Clinical Study

Relationship between leptin and adiponectin concentrations in plasma and femoral and spinal bone mineral density in spinal cord–injured individuals

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Abstract

BACKGROUND CONTEXT: Previously, the associations between leptin and adiponectin levels with bone mineral density (BMD) have been reported in different populations, and occasionally, controversial results have been demonstrated. Until now, these relationships in spinal cord–injured individuals have not yet been described.

PURPOSE: We tried to investigate the correlation between leptin and adiponectin concentrations in plasma and BMD in Iranian patients with spinal cord injury (SCI).

STUDY DESIGN/SETTING: Cross-sectional investigation.

PATIENT SAMPLE: Referred patients with SCI who did not meet our exclusion criteria such as pregnancy, lactation, amputation, history of diabetes, cancer, endocrinology disease, and use of special medications entered the study.

OUTCOME MEASURES: Bone mineral density of femoral neck, trochanter, intertrochanteric zone, total hip, and lumbar vertebrae assessed by dual-energy X-ray absorptiometry and serum leptin and adiponectin levels measured by blood sample analysis using immunoassay techniques.

METHODS: Patient demographic characteristics were measured during face-to-face visits. Injury level and Spinal cord Injury Association (ASIA) score were assessed by clinical examination and were confirmed by imaging aids. Measured levels of leptin and adiponectin and dual-energy X-ray absorptiometry results were analyzed with partial correlation analysis method after adjustment for weight, body mass index (BMI), and age.

RESULTS: Total of 104 patients (19 females and 85 males) entered this investigation. Higher leptin concentration was significantly associated with higher BMD in femoral neck (p = .006, r = 0.73), femoral intertrochanteric zone (p = .001, r = 0.83), and hip (p = .001, r = 0.81) only in female patients, whereas no such association was detected in male participants after adjusting for BMI and age. Leptin and adiponectin levels were not associated with lumbar spine BMD in both genders. Neither injury level nor ASIA score and plegia type (paraplegia or tetraplegia) influenced on leptin and adiponectin concentrations.

CONCLUSIONS: We found no association between leptin concentration and BMD in male individuals, whereas a positive correlation between leptin and BMD of femoral neck, intertrochanter, and hip was observed in female patients that shows a sexual polymorphism in this relationship. However, by considering the low number of female participants, these results should be interpreted...
Introduction

It has been proposed that body fat mass may be positively associated with bone mineral density (BMD) \[1–3\]. This protective effect of obesity against bone mineral loss is known, and several mechanisms have been proposed such as increased mechanical loading and changes in some lipid-derived hormones’ level \[4\]. Leptin is a 14-kDa protein that is mainly derived from fat tissue and is known as an appetite suppressor and stimulator of energy expenditure \[5\]. Its various endocrine functions have also been shown \[6\]. Many investigations have supported the positive effect of leptin on BMD as it has been shown that leptin promotes osteoblastic differentiation \[7\] along with inhibition of osteoblast apoptosis and osteoclastogenesis \[8,9\]. However, results in human models showed controversy in different investigated populations. Whereas some literature reported no association between leptin level and BMD \[10–18\], some reported a positive relationship \[19–24\] and some studies even revealed negative correlation \[25–30\]. In this regard, many populations have been investigated, and various outcomes can be because of differences in characteristics of studied cases. Many factors may influence the relationship between leptin and adiponectin concentrations and BMD. Adiponectin is an adipocytokine that is mainly expressed in visceral fat and bone marrow fat deposits \[31\]. As it has been shown that osteoblasts have adiponectin receptors, it has been proposed that this hormone influences bone metabolism \[32\]. The characteristics of the status of investigated population, background diseases, gender, and other hormonal changes that noticeably influence on fat distribution may play a part in BMD changes in response to alterations of leptin and adiponectin concentrations. Investigations in human immuno-deficiency virus–infected men revealed that fat distribution may modify the relationship between leptin and bone density \[27\]. Up to now, the relationship between leptin and adiponectin levels and BMD has been investigated in premenopausal and postmenopausal women \[12,18\], hemodialysis patients \[29\], kidney transplant recipients \[33,34\], patients with Type II diabetes \[21\], and even healthy men and women \[13,20,35,36\], but until now, this association in spinal cord–injured individuals was not evaluated. In this study, we tried to investigate the effect of leptin and adiponectin concentrations on BMD in patients with spinal cord injury (SCI). Mostly, the negative association between adiponectin and BMD has been reported \[37–39\], but still, the controversial results exist as some studies have also detected no association between adiponectin level and BMD \[40\]. Again, different investigated population characteristics, gender, fat distribution, genetic tendency of each specific nationality, and background diseases affect this relationship noticeably and lead to these variety of outcomes. Up to now, these associations were not described in SCI population. Here, we investigated the population of Iranian spinal cord–injured individuals to find out whether the correlation between leptin and adiponectin concentrations in plasma with BMD shows a special pattern in these patients.

Materials and methods

Participants

Spinal cord–injured individuals who were referred to Brain and Spinal Injury Research Center were invited to participate in these investigations, and patient selection was based on the inclusion criteria such as traumatic SCI and post-injury duration longer than 1 year. All patients were wheelchair users. It is noticeable that spared ability to walk after SCI is an important confounding factor because patients who are able to walk (assisted with canes or nonassisted) have a higher BMD because of lesser mechanical unloading. Exclusion criteria were pregnancy, lactation, amputation, and nontraumatic SCI etiology. Patients with history of diabetes, cancer, endocrinology disease, acute infection, use of special medications, such as glucocorticoid, hormones, thyroid hormones, anticonvulsive drugs, heparin, aluminum-containing antacids, lithium, omega-3 fatty acids, or other nutrient supplements, and smoking or alcohol consumption were also excluded.

Study design

This investigation is a cross-sectional study aiming to evaluate the plasma concentrations of leptin and adiponectin in spinal cord–injured individuals and assess their relationship with BMD. Data were collected from November 2010 till 2011. All patients received adequate information about the study, and written consents were obtained before enrollment. The protocol was approved by the ethics committee at Tehran University of Medical Sciences.

Anthropometric measurements

Patients’ demographic characteristics including gender, age, and postinjury duration were obtained during face-to-face interviews. Body weight was measured using a digital wheelchair scale, body height was obtained measuring the supine length, and body mass index (BMI) was calculated as body weight (in kilograms) divided by height (in meters) squared.
Laboratory measurements

Blood samples were taken under antiseptic conditions from antecubital vein and centrifuged at 3,000 rpm for 10 minutes at 4°C. Single-session analysis was used to reduce interassay variation in serum samples. Samples were sent to the laboratory of Endocrinology and Metabolism Research Center for analysis and were frozen immediately. The levels of leptin and adiponectin were measured and were reported as nanogram per milliliter. Morning blood samples were also collected to measure total testosterone concentration that was reported as nanomoles per liter.

BMD measurements

Dual-energy X-ray absorptiometry, which is the proposed method to assess BMD, was used. Calibration of bone densitometer Lunar DPXMD device (Lunar Corporation, Madison, WI, USA) was performed weekly by using appropriate phantoms. The precision error for BMD measurements was 2 to 3 in the femoral and 1 to 1.5 in the lumbar regions. All scans were performed according to the manufacturer’s guidelines. T and Z scores of femur neck, trochanters, intertrochanteric zone, and also lumbar vertebra (L1–L4) were investigated. In patients with spinal implant, the involved lumbar vertebrae were excluded, and the mean bone density of noninvolved vertebrae was entered into the analysis. Assessment of femur BMD was conducted using the mentioned three points (neck, trochanters, and intertrochanteric zone) that seemed to be adequate as an indicator of long bones. We also measured total hip BMD. According to the World Health Organization/Osteoporosis Foundation diagnostic categories, we defined osteoporosis as BMD T score −2.5 or less standard deviation (SD) and osteopenia as BMD T score more than −2.5 SD and −1 SD or less, and BMD T score more than −1 SD young adult mean was considered as normal.

Neurologic assessment

The International Standards for Neurological Classification of Spinal Cord Injury, which is an examination used to determine the motor and sensory impairment and severity of an SCI, was used, and the related American Spinal Cord Injury Association (ASIA) score was estimated [42]. Injury level was assessed preliminary with physical examination by an expert neurologist and was confirmed by imaging aids such as magnetic resonant imaging.

Statistical analyses

All statistical analyses were performed using SPSS 18.0 (SPSS, Inc., Chicago, IL, USA). We reported results by expressing percentages, mean±standard deviation, and the proper comparison of means using t test and one-way analysis of variance. Pearson correlation was used to investigate correlations between variables along with linear regression and bivariate models. p Value less than .05 was considered statistically significant. The association between BMD and serum concentration of leptin and adiponectin was assessed using a partial correlation with adjustment for weight, BMI, and age.

Results

Total of 104 patients (19 females and 85 males) entered this investigation. Mean age in male group was 51.80±13.44 and in female population with SCI was 56.05±7.89. As expected, male participants had significantly higher weight and height (p = .01 and p = .001, respectively), whereas BMI showed no statistical significant difference among genders (Table 1). Most patients had spinal injury at the thoracic level (57.6% of males and 73.7% of females), and the most common ASIA score was A. All patients were wheelchair users. Total of 10 patients had ASIA score D but still were not able to walk. Previously, Morganti et al. [43] illustrated that 51.3% of patients with ASIA score C and 88.6% of patients with ASIA score D are able to walk (assisted or nonassisted) and so 11% of patients with ASIA score D are still wheelchair users. Table 1 shows demographic features of patients with SCI. Dual-energy X-ray absorptiometry in femoral neck showed osteopenia in both males and females, and no significant difference was detected between
Adiponectin (ng/mL) 5.65 (2.87) 7.23 (3.35) .08
Leptin (ng/mL) 11.66 (10.76) 31.32 (33.85) .0001**

these two groups. Moreover, male participants had lower BMD in femoral trochanter, intertrochanteric zone, hip and spinal lumbar vertebrae (Table 2). Measures of BMD in femoral bone sites showed osteopenia in both genders, whereas spinal lumbar vertebrae’s BMD was more spared after injury. In fact, femoral bone mineral loss was more severe than spinal lumbar vertebrae in both genders.

Leptin level was 11.66±10.76 ng/mL in male and 31.32±33.85 ng/mL in female patients. Adiponectin concentration was 5.65±2.87 and 7.23±3.35 ng/mL in spinal cord–injured men and women, respectively. Female individuals had significantly higher leptin concentration in plasma (p<.0001), whereas the measures of adiponectin showed no significant difference between genders (p=.08) (Table 2).

Our study shows that the relationship between leptin and BMD of spine and femur has a different pattern in female patients in comparison with male individuals. Higher leptin concentration was significantly associated with higher BMD in femoral neck (p=.006, r=0.73 and p=.003, r=0.77, respectively, for T and Z scores) only in female patients, whereas no such association was detected in male participants after adjusting for BMI and age. Moreover, the same pattern could be observed in intertrochanteric zone of femur and hip (Table 3). This strong positive correlation between leptin level and BMD of femoral intertrochanteric zone (p=.001, r=0.83 and p<.0001, r=0.87 for T and Z scores, respectively) in female group was not observed in male patients after BMI and age adjustments. However, results on female patients should be interpreted cautiously when considering the low number of female participants. Furthermore, although the same pattern was observed in hip BMD (p<.001, r=0.81 and p<.0001, r=0.85 for T and Z scores, respectively), there was no significant relationship between leptin level and spinal vertebrae’s BMD in both genders. Besides, BMD of femoral trochanter also revealed no association with leptin level in both male and female patients. It is recommended that these results on female individuals be confirmed by future studies on a higher number of patients.

Adiponectin concentrations were not related to any of measured BMDs in all patients (Table 3). Spinal vertebrae’s BMD also revealed no correlation with leptin and adiponectin levels in both genders.
Injury level was not associated with leptin and adiponectin levels. Similarly, ASIA score and type of plegia did not affect their plasma concentration (Table 4). As it was expected, leptin had a positive strong correlation with weight (p<.0001, r=0.52 in males and p<.0001, r=0.87 in females) and BMI (p<.0001, r=0.53 and p<.0001, r=0.95 in males and females, respectively). Age and post-injury duration showed different patterns in males and females. Whereas age was negatively associated with adiponectin in male participants, no such relationship was detected in female individuals. Moreover, postinjury duration was positively correlated with adiponectin level only in females. Leptin was not related to age and time since injury in both genders (Table 4).

In male participants, total testosterone level was positively associated with femur neck and trochanter (p=0.45, r=0.22 and p=0.48, r=0.22, respectively), whereas there was no such association with spinal lumbar vertebrae’s BMD. The association between BMD of femoral intertrochanteric zone and testosterone level was also insignificant (p=.07). Leptin and adiponectin concentrations were not associated with total testosterone’s level (p=.19 and p=.23, respectively).

### Discussion

Previous experiments have shown that adiponectin, which is an adipocytokine, has a stimulatory effect on bone formation [44] that can result in increased BMD [45]. On the other hand, there are various investigations supporting the negative correlation between adiponectin and BMD [38]. Richards et al. [46] reported a negative association between adiponectin and BMD in women, and same results were reported in men by Peng et al. [47], in diabetic patients by Kanazawa et al. [48], in hemodialysis patients by Amemiya et al. [49] and Okuno et al. [50], and in acromegaly by Sucunza et al. [51]. Moreover, Ahn et al. [52] detected no association between BMD and adiponectin level in postmenopausal women with subclinical hyperthyroidism, and same observation was reported by Kontogianni et al. [53] in perimenopausal women. Our results revealed no association between adiponectin concentration and BMD of femur and spinal lumbar vertebrae in spinal cord–injured population, which is in line with the studies by Kontogianni et al. [52] and Ahn et al. [53]. However, the controversies of results with other previous published reports [44–51] can be because of differences in study populations. Patients with SCI suffer from rapid BMD loss mostly because of mechanical unloading and immobility [54,55]. The existence of background osteopenia in spinal cord–injured patients may affect the relationship between adiponectin and BMD. Changes of fat distribution that occur in spinal cord–injured individuals may also play a role in this field. In this regard, Tankó and Christiansen [56] proposed free estradiol as a plausible confounder of these associations and as fat distribution is an important determinant of free estradiol in both genders (increased level of free estradiol is observed by upper body obesity, whereas lower body obesity decreases it). We concluded that this

### Table 3

<table>
<thead>
<tr>
<th>Femoral neck</th>
<th>Leptin</th>
<th>Adiponectin</th>
<th>Femoral trochanter</th>
<th>Leptin</th>
<th>Adiponectin</th>
<th>Femoral intertrochanteric zone</th>
<th>Leptin</th>
<th>Adiponectin</th>
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BMD, bone mineral density.

Note: p Values stand for multiple linear regression analysis between continuous variables using Pearson correlation determination. Significance at level of **p<.01.

### Table 4

<table>
<thead>
<tr>
<th>Males</th>
<th>Leptin</th>
<th>Adiponectin</th>
<th>Females</th>
<th>Leptin</th>
<th>Adiponectin</th>
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<td>.0001 (r=0.87)</td>
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<td>.028 (r=−0.27)</td>
<td>.11</td>
<td>.34</td>
<td></td>
</tr>
<tr>
<td>BMI*</td>
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<td>.048 (r=−0.25)</td>
<td>.0001 (r=0.95)</td>
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<tr>
<td>Time since injury*</td>
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<td>.93</td>
<td>.77</td>
<td>.02 (r=0.63)</td>
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<td>.18</td>
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<tr>
<td>ASIA score</td>
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ASIA, American Spinal Cord Injury Association; BMI, body mass index.

* p Values stand for bivariate correlation of Pearson test between continuous variables.

† p Values stand for one-way analysis of variance to perform proper comparison of means.
known alteration in fat distribution in patients with SCI affects the correlation between adiponectin and BMD. Generally, it seems that adiponectin is not a determinant for BMD. Although adiponectin increases osteoblast differentiation through increasing cyclooxygenase-2 expression in fat tissue [57], various investigations, including our study, show no significant association between adiponectin and BMD [53,58].

Leptin that is released by adipose tissue is strongly correlated with fat mass [59]. Although it has been shown that higher fat mass is associated with higher BMD [4], results on leptin role on bone mass changes are controversial. Although some investigations detected no direct effect of leptin on BMD [10,15,17,25], some supported its positive effect on BMD [19–24] and some even demonstrated negative association of leptin with BMD [25–30]. One of the most important reasons of these controversial reports is differences in studied populations and their characteristics. It has been proposed that leptin decreased bioavailability of testosterone [59], and as testosterone has a known positive effect on BMD [60], it is assumed that leptin may impose a negative effect on BMD through decreasing testosterone level especially in men [61]. Our study revealed no relationship between leptin concentration and BMD in male individuals with SCI, which is in line with the study by Mohiti-Ardekani et al. [10] who also found no effect of leptin on BMD in osteoporotic patients. However, other known medical conditions that are associated with decreased BMD (like hemophilia) did not show the same results in male individuals [62], which shows that existence of background osteopenia or osteoporosis is not the only factor affecting the relationship between BMD and leptin level in males. Moreover, the relationship between leptin level and testosterone concentration was insignificant (p = .19), and adiponectin also showed no association with testosterone concentration (p = .23). Although testosterone showed a positive effect on BMD in femoral BMD (and not spinal lumbar BMD), it seems that this influence is not modulated by leptin and adiponectin concentrations.

Rao et al. [27] showed that the existence of peripheral lipoatrophy (which was defined as <3 kg appendicular fat) affects this relationship in human immunodeficiency virus–affected men, and the inverse correlation between leptin and BMD was only detected in those with peripheral lipoatrophy. Spinal cord–injured individuals show a specific pattern of fat distribution alteration as we observed more severe muscle and fat tissue atrophy in lower body in these patients. Although previous investigations have shown increased leptin level after SCI [63], the effect of leptin on BMD in male individuals seems to be insignificant.

Our study revealed a positive association between leptin and BMD of femoral neck, intertrochanter, and hip in female patients, which is in line with the results by Yamamura et al. [22], Pasco et al. [23], and Roux et al. [24] in able-bodied women. Zhong et al. [20] illustrated this positive association on lumbar, femoral neck, and hip BMD in Chinese women. Here, we illustrated the same results in femur and hip, but we could not detect such a relationship in lumbar spine. It is noticeable that BMD reduction after SCI is more severe in long bones, whereas vertebrae are mostly spared. Increased level of leptin that occurs after SCI [63] mostly contributed in preserving long bone BMD in female patients, whereas the lower bone mineral loss of spines shows lesser association with leptin concentration. Moreover, the difference in the relationship pattern between femoral and spinal BMD and leptin level has been previously reported in prepubertal girls by Rhie et al. [64].

The existence of a sexual polymorphism in the relationship between leptin and BMD has been previously proposed by Thomas et al. [36]. They showed that leptin was positively related to BMD in women and not in men, which is similar to our results. This difference between genders can be because of higher estrogen production that could affect bone turnover [65]. It is known that both leptin and estrogen can be produced by adipose tissue [66]. These findings support the idea that BMD is more strongly related to fat mass in women than in men, which is described previously by Thomas et al. [36] and Reid et al. [67]. Here, we report the same results in spinal cord–injured population. It is noticeable that the competing effects of leptin on BMD that have been described by Battaglino et al. [68] be also considered as it has been shown that leptin can suppress bone formation by inhibiting osteoblast activity [69] and in another hand suppresses osteoclast differentiation from human peripheral blood mononuclear cells [68]. So the various effects of leptin on bone depending on the signaling pathway must be taken into consideration when interpreting data on leptin’s association with BMD. These different pathways may be activated in different concentrations of leptin in plasma [70]. Leptin level is dependent on adipose tissue and can be altered by changes in fat distribution that occurs after SCI. The trend of changes is toward significant reduction of lean mass in lower extremities, and women have greater total body fat mass [71] that can play a part in sexual polymorphism in leptin’s effect on bone.

In our study, neither injury level nor ASIA score and plegia type (paraplegia or tetraplegia) influenced on leptin and adiponectin levels. Wang et al. [72] found higher leptin concentration in spinal cord–injured patients with higher injury level. However, Maimoun et al. [73] and Huang al. [74] detected no effect of injury level of plegia type on leptin concentration, which is in line with our findings in this study.

Conclusions

Here, we investigated leptin and adiponectin association with BMD in spinal cord–injured patients. Our results revealed no association between adiponectin concentration and BMD of femur and spinal lumbar vertebrae in spinal cord–injured population. We found no relationship between
leptin concentration and BMD in male individuals, whereas a positive association between leptin and BMD of femoral neck, intertrochanter, and hip was observed in female patients that shows a sexual polymorphism in this relationship. Lumbar spine BMD was neither associated with leptin nor adiponectin level in both gender.

Study limitations

Although in this study the total number of recruited patients is acceptable, the low number of female participants limits the power of this study. It is highly recommended that the results on female patients be confirmed by future investigations on a higher number of participants.

Acknowledgments

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References


