFs in the United States. Participants: 1154 patients suffering first-ever stroke, admitted to an IRF within 6 weeks poststroke (n=532 from CERISE, n=622 from PSROP). Interventions: Not applicable. Main Outcome Measures: Discharge disposition and Barthel Index at discharge. Results: Overall, 81.2% of the patients were discharged home, with no significant differences between the CERISE group and the PSROP group (81.71%, 80.54%, respectively, P=.618). The Barthel Index score at discharge differed significantly between both groups (median values: CERISE, 17; PSROP, 13). Stepwise regression modeling revealed no significant differences in the likelihood to be discharged home (OR=1.31; 95% CI, 0.85–2.01). Conclusions: Discharge disposition did not differ between both patient groups. However, functional status at discharge differed significantly. Incorporating contextual information on the organization of health care is needed to improve the comparison of results enabling a better evaluation of rehabilitation programs. Key Words: Rehabilitation; Stroke.

Poster 46
The Provision of Assistive Technology Devices to Veterans After Stroke. Sandra Hubbard (No. Florida/Southern Ga. Veterans Health System, United States), Dean Reker, Diane Cowper, Helen Hoenig, Bruce Vogel, Sam Wu, Shirley Fitzgerald, Bill Mann. Disclosure: None declared.
Objective: To determine: (1) the geographic variance in (A) utilization patterns of assistive technology (AT) devices and (B) demographics; and (2) the relationship between provision of devices and discharge location, length of stay (LOS), function, and cost. Design: Retrospective design with descriptive analyses and z scores; there were 11 categories of AT: 5 were wheelchairs and scooters, beds, ankle-foot orthotics (AFOs), walkers/crutches/canes, activities of daily living devices, ramps, and patient lifts. Setting: Veterans Affairs databases (National Prosthetic Patient Database, Integrated Stroke Outcome Database, Decision Support System). Participants: 12,169 veterans post-stroke (FY 2001–2002). Interventions: Not applicable. Main Outcome Measures: AT utilization patterns, demographics, discharge location, LOS, function measured by the FIM instrument, and 1-year poststroke cost. Results: Significant geographic variation in utilization patterns of AT per category was found. Veterans who received AT devices tended to be older, service connected, married, and nonwhite (P=.000). Most veterans receiving mobility devices were discharged to the community. Veterans receiving AFOs had the highest mean inpatient LOS, outpatient visits, cost, lowest level of functional independence (FIM), and smallest percentage of discharge to community. Conclusions: Significant variation in utilization patterns and demographics by geographic area was found. Further research is necessary to determine whether such variations are (1) appropriate, given variations in patient condition or (2) indicative of reduced access to AT. Key Words: Quality of life; Rehabilitation; Treatment outcomes; Wheelchairs.

Poster 47
Enhancing Wheelchair Accessibility: Consumer Involvement and Restaurants' Willingness to Change. David Tulsky (Kessler Medical Rehabilitation Research and Education Center, United States), Pamela Kisala, Rachel Gold, Trevor Dyson-Hudson, Brígida Hernandez. Disclosure: None declared.
Objectives: To improve restaurant accessibility and to test impact of the person providing feedback to restaurant managers. Design: Randomized community intervention trial. Setting: Community. Participants: 30 restaurants selected by people with spinal cord injury (SCI). Interventions: 3 members of Northern New Jersey Spinal Cord Injury System (NNJS/CIS) research staff were randomized to visit the 30 restaurants and provide feedback: (1) the non-disabled NNJS/CIS director (n=10 restaurants), (2) a wheelchair user with SCI (n=10), and (3) a non-disabled research assistant (n=10). The team utilized the Hernandez method (2005) of assessing compliance with American With Disabilities Act (ADA) standards and providing feedback and recommendations to the manager. Main Outcome Measures: The ADA checklist identifying barriers to accessibility and a rating scale assessing managers' receptiveness to feedback. Results: Only 1 restaurant was fully accessible. 80% of the restaurants had restroom barriers, 37% had excessively steep ramps, and 35% lacked adequate accessible parking. Managers were more receptive to feedback and recommendations delivered by the person with SCI (χ² test=4.8, P=.045) than the other 2 staff members. Conclusions: Despite passage of the ADA in 1991, many restaurants remain inaccessible. Restaurant managers are most receptive to changes suggested by people with disabilities. Key Words: Architectural accessibility; Rehabilitation; Wheelchairs.

Poster 48
Identifying the Specific Needs of Adolescents After a Mild Traumatic Brain Injury: A Service Provider Perspective. Isabelle Gagnon (University of Montreal, Canada), Bonnie Swaine, François Champagne, Hélène Lefebvre, Jeffrey Atkinson, Debbie Feldman. Disclosure: None declared.
Objectives: To identify the specific service needs of adolescents with mild traumatic brain injury (TBI) and those of their parents to better understand the situation and particularities of this clientele through the perspective of expert service providers, as well as to compare it with the perspective of adolescents and their parents obtained in a prior study. Design: Qualitative design, including a focus group and a validation survey. Setting: Trauma and rehabilitation centers. Participants: 8 experts in the field of adolescent TBI for the focus group and 33 for the validation study. Interventions: Not applicable. Main Outcome Measures: Discussion of adolescent development and of the specific needs after a mild TBI. Results: Experts questioned through both methods are generally in agreement and acknowledge that adolescents are unique, but they often find them challenging. Like adolescents themselves, experts identify the need for information as the most important, but are wary of offering too much detail and fear that this could encourage malingering in symptoms and problems. Service providers also recognize the importance of supporting adolescents and parents when returning to activities (school and physical activities). Conclusions: The notion that teens represent a specific group of consumers of health care services is supported by findings in this study. These results provide important information to
those involved in the structuring of service organization and the provision to adolescents following mild TBI. Key Words: Adolescent health services; Brain injuries; Rehabilitation.

Poster 49
When is Inpatient Rehabilitation Delivered to Veterans With a Lower-Extremity Amputation? Janet A. Prvu-Bettger (University of Pennsylvania, United States), Barbara E. Bates, Pui L. Kwong, Jibby E. Kurichi, Douglas E. Bidelspach, Margaret G. Stineman. Disclosure: None declared.

Objective: To determine the patterns of when inpatient rehabilitation is provided in the 12 months following a lower-extremity (LE) amputation. Design: Retrospective longitudinal. Setting: Veterans Affairs inpatient acute and postacute care. Participants: Veterans (N=4349) with LE amputation discharged from October 1, 2002 to September 30, 2004. Interventions: Not applicable. Main Outcome Measures: Receipt of preoperative acute, postoperative acute, and late (postacute) rehabilitation relative to the index surgical hospital admission, surgical, and index surgical hospital discharge dates defined using care class codes and dates in the Functional Status Outcomes Database. Results: This sample predominantly included nontraumatic LE amputations (86.1%), with 60.2% transfemoral and 38.8% transtibial. The most common inpatient rehabilitation pattern was to only receive postoperative acute rehabilitation (30.0%), followed by a combination of postoperative acute and late rehabilitation (25.7%). For 6.4%, rehabilitation began in the preoperative acute phase, with the majority also receiving postoperative acute (4.2%). Almost 30% did not have documented inpatient rehabilitation in the 12 months following an LE amputation but may have received rehabilitation as outpatients or at home. Conclusions: There is substantial variability in when rehabilitation care is delivered. Further investigation is needed to determine the factors influencing the pattern of care and the impact of pattern on outcomes. Key Words: Amputation; Rehabilitation.

Poster 50
Scheduling Guidelines: A Tool for Triage of Rehabilitation Services in Acute Medical Settings. Mary Vining-Radomski (Sister Kenny Rehabilitation Institute, United States), Trevor Carlson. Disclosure: None declared.

Objective: To investigate the interrater reliability among rehabilitation therapists in their use of scheduling guidelines to assure that limited staffing resources are directed toward those acute care patients in greatest need for rehabilitation services on a given day. Design: Development and interrater reliability evaluation of scheduling guidelines (a process involving refinement of a tool over 3 surveys to establish agreement among raters). Setting: 4 acute care hospitals within a broader health care system in the U.S. Midwest. Participants: 125 occupational therapists, physical therapists, and speech-language pathologists. Interventions: Not applicable. Main Outcome Measures: Interrater agreement among therapists from 3 disciplines based on a coefficient of concordance (Kendall W). Results: Rehabilitation therapists used scheduling guidelines to assign level of scheduling priority (“See today” or “On Deck”) for 10 case examples, achieving a high level of overall agreement (.806), as well as by discipline (range, .785-.833) and by site (range, .775-.868). Conclusions: These findings suggest that a common metric can be used across rehabilitation disciplines for determining scheduling priority with reasonable agreement among clinicians. Key Words: Amputation; Scheduling; Triage.

Poster 51
Metropolitan and Rural Differences in Perceived Barriers to Rehabilitation Services and Health Outcomes Among Canadian Trauma Survivors. Marie-Josée Sirois (Laval University and Trauma Research Unit, Enfant-Jésus Hospital, Canada), André Lavioie. Disclosure: None declared.

Objective: To compare perceived barriers to rehabilitation services in metropolitan, urban, and rural areas, as well as health outcomes at 3 years postinjury of trauma survivors who required rehabilitation services in each area. Design: Cohort study with retrospective measures of exposure and cross-sectional health outcomes measures. Setting: Metropolitan, urban, and rural areas of the Province of Quebec, Canada. Participants: The study included 435 trauma survivors, aged 18 to 65 years old, admitted to either a metropolitan level I or an urban/rural level II trauma center between January 1, 2000, and December 31, 2001, who required postacute rehabilitation services. Subjects were interviewed by telephone. Interventions: Not applicable. Main Outcome Measures: A 73-item telephone questionnaire assessed perceived barriers (barriers, no barrier) to 18 types of rehabilitation services. Health outcomes were measured by the Medical Outcome Study 12-Item Short-Form Health Survey (SF-12) and by the FIM instrument (short-version). Results: Barriers to functional rehabilitation were similar across areas: 39.2% (metropolitan), 35.9% (urban), and 42.6% (rural) (P=.23). Barriers to social and vocational services were significantly more important in urban (54.8%) and rural (54.7%) areas than in metropolitan areas (45.5%) (P=.09); community integration services were less accessible in urban (46.4%) and rural (50.3%) areas than in metropolitan zones (41.4%) (P=.07). SF-12 aggregated physical score and SF-12 physical function scores were 3.9 (P=.10) and 7.7 (P=.04) points lower in rural areas. Conclusions: Trauma survivors from rural areas experienced more barriers to social/vocational and community integration rehabilitation services. Of the 5 health indicators, only 2 were minimally and significantly worse in rural trauma survivors. Key Words: Access to health care; Hospitals; metropolitan; Rehabilitation; rural health.

Poster 52
Looking Upstream: Factors Shaping the Demand for Postacute Joint Replacement Rehabilitation. Wenqiang Tian (National Rehabilitation Hospital, United States), Gerben DeJong, Zvezdomir Zamfirov, Ching-Hui Hsieh. Disclosure: None declared.

Objectives: To describe and characterize the trends in the numbers of total hip and knee replacements among Americans in the last decade, the factors shaping the increase in the use of the procedure, and its implications for postacute rehabilitation and postacute health policy. Data Sources: Articles published from 1990 to 2006 were identified through the electronic searches of Medline and Scholar Google, and secondary analyses using Healthcare Cost and Utilization Project (HCUP) data. Study Selection: Articles were included if they were health services studies related to the access, utilization, and supply of joint replacements (knee replacement, hip replacement), health policy studies related to the impact of reimbursement and cost-containment policies on demand for joint replacement, or clinical research on the improvement in joint replacement. Articles were excluded if they did not focus on the U.S. health care system or if they were not written in English. Data Extraction: Key words used to search were: growth of joint replacement, utilization, access and supply of joint replacement, payment policy changes and joint replacement, rehabilitation and joint replacement, and Medicare policy and joint replacement. HCUP data from 1993 to 2004 were analyzed through HCUPnet. Data Synthesis: The number of total lower-ex-

Objective: To provide an overview of rehabilitative and preventive practices in the Russian health care system. Data Sources: Data from Russian health care legislation, health statistics, evidence-based research, sociologic survey, and key informant interviews. Study Selection: Both online databases and health care literature were searched, using a set of preselected key words. Data Extraction: An integrated methodology was used, including content analysis, comparative charts analysis, and qualitative survey with field experts. Data Synthesis: Based on the analysis of the development of the health care system in Russia, explanatory factors related to the development of rehabilitative and preventive practices were identified and verified via an expert panel. Conclusions: The field of rehabilitation and prevention in Russian health care system is very contradictory and sometimes inadequate to meet public needs. Considering a great variety of approaches, as well as the diversity of human and institutional resources, an organizational factor, such as a competent leadership, becomes crucial. Another harmonizing factor concerns national standards compliance with international regulations (eg, International Classification of Functioning, Disability and Health). Current trends in health care reform emphasize the importance of rehabilitation and prevention in the health care system. Key Words: Health care systems; Primary prevention; Rehabilitation; Russia.

Consumers’ Understanding of Rehabilitation Quality Indicators. Anne Deutsch (Rehabilitation Institute of Chicago, United States), Elizabeth Durkin, Michael Wolf. Disclosure: None declared.

Objective: To explore consumers’ and caregivers’ decision-making processes when selecting a rehabilitation program and consumers’ and caregivers’ comprehension of rehabilitation quality indicators. Design: Semi-structured interviews of consumers and their caregivers. Setting: 2 inpatient rehabilitation facilities and 2 skilled nursing facilities. Participants: 16 inpatient medical rehabilitation patients and 12 caregivers of such patients. Interventions: Not applicable. Main Outcome Measures: Accurate comprehension of 10 quality indicators. Results: Participants’ selection of the rehabilitation program was based on word-of-mouth recommendations, facility reputation, previous experiences of family and friends, physician referrals, and the proximity of the facility to their home. Participants expressed an interest in facility quality data, but their understanding of the key concept in quality indicators varied: patient satisfaction (83%), length of stay (81%), moderate to severe pain (76%), motor function (68%), pressure ulcers (63%), delirium (60%), cognitive function (46%), and discharge to home or the community (42%). Participants sometimes had difficulty describing how an indicator was related to quality care at a facility. Conclusions: Most consumers and their caregivers understood some, but not all, key terminology used in rehabilitation quality indicators. Key Words: Quality indicators; Rehabilitation.

Poster 54


Objective: To evaluate a model of rehabilitation care in which specialist physicians are integrated into the rehabilitation continuum, examining (1) care outcomes for persons with, or at risk of, disability; (2) satisfaction with practice for specialist physicians; and (3) economic impact on the health care delivery system. Design: Prospective, multimethod evaluation. Setting: Free-standing rehabilitation center in suburban southern California. Participants: Outpatients and specialist physicians. Intervention: Care model where specialist physicians maintain shared clinic space in an outpatient rehabilitation center on a campus with a complete continuum of inpatient and outpatient services. Main Outcome Measures: Patient adherence to therapy referrals; patient functional outcomes; physician satisfaction; outpatient visit volume; and revenue and expense. Results: Preliminary results suggest: (1) adherence to referral for therapy was significantly higher among patients seen in the rehabilitation center than in the community office for 1 participating physician (87% vs 38%); (2) practice satisfaction was slightly higher among integrated specialist physicians; and (3) there was a stable volume of therapy visits referred from integrated specialist physicians in a market strongly affected by negative changes in worker compensation policy. Conclusions: Pilot and preliminary results suggest that the model is successful; but we need to await completion of the 3-year evaluation. Key Words: Delivery of health care; Rehabilitation; Specialties, medical.
**Clinical Care**

**Poster 56**

**Antihypertensive Efficacy and Cerebral Hemodynamic Advantage of Olmesartan Medoxomil Compared With Amlodipine in Post-stroke Patients.** Shuji Matsumoto (Kagoshima University, Japan), Megumi Shimodzono, Ryuji Miyata, Kazumi Kawahira.

**Disclosures:** None declared.

**Objective:** To compare the antihypertensive efficacy of the angiotensin II receptor blocker olmesartan medoxomil (olmesartan) with that of other antihypertensive agents. **Design:** Prospective, randomized double-blind study. **Setting:** A rehabilitation center. **Participants:** 24 hypertensive patients who had an episode of stroke more than 4 weeks before being recruited for this study. **Intervention:** We evaluated the action of the angiotensin II type 1 receptor antagonist olmesartan medoxomil on cerebral hemodynamics in hypertensive patients using xenon-computed tomography (Xe-CT). We administered 10 to 20mg of olmesartan (12 patients) or 2.5 to 5mg of amlodipine (12 patients) once daily for 8 weeks. **Main Outcome Measures:** Cerebral blood flow (CBF) and cerebrovascular reserve capacity of the affected and nonaffected sides were quantified using Xe-CT. We measured the effects of olmesartan and amlodipine on 24-hour ambulatory blood pressure and examined the improvement in CBF related to olmesartan and amlodipine on Xe-CT after administration of the drugs for 8 weeks. **Results:** Pharmacotherapy for patients with impaired CBF autoregulation aims to reduce the blood pressure while preserving the CBF. Here, 24 hypertensive patients with a history of stroke were administered olmesartan (10–20mg) daily for 8 weeks. Systolic and diastolic blood pressures were recorded for 24 hours using an ambulatory blood pressure monitoring system. During 24-hour monitoring, both drugs caused a decrease in systolic blood pressure of 18.3mmHg and caused a decrease in diastolic blood pressure of 10.2mmHg. The Xe-CT results indicated that the increase of CBF from olmesartan was 10.2±3.9mL/min per 100g and that from amlodipine was 1.2±4.1mL/min per 100g. **Conclusions:** Thus, despite the reduction in blood pressure, CBF was significantly increased in the olmesartan group compared with the amlodipine group. We consider the use of olmesartan to be advantageous for hypertensive patients with a history of stroke in whom autoregulation of CBF is potentially impaired. **Key Words:** Hypertension; Rehabilitation; Stroke.

**Poster 57**

**Persistent Vegetative State: New Approaches in Complex Treatment.** Konstantin Lyadov (Medical and Rehabilitation Center, Russian Federation) Tatiana Shapovalenko, Irina Sidyakina, Tatiana Isaeva.

**Disclosures:** None declared.

**Setting:** Not provided. **Patients:** 15 patients with a diagnosed vegetative condition were observed and treated. The level of consciousness, according to Glasgow Coma Scale (GCS), was 7 to 9 points. The reasons for the comas that led to the vegetative state were poliomyelitis in 9 cases and cerebral stroke in 6 cases. **Case Descriptions:** All patients had complete evaluations, including neuroimaging, magnetic resonance tomography of the brain, defining the parameters of brain blood flow (transcranial Doppler), electroencephalography, study of brain-evoked potentials (somatosensory, cognitive), transcranial magnetic stimulation, and neurophysiological testing. For 2 to 3 months, patients received complex rehabilitation (eg, medical treatment, kinesitherapy, massage, verticalization, selective vibrostimulation of feet in the regime of cyclogram of walking, programmed electrostimulation, leg-neric exercises). According to the GCS, patients’ levels increased by 1 to 2 points. In the following 2 months, to basic rehabilitation, we added walking training on the Lokomat system and monitored hemodynamic indices. The Lokomat allows one to reproduce normal walking as closely as possible by using biomechanic indices and contributes to the formation of complex polysystematic synchronized reactions of the organism. The inclusive criteria for each patient were readiness for walking, training for the ability to keep systolic pressure between 80 and 90mmHg, and to keep diastolic blood pressure not lower than 50mmHg for 7 to 10 minutes in the vertical position on the verticalizer. Training was held 5 times a week, for 10 to 20 minutes, the course 10 to 20 procedures. Prime speed was 1.5km/h; maximum speed was 2km/h. **Assessment/Results:** There was an increase in the level of the consciousness (GCS, minimally conscious state [MCS]); in 3 patients with craniocerebral insult at the end of the fourth month of observation, we noticed signs of “the condition of little consciousness” (according to the MCS) in the form of prolonged fixation, stable reaction of eyes, stable behavioral reactions on the corresponding polymodal stimuli, and the level of consciousness, which increased up to 12 to 13 points. 2 patients with craniocerebral trauma had the locked-in syndrome. 4 patients with craniocerebral trauma improved to the level of psycho-organic syndrome (15 points). 1 stroke patient after the fourth month improved to the level of akinetic mutism, with speech understanding (11 points). 3 patients from the stroke group at the end of the fifth month also showed an increase in consciousness, up to 12 to 14 points and, according to the MCS, up to the “condition of little consciousness.” 1 patient from the stroke group showed no change in rehabilitation status during treatment. **Discussion:** There was improvement of postural control (restoration of the correct position and increase of the strength of spine, neck and shoulder muscles). The spasticity decrease (measured by the Ashworth Scale) allowed for an increase in movement amplitudes of the lower-extremity joints. Hemodynamic indices stabilized. The amplitude of the sensory component (peak 2) in the investigation of cognitive indices increased. **Conclusions:** The inclusion of robotic training for walking allowed patients with stroke and craniocerebral trauma to increase their levels of consciousness. This method should be tested in further clinical investigations. **Key Words:** Cognitive disorders; Cranial trauma, penetrating; Rehabilitation.

**Poster 58**

**Optimizing Spinal Cord Injury Skin Best Practices in Acute Care Nursing.** Donal Lauderdale (National Rehabilitation Hospital, United States), Alexander Libin, Thilo Kroll, Ching-Hui Hsieh, Suzanne Groah.

**Disclosures:** None declared.

**Objective:** To identify an optimal knowledge management process for integrating spinal cord injury (SCI) skin health best practices into acute-phase nursing practice. **Data Sources:** Sources were journals and conference proceedings germane to knowledge generation and management in acute care nursing. Nursing practice and education, cognitive psychology, and process and system optimization were domains queried. **Study Selection:** Studies completed in the last decade across the domains of nursing education, cognitive psychology, and process and system engineering were candidates for review. **Data Extraction:** The literature was searched for successful nursing education, cognitive strategies shown generally to promote rapid acquisition and retention of learning, and applicable nursing workflow process optimization techniques. **Data Synthesis:** Concept mapping, a graphical representation of knowledge where nodes represent concepts and links represent the relationship between concepts, has been shown to be a successful means of helping nurses integrate new knowledge into their existing clinical framework. Processes and workflow can be variously optimized. N² charting, a technique based on graph theory, figures prominently. **Conclusions:** N² charting is a promising tech-
nique for optimization of processes and activities bearing on SCI skin health. N² charts reduced to concept maps may be effective in helping nurses integrate new knowledge on SCI skin health into their existing clinical practice framework. **Key Words:** Nursing education; Rehabilitation; Skin; Spinal cord injuries.

**Poster 59**

Clinical Improvements in a Patient With Normal Pressure Hydrocephalus Status Post Lumbar Puncture and Ventriculoperitoneal Shunt Placement. Beth Myers (Kennedy Krieger Institute, United States), Rebecca Martin.

Disclosure: None declared.

**Objectives:** To describe, in a patient with normal pressure hydrocephalus (NPH), the clinical response to a diagnostic lumbar puncture, and to report on the stability of this response over time, after permanent ventriculoperitoneal (VP) shunt placement. **Design:** Single-case study: within-subject, repeated measures at 3 time points: preintervention, postintervention, and long-term follow-up. **Setting:** Outpatient physical therapy (PT) and medical clinics at a spinal cord injury center.

**Participant:** A 74-year-old white man, presented with bradykinesia and flat affect. He complained of balance impairments, gait disturbance, and memory loss, and was diagnosed with NPH. He had a VP shunt placed on April 11, 2005, then fell on April 13, 2005, while still an inpatient, and fractured his right femoral neck, requiring internal stabilization with hardware. He also developed a VP shunt infection, requiring its removal on August 23, 2005. During this period post-shunt removal, he received PT intervention 3 times a week at this clinic, from September 12, 2005 until December 13, 2005, to address endurance, functional skills (eg, bed mobility, transfers), and gait training. At this time, he was using a manual wheelchair, with caregiver assistance, for all functional mobility tasks. The subject had a permanent VP shunt placed in February 2006. His history was also remarkable for pneumonia, infections, congestive heart failure, myocardial infarction, history of pacemaker placement, and chronic atrial fibrillation. **Intervention:** Lumbar puncture (LP) with resulting reduction of cerebrospinal fluid volume on November 10, 2005. **Main Outcome Measures:** Gait analysis (temporospatial) using GAITRite system, Berg Balance Scale (BBS), video of ambulation, Mini-Mental State Examination (MMSE), and the Minnesota Test of Hand Function. These outcome measures were performed the day before the LP, and within hours after the procedure. For long-term follow-up, the measures were to be repeated 14 months after he underwent permanent VP shunt placement. **Results:** Comparing pre- and post-lumbar puncture measures, the subject’s cadence increased from 85.1 to 110.7 steps/min (30% increase) (age norm, 104 steps/min). Velocity increased from 21.2 to 41.9cm/s (a 98% increase) (age norm, 108.7cm/s). Step length of the left leg increased from 23.2 to 27.8cm (a 20% increase) and step length of the right leg increased from 7.4 to 18.6 (a 148% increase) (age norm, 60cm). Stride lengths of the right and left legs increased from 31.2 to 47.3cm (a 53% increase) and from 31.6 to 48.3cm (a 52% increase), respectively. Age norm for stride length is 119cm. BBS score increased from 18/56 (pre-LP) to 32/56 (post-LP) (age norm, 56/56). Interpretation of BBS: 0 to 20 is wheelchair bound; 21 to 40 is walking with assistance; and 41 to 56 is independent. These results of the study are ongoing: long-term follow-up data on gait analysis and balance will be discussed. The MMSE score increased from 22/30 (pre-LP) to 24/30 (post-LP) (age norm, 28/30). On the Minnesota Test of Hand Function, his time pre-LP was 2:20.87 and his post-LP was 1:42.69. **Conclusions:** Preliminary results show meaningful changes in gait, including velocity, cadence, step and stride lengths, as well as standard measures of balance and cognitive function. In this case, LP had an immediate impact on his function, and may be useful in predicting outcomes of permanent VP shunt placement. **Key Words:** Gait; Hydrocephalus; Rehabilitation.

**Poster 60**

Do Certain Neurologic Comorbidities Increase the 1-Year Mortality Risk for Veterans With Lower-Extremity Amputations? Janet A. Prvu-Bettger (University of Pennsylvania, United States), Barbara E. Bates, Douglas E. Bidelspach, Margaret G. Stineman.

Disclosure: None declared.

**Objective:** To determine if neurologic comorbidities influence the risk of 1-year mortality in veterans with lower-extremity (LE) amputation. **Design:** Retrospective longitudinal. **Setting:** All Veterans Affairs medical centers. **Participants:** All veterans with LE amputation discharged in FY 2003 to 2004. **Interventions:** Not applicable. **Main Outcome Measure:** Death within 1 year of amputation. **Results:** Of the 4727 LE amputees, 2261 had a neurologic comorbidity: 18.3% had a previous history of stroke; 1.8%, cerebral degeneration disorders including Alzheimer’s and dementia; 1.5%, movement disorders; 3.1%, spinal cord injuries or unspecified paralytic disorders; 14.4%, peripheral nervous system disorders; 2.9%, autonomic disorders; 4.6%, diabetes with neurologic complications; and 1.4%, other conditions including multiple sclerosis or brain injuries. Within 1 year, 1111 (23.5%) veterans died. After controlling for patient and clinical characteristics, stroke and cerebral degenerations increased the risk of mortality within 1 year of amputation (for stroke, hazard ratio [HR], 1.26; 95% CI, 1.09–1.46; P = .002; for cerebral degenerations, HR = 1.24; 95% CI, 1.03–1.49; P = .021), whereas the other neurologic comorbid conditions were not associated with an increased risk when compared with LE amputees without neurologic comorbidity. **Conclusions:** Neurologic comorbidities affect the risk of mortality. Further research should focus on the relationship between dual-diagnoses and outcomes and the care delivered to this population. **Key Words:** Amputation; Comorbidity; Rehabilitation; Survival.
Clinical Trials: Methods

Poster 61
Disclosure: None declared.
Objective: To develop, with a team planning and development grant from Canadian Institutes of Health Research (CIHR), an Ontario program of research focused on improving management of spinal cord injury (SCI) chronic pain based on current Ontario data indicating that 30% to 80% of SCI clients living in the community continue to experience pain-related decreased quality of life (QOL) years after initial injury. Design: Modified Delphi consensus-building approach for research priorities identification; introduction of targeted pilot study seed funds to stimulate research team-building and grant application submissions. Setting: Ontario rehabilitation research institutes, SCI centers, universities, and pain clinics and services. Participants: Rehabilitation researchers, SCI clinicians, SCI consumers, and federal and provincial rehabilitation research funders. Interventions: A 1-day working meeting of participants to arrive at consensus on SCI pain and QOL research priorities; and launching of seed funds competition. Main Outcome Measures: Consensus on priority research areas and number of seed fund applications. Results: 5 priorities identified by consensus: pain management/treatment; mechanisms of pain; measurement tools; health services policy and advocacy; and knowledge transfer. 5 pilot study submissions. Conclusions: CIHR’s research development strategy has succeeded in spawning 5 new pilot studies in the SCI pain and QOL field in Ontario, a solid return on CIHR’s initial investment. Key Words: Pain; Quality of life; Rehabilitation; Spinal cord injuries.

Poster 62
Establishing a Network for Conducting Multicenter Trials of Neurorehabilitation Interventions. Prudence Plummer-D’Amato (University of California Los Angeles, United States), Valerie Nenov, Bruce Dobkin.
Disclosure: None declared.
Objectives: To unite clinicians in an international network to conduct multicenter, randomized controlled trials (RCTs) of simple, low-cost interventions, to promote education and research among clinicians who might not otherwise have opportunities to participate in clinical trials, and to study the effects of daily reinforcement of walking speed on recovery of gait and the duration of inpatient care in people after stroke. Design: RCT. Setting: Acute inpatient rehabilitation facilities. Participants: People admitted to inpatient rehabilitation after stroke. Interventions: Participants will be randomized to receive daily reinforcement or no reinforcement of walking speed during their usual therapy. Main Outcome Measures: Gait speed at discharge from inpatient rehabilitation. Secondary outcomes are distance walked in 3 minutes and inpatient length of stay. Results: More than 40 sites from 20 different countries have joined the multicenter RCT network. At least 15 sites will start the first trial in 2007. Conclusions: A multicenter RCT that includes sites and patients who might not otherwise have the opportunity to participate in clinical research may enrich their experience about rehabilitation, improve outcomes, and open other possibilities for modestly funded, clinically relevant trials. Key Words: Randomized controlled trials; Rehabilitation; Stroke.

Poster 63
Utility of Treatment Implementation Methods in a Clinical Trial With Rehabilitation Teams. Alan B. Stevens (Scott and White Memorial Hospital, United States), Dale Strasser, Jay Uomoto, Susan Bowen, Judith Falconer.
Disclosure: None declared. (Clinicaltrials.gov number NCT00237757).
Objective: To evaluate the utility of treatment implementation methods in the design and implementation of a team training intervention in a national clinical trial on process improvement and rehabilitation team functioning. Design: Description of research methods. Setting: Veterans Affairs hospitals. Participants: 29 team leaders from 15 intervention sites. Intervention: 6-month intervention (concentrated skills training workshop, written information feedback; consultation) for 2 team leaders from each site. Main Outcome Measures: Treatment implementation indicators for intervention delivery, receipt, and enactment. Results: Positive findings reported (1) consistent and accurate presentation of intervention components and (2) evidence of receipt and enactment of intervention strategies by study participants. For example, for intervention receipt, 81% of the workshop participants strongly agreed that the workshop provided skills to enhance team functioning. For intervention enactment, 9 (60%) of the 15 sites reported implementation of team activities revealed during the workshop exercises to address problematic areas of their own team functioning. Conclusions: Treatment implementation methodology helps organize the information content and intervention delivery in a consistent, reliable manner, and provides a framework to monitor the actual enactment of a team training intervention. Key Words: Health care team; Rehabilitation; Training programs.

Poster 64
Rehabilitation Researchers’ Receptivity and Perceived Barriers to Designing Intervention Studies to Facilitate Knowledge Translation. Pimjai Sudsawad (University of Wisconsin-Madison, United States).
Disclosure: None declared.
Objective: To examine rehabilitation researchers’ receptivity and perceived barriers to using a model of designing intervention studies that includes (1) incorporating research user’s input when selecting topic and questions; (2) seeking research user’s feedback on feasibility of intervention; (3) incorporating research user’s input in choosing outcomes; (4) using outcome measures that reflect performance in natural settings; and (5) demonstrating intervention effectiveness by its positive impact on everyday lives. Design: Telephone focus group and Internet survey. Setting: Nationwide. Participants: 74 rehabilitation researchers who published intervention studies in peer-reviewed journals. Interventions: Not applicable. Main Outcome Measures: Survey questionnaire and focus group transcript. Results: Most respondents viewed this model positively and agreed that it would be useful in making intervention studies more applicable to practice. Perceived barriers to using this model to design future studies included (1) lack of good measurement tools to capture real-life performance in natural settings; (2) universally accepted intervention difficult to achieve; (3) study topic/question dictated by other factors; and (4) self-reported performance (in natural settings) from study participants may not be valid. Conclusions: There is a need to examine the logistics of and overcome barriers to creating intervention studies that can be applied in practice to facilitate knowledge translation in rehabilitation. Key Words: Intervention studies; Rehabilitation; Researchers.
Measurement

Poster 65
Measurement of Community Participation From the Perspective of Multiple Stakeholders. Allen W. Heinemann (Northwestern University Feinberg School of Medicine, United States), Gale Whiteneck, C.A. Brooks, John Corrigan, Jennifer Bogner, Joy Hammel, Susan Magasi, Kendall Stagg, Holly Demark, Patrick Semik.

Disclosure: None declared.

Objectives: To develop and evaluate a measure of community participation that is grounded in the perceptions of rehabilitation stakeholders. Design: Instrument development included qualitative and quantitative components: (1) focus groups of stakeholders to identify components of participation as a basis for item development, (2) pilot test of items with former rehabilitation clients and other people with disabilities, and (3) implementation of the instrument in a statewide, population-based survey. Setting: Various community settings. Participants: 18 focus groups included 218 disability stakeholders representing people with disability, their family and caregivers, rehabilitation professionals, insurers, and policy-makers. Pilot-test participants included 255 people with disabilities and 244 people from the general population. The Behavioral Risk Factor Surveillance Survey disability questions were used to identify a target of 500 people with disabilities and 500 people without disabilities in Colorado. Interventions: Not applicable. Main Outcome Measure: 55 items comprising the Community Participation Index. Results: Qualitative analysis of the focus groups identified participation as a cluster of values that included active and meaningful engagement-being a part of, choice and control, access and opportunity, personal and societal responsibilities, having an impact and supporting others, and social connection, inclusion, and membership. Quantitative analyses of the draft instrument included principal component analysis and rating scale analysis. Factor and rating scale analyses supported the presence of 2 distinct factors (objective performance and subjective values). By sequentially deleting misfitting items, a subset of 19 participation value items demonstrated reliability of .77, and 21 performance-focused items demonstrated reliability of .82. Low levels of participation were characterized by not leaving one’s house often, while high levels of participation were characterized by spending time in civic activities, sports, movie-going, cultural events, and employment or school attendance. Conclusions: We operationalized 2 indicators of community participation that may be useful to guide rehabilitation services, monitor rehabilitation outcomes, and that inform the need for community-based supports. Key Words: Community outreach; Educational measurement; Rehabilitation.

Poster 66
Development and Validation of IMPACT: An ICF-Based Measure of Activity Limitations and Participation Restrictions. Marcel Post (De Hoogstraat, Netherlands), Luc de Witte, Rom Penenboom, Gert Jan Wijllhuizen.

Disclosure: None declared.

Objective: To examine the test-retest reliability and validity of the screener part of IMPACT, which consists of 33 items covering all 9 activity and participation domains from the International Classification of Functioning, Disability and Health. Design: Repeated administration of a postal questionnaire. Setting: Community in the Netherlands. Participants: Victims of traffic collisions were recruited via hospitals and rehabilitation centers. A total of 276 patients participated, 205 of whom took part in both measurements. Interventions: Not applicable. Main Outcome Measures: IMPACT and the World Health Organization Disability Assessment Schedule (WHODAS).

Results: Types of main injury were fractures (38%), traumatic brain injury (37%), spinal cord injury (13%), whiplash (9%), and other (3%). Mean time after injury ± SD was 2.2 ± 0.9 years. Internal consistency of IMPACT was satisfactory for all 9 domains (α range, .75–.89) and the total score (α = .96). Test-retest reliability was good at item level (κ range, .44–.72), domain level (ICC range, .75–.092), and total scores (ICC = .92). Strong correlations (r = .80–.85) between IMPACT and WHODAS scores were found. Conclusions: IMPACT is a promising generic measure of activity limitations and participation restrictions of persons with disabilities. Key Words: Outcomes Research; Rehabilitation; Reproducibility of results.

Poster 67
Neuropsychologic Performance in Greek and English Speakers: Multicultural Comparisons and Implications for Measuring Rehabilitation Outcomes. Fofi Constantinidou (University of Cyprus, Cyprus).

Disclosure: None declared.

Objectives: To compare older and younger Greek and English (U.S.) speakers on a battery of common neuropsychologic tests and to identify patterns of performance as a function of age and language. Design: Between-group experimental design. Setting: Standard clinical setting. Participants: 34 young native Greek speakers (age range, 16–46 years; mean ± SD, 26.53 ± 7.58 years), 47 young English speakers (age range, 16–50 years; mean, 25.62 ± 5.82 years), 26 older Greek speakers (age range, 55–90 years; mean, 66.92 ± 8.02 years), and 32 older English speakers (age range, 55–92 years; mean, 70.03 ± 6.39 years). Subjects were matched for sex and education. Interventions: A battery of common neuropsychologic tests administered in subjects’ native languages. Main Outcome Measures: Mini-Mental State Examination (MMSE), Rey Auditory Verbal Learning Test (RAVLT), Trail-Making Test (TMT) parts A (TMT-A) and B (TMT-B), Rey Complex Figure Test (RCFT), verbal fluency, digit span forward and backward, spatial span forward and backward, and logical memory from the Wechsler Memory Scale–III. Results: Older subjects performed 1 SD lower than younger subjects (MANOVA, α = .05) across languages. English subjects performed significantly better than Greek subjects on the MMSE (P = .001), digits forward (P = .001), digits backward (P = .002), TMT-A (P = .001), TMT-B (P = .001), semantic (P = .032), and phonemic fluency (P = .001), and logical memory (P = .001). Significant age by language interaction effects were found on the RAVLT (P = .01) and the RCFT (P = .026); older Greek subjects performed worse than the English subjects; no differences were found between younger Greek and English subjects. Conclusions: Language and culture affect neuropsychologic performance differently across age groups. Important considerations for assessing injury effects and rehabilitation efficacy will be discussed. Key Words: Multiculturalism; Patient outcome assessment; Rehabilitation.

Poster 68
Utility of Self-Report and Performance-Based Measures of Physical Function in Clinical Trials. Alan Jette (Boston University, United States), Nancy Latham, Allison Martin Nguyen, Vinjay Mehta, Julie Chandler, Dimitris Papanicolaou.

Disclosure: AM Nguyen, V Mehta, J Chandler, D Papanicolaou are employees of Merck, United States.

Objective: To assess the validity, sensitivity, and responsiveness of self-report and standardized, performance-based measures of physical function: Activity Measure for Post-Acute Care (AM-PAC) basic mobility and daily activity; 36-Item Short-Form Health Survey physical function (PF-10); Physical Functional Performance (PPF-10); Short Physical Performance Battery (SPPB); gait speed; and six-

Main Outcome Measures: Known-groups, construct, and predictive validation, effect size, and minimal detectable change (MDC90) at 12 weeks. Results: All measures achieved acceptable known-groups and construct validity. Odds ratios (ORs) in predicting patient global assessment of improvement were: AM-PAC basic mobility (OR=5.3); AM-PAC daily activity (OR=3.6); PF-10 (OR=4.3); PFP-10 (OR=2.5); gait speed (OR=1.9); and 6MWT (OR=2.4). All effect sizes exceeded 1 standard deviation. Percentage of patients exceeding MDC90 were: AM-PAC basic mobility (90%); AM-PAC daily activity (74%); PF-10 (66%); PFP-10 (75%); SPPB (36%); gait speed (69%); and 6MWT (75%). Conclusions: The validity, sensitivity, and responsiveness of self-report and performance-based measures are comparable in this population. Both types of measures are recommended for trials with physical function endpoints.

Key Words: Hip fracture; Rehabilitation; Treatment outcome.

Poster 69
Use of Mayo-Portland Adaptability Inventory–4 to Measure Treatment Outcome in an Outpatient Neurorehabilitation Program. Rebecca Sophir-Kusnetz (North Shore-LIJ Health System, United States), Deborah Benson.

Disclosure: None declared.

Objective: To test the hypothesis that the Mayo-Portland Adaptability Inventory–4 (MPAI-4) will reflect functional improvements demonstrated by acquired brain injury survivors over the course of participation in an outpatient multidisciplinary neurorehabilitation program. Design: Single-group, pre-post study. Setting: Outpatient multidisciplinary neurorehabilitation program. Participants: 19 adult subjects consecutively admitted for multidisciplinary (physical, occupational, speech-language, and/or neuropsychologic) evaluations and treatment following an acquired brain injury. Intervention: Each subject was assessed using the MPAI-4 on initial evaluation (admission) and discharge from treatment. Ratings were determined by professional (physical therapy, occupational therapy, speech-language pathology, neuropsychology) consensus. Main Outcomes Measure: Change scores (admission to discharge) on MPAI-4 total score and subscales (abilities, adjustment, participation). Results: Statistically significant improvements were noted in total MPAI-4 score (P<.001), as well as each subscale (abilities, P<.01; adjustment, P<.01; participation, P<.001). Conclusions: The MPAI-4 can be used as a standardized measure of outcome following participation in a multidisciplinary neurorehabilitation program. It reflects not only improvements in functional abilities, but also in psychosocial adjustment and community participation. Key Words: Brain injuries; Rehabilitation.

Poster 70
A Novel Methodology to Objectively Quantify Functional Improvement After Chemoneurolytic Intervention. Karen J. Nolan (Kessler Medical Rehabilitation Research and Education Center, United States), Krupa K. Savalia, Mathew Varossi, Elie P. Elovic.

Disclosure: None declared.

Objective: To demonstrate the utility of wireless pedobarography and an innovative analysis program to objectively functional changes in gait parameters following clinical intervention. Design: Pre- and post-intervention. Setting: Outpatient rehabilitation center. Participants: 6 patients with acquired brain injury–related spasticity. Interventions: Two-minute walk test data on a level surface, at a self-selected pace, before and after chemoneurolytic intervention.

Main Outcome Measures: Temporospatial gait parameters (cadence, walking speed, double support, single support, step length) were used for analysis; and pressure distribution throughout stance phase. Results: The novel metric used in this research was able to demonstrate functional changes in gait parameters and indicate normalizing of loading during ambulation. Comprehensive analysis software was developed to provide specific quantifiable information throughout the gait cycle. Conclusions: Wireless pedobarography is a noninvasive and well-tolerated means of objectifying improvements in gait. This innovative technology is a portable and accurate way to provide information about magnitude, location of plantar loading, and step timing characteristics during dynamic activities. Key Words: Ankle; Brain injuries; Foot; Gait; Hemiplegia; Orthoses; Rehabilitation; Stroke.

Poster 71
Relative Efficiency of the Patient Health Questionnaire–9 by Demographic Categories: An Item Response Theory Analysis. Daniel Graves (Baylor College of Medicine, United States), Charles Bombardier.

Disclosure: None declared.

Objective: To determine the influence of demographic variables on the relative efficiency of the Patient Health Questionnaire (PHQ) for 9 items. Design: Retrospective analysis of the National Spinal Cord Injury Database utilizing item response theory methods. Setting: National database. Participants: Data from 3736 National Database participants were extracted. The sample was 78.5% male (n=2933) and 21.5% (n=803) female; whites comprised 77.1%; 26.7% had fewer than 12 years of education; 54.8% had 12 years, and 15.2% had more than 12 years; meal age at onset was 31.79 years; and the interview was conducted a mean of 9.5 years postinjury. Sex, time since injury, years of education, and ethnicity are used to form groups for comparison. The items from the PHQ were analyzed with the graded response model using Multilog 7. The information function of the 9-item test were calibrated on the larger subsample and compared with the information function-calibrated smaller subsample sample. Interventions: Not applicable. Main Outcome Measure: The relative efficiency of the PHQ in comparison groups. Results: The relative efficiency of the PHQ calibrated on a female sample was only 83.7%, compared with the function calibrated on the male sample. The relative efficiency for time since injury was 1.01, comparing persons 2 years or fewer from injury with those more than 2 years post. Efficiency between education groups was .96 and comparison of whites with nonwhites gave an efficiency of .97. That means that the PHQ functions less efficiently when used on women than on men. However, the effect on the efficiency was not as great for time since injury, education, and ethnic background. Conclusions: Screening for depression in patients with spinal cord injury is very important. It is important that sex differences do exist in the response patterns of men and women. Attention should be paid to more than the total scores when screening for depression. Key Words: Depression; Rehabilitation.

Poster 72
A New Approach to Functional Assessment in Persons With Multiple Sclerosis: Actual Reality. Amanda O’Brien (Kessler Medical Rehabilitation Research and Education Center, United States), Yael Goverover, Alexis Lenz, Nancy Moore, John DeLuca.

Disclosure: None declared.

Objectives: To discuss the development, use, and validity of the actual reality tasks and scoring system in persons with multiple sclerosis (MS). Design: Measurement development; cross-sectional correlational study of neuropsychologic and functional actual reality task
performance. Setting: Neuropsychology research laboratory. Of note, the actual reality task can be performed anywhere as an Internet-based task. Participants: Persons in the community with relapsing-remitting MS and age- and education-matched healthy controls between 20 and 60 years. Interventions: Not applicable. Main Outcome Measures: Actual reality scores and the MAC-FIMS (a neuropsychologic assessment battery sensitive for use in persons with MS). Interrater reliability for actual reality scoring is also reported. Results: Persons in the MS group committed significantly more errors on the actual reality task than healthy controls. Interrater reliability for the actual reality scoring system is very high (> .90) for scoring errors and classifying cognitive capacity scores, respectively. There were significant correlations between the actual reality task and measures of processing speed, working memory, and verbal learning and memory. Conclusions: Actual reality and its scoring system have support as a valid and sensitive functional assessment approach in persons with MS. Key Words: Cognition; Multiple sclerosis; Rehabilitation.
INDEX TO AUTHORS OF CONGRESS ABSTRACTS

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