The association between body fat and rotator cuff tear: the influence on rotator cuff tear sizes

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Background: Rotator cuff tear (RCT) has a multifactorial etiology. We hypothesized that obesity may increase the risk of RCT and influence tear size.

Materials and methods: A case-control design study was used. We studied 381 consecutive patients (180 men, 201 women; mean age ± standard deviation, 65.5 ± 8.52 years; range, 43-78 years) who underwent arthroscopic rotator cuff repair. Tear size was determined intraoperatively. The control group included 220 subjects (103 men, 117 women; mean age ± standard deviation, 65.16 ± 7.24 years; range, 42-77 years) with no RCT. Body weight, height, and bicipital, tricipital, subscapularis, and suprailiac skinfolds of all participants were measured to obtain body mass index (BMI) and the percentage of body fat (%BF).

For the purposes of the study, the 601 participants were divided into 2 groups by BMI (group A, BMI ≥ 25; group B, BMI < 25). The odds ratios (ORs) were calculated to investigate whether adiposity affects the risk of RCT. Data were stratified according to gender and age. Multiple linear regression analyses were applied to explore the association between obesity and tear size.

Results: The highest ORs for both men (OR, 2.49; 95% confidence interval, 1.41-3.90; \(P = 0.0037\)) and women (OR, 2.31; 95% confidence interval, 1.38-3.62; \(P = 0.0071\)) were for individuals with a BMI ≥ 30. 69% (\(N = 303\)) of group A and 48% (\(N = 78\)) of group B had RCTs. Patients with RCT had a BMI higher than that of subjects with no RCT in both groups (\(P = 0.031\), group A; \(P = 0.02\), group B). BMI and %BF significantly increased from patients with a small tear (BMI, 27.85; %BF, 37.63) to those with a massive RCT (BMI, 29.93; %BF, 39.43). Significant differences were found (\(P = 0.004\); \(P = 0.031\)).

Conclusions: Our results provide evidence that obesity, measured through BMI and %BF, is a significant risk factor for the occurrence and severity of RCT.

Level of evidence: Level IV, Case Series, Prognosis Study.

Keywords: Rotator cuff tear; shoulder pain; BMI; percentage of body fat; obesity; rotator cuff tear etiology

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Rotator cuff tear (RCT) has a multifactorial etiology. Causes are traditionally divided into extrinsic and intrinsic. The extrinsic causes include traumatic injuries.\textsuperscript{23} Anatomic factors,\textsuperscript{2,32} age-related degeneration,\textsuperscript{33} and genetic conditions\textsuperscript{18} are considered intrinsic factors.
Tendon hypovascularity is another important cause. In fact, the origin of RCTs is represented by an area of the supraspinatus and infraspinatus tendons within 15 mm of their insertion characterized by relative hypovascularization. This insufficient blood supply is only partially improved by microvascular anastomoses that are present in this critical zone near the tendon insertion.

The condition of this area may become worse in many patients with smoking habit, hypertension, and lung and other cardiovascular diseases. Obesity may contribute to peripheral vascular deficiencies through its associations with increased production of adipokines (leptin; adiponectin; plasminogen activator inhibitor; tumor necrosis factor-α; angiotensinogen; interleukins 6, 8, 10, and 18); these molecules are able to induce oxidative stress, inflammation, thrombosis, and endothelial dysfunction. The consequent release of many reactive oxygen species causing oxidative stress and cell apoptosis may lead to degeneration of the tendon and predispose it to rupture. Adiposity may induce peripheral hypovascularity and worsen the hypoxia of the rotator cuff critical zone through its known associations with atherosclerosis, elevated cholesterol level, diabetes, and metabolic syndrome.

Subjects with a body mass index (BMI) between 19 and 24.99 kg/m² are considered normal weight; a BMI between 25 and 30 kg/m² is pathognomonic for overweight; finally, a BMI of at least 30 kg/m² is considered obese in men and women. The alternative definition of obesity is based on percentage of body fat (%BF). A %BF ≥25% of body weight in men and ≥30% in women is considered obese.

To our knowledge, only Wendelboe et al have investigated the associations between obesity, measured by BMI, and different shoulder conditions, including RCT. However, no previous studies have analyzed whether obesity is related not only to RCT but also to the dimension of the tear. Therefore, the aim of our study was to verify whether adiposity, measured as BMI and %BF, increases the risk of RCT and influences tear size.

**Materials and methods**

A case-control design study was used. The cases consisted of 381 consecutive patients (180 men, 201 women; median age 7.24 years; range, 42-77 years) who underwent arthroscopic repair of a full-thickness RCT between January 2010 and May 2013. Diagnosis of RCT was made by physical examination, x-ray imaging (true anteroposterior and axillary views), and magnetic resonance imaging.

The control group included 275 consecutive healthy men and women asymptomatic for shoulder diseases enrolled in the outpatient clinic of our hospital. All of these subjects had no history of shoulder disease, and all were submitted to a physical examination of both the posterosuperior (full can test, Patte test, external rotation lag sign, strength in external rotation) and anterior (lift-off test, Napoleon test, bear-hug test) rotator cuff tendons, performed by the most expert of the authors (S.G.) to evaluate rotator cuff integrity; if only one of the test results was positive, the subject was excluded from the control group because he or she could have an asymptomatic RCT. Finally, the control group consisted of 220 subjects (103 men, 117 women; mean age 65.16 ± 7.24 years; range, 42-77 years) because one or more test results were positive in 55 subjects, who were so excluded.

Exclusion criteria for all participants were primary osteoarthritis of the surgical or contralateral shoulder, a previous operation on the shoulder, and inflammatory joint disease.

Anthropometric measures of all participants were taken by one author while subjects were lightly clothed and wearing no shoes. Body weight was measured to the nearest 0.1 kg with a calibrated scale (Seca Inc, Hamburg, Germany). Standing height was measured without shoes to the nearest 0.5 cm with the height rod attached to the scale. BMI was calculated as weight (kg) divided by height squared (m²). Circumferences were measured with a heavy-duty inelastic plastic fiber tape measure to the nearest 0.5 cm while the subject stood balanced on both feet, with the feet touching each other and both arms hanging freely.

The %BF estimates were determined with a calibrated Harpenden plicometer (John Bull British Indicators, Baty International, Burgess Hill, UK) with a constant pressure of 10 g/mm², through the Siri formula and the Durnin and Womersley equations. Bicipital, tricipital, subscapularis, and suprailiac skinfold measurements were taken.

For the purposes of the study, participants were divided into 2 groups, depending on the BMI value: BMI ≥ 25 kg/m² (group A) or BMI < 25 kg/m² (group B).

One of the authors (S.G.) performed all arthroscopic treatments, with patients in the beach chair position under general anesthesia and interscalene block. After the intra-articular evaluation, the scope was placed in the subacromial space. A clear view of the RCT was obtained after removal of the subacromial bursa. The Southern California Orthopedic Institute classification of complete RCTs was used to classify tendon tears intraoperatively, as follows:

- a small, complete tear, such as a puncture wound (type I);
- a moderate tear (usually <2 cm) that still encompasses only 1 of the rotator cuff tendons, with no retraction of the torn ends (type II);
- a large, complete tear involving an entire tendon, with minimal retraction of the torn edge, usually 3 to 4 cm (type III); and
- a massive RCT involving 2 or more rotator cuff tendons, frequently with associated retraction and scarring of the remaining tendon ends and often an L-shaped tear that is frequently irreparable (type IV).

To limit the number of groups and to make the sample more representative, we considered the lesions belonging to type I as small, those of types II and III as large, and those of type IV as massive.

All participants signed an informed consent form in accordance with the Declaration of Helsinki. According to Italian law, this study did not need any ethics committee approval.

**Statistical analysis**

Data were analyzed by a single researcher. Statistical Package for Social Sciences (SPSS version 18; IBM, Armonk, NY, USA) was used for calculations. Differences with P values ≤ .05 were
considered to be statistically significant, and all results were expressed with a 95% confidence interval. After using a Kolmogorov–Smirnov test to verify that the variables were normally distributed, we applied parametric tests.

The $\chi^2$ statistic was used to test the association between BMI and RCT. The odds ratio (OR), defined as the ratio of the odds of an outcome in 2 groups, was used to assess whether there is an association between BMI and RCT. According to the gender, the OR was considered the measure of association between RCT and a specific value of BMI ($\geq 25.0$ kg/m$^2$, $25.0-29.99$ kg/m$^2$, $\geq 30.0$ kg/m$^2$). A significant OR $> 1.0$ in a BMI stratum higher than 25.0 kg/m$^2$ would mean that someone in that BMI category has a higher risk of RCT compared with someone who is not overweight.

According to BMI, 2-way analysis of variance was performed to evaluate the differences between the 2 groups. Significance levels for multiple comparisons were adjusted with the Bonferroni-Holm procedure.

### Sample size

Power calculations based on a pilot study with the first 60 patients to detect a significant difference in total BMI score revealed a total BMI score of $27.75 \pm 4.8$ among patients with RCT and $26.65 \pm 4.2$ in healthy subjects. From these differences and assuming a 2-tailed $\alpha$ value of .05 (sensitivity of 95%) and a $\beta$ value of .20 (study power, 80%), we determined that at least 209 patients were required in both case and control groups (G*Power 3 power analysis program).

### Results

A total of 601 subjects (mean age $\pm$ SD, 65.38 $\pm$ 8.0 years; range, 42-78 years; 319 women and 282 men) were enrolled in the study. Of the sample, 66.5% (N = 440) was enrolled in group A and 33.5% (N = 161) in group B, according to BMI. The baseline characteristics are shown in Table I.

Table I  Baseline characteristics of the groups

<table>
<thead>
<tr>
<th></th>
<th>Group A (BMI $\geq 25$) (N = 440)</th>
<th>Group B (BMI $&lt; 25$) (N = 161)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>64.90 $\pm$ 7.70</td>
<td>66.70 $\pm$ 8.78</td>
</tr>
<tr>
<td>Sex</td>
<td>224 F, 216 M</td>
<td>95 F, 66 M</td>
</tr>
<tr>
<td>BMI $\pm$ SD (range)</td>
<td>30.52 $\pm$ 4.66 (25.03-66.17)</td>
<td>22.52 $\pm$ 2.15 (14.35-24.97)</td>
</tr>
<tr>
<td>%BF $\pm$ SD (range)</td>
<td>38.51 $\pm$ 5.51 (18.88-57.41)</td>
<td>34.70 $\pm$ 5.61 (19.55-48.59)</td>
</tr>
</tbody>
</table>

BMI, body mass index; %BF, body fat percentage; SD, standard deviation; F, female; M, male.

Figure 1 and Table II show the regression analysis between BMI and %BF.

RCTs were present in 69% (N = 303) of group A and 48% (N = 78) of group B (Table III). Patients with RCT had a BMI value greater than that of subjects with no RCT in both groups ($P = .031$ in group A; $P = .02$ in group B).

The $\chi^2$ test demonstrated a significant relationship between BMI value and the presence of the RTC ($\chi^2 = 21.17$; $P < .001$). In particular, significance was achieved for subjects of group A (OR, 2.35; 95% confidence interval, 1.63-3.40; $P < .001$).

Moreover, significance was achieved for both men (OR, 2.10; 95% confidence interval, 1.27-3.52; $P = .0036$) and women (OR, 1.94; 95% confidence interval, 1.18-3.18; $P = .0082$) with a BMI between 25.00 and 30.00 kg/m$^2$ as well as for both men (OR, 2.49; 95% confidence interval, 1.41-3.90; $P = .0037$) and women (OR, 2.31; 95% confidence interval, 1.38-3.62; $P = .0071$) with a BMI of $\geq 30.00$ kg/m$^2$ (Fig. 2 and Table IV).

BMI values in RCT patients and in healthy subjects were, respectively, 28.80 $\pm$ 5.0 and 27.66 $\pm$ 6.0. We found significant differences between the groups ($P = .014$). Table V shows the average values of BMI and %BF of patients with different-sized RCTs. Patients with massive RCT have a BMI and %BF, respectively, of 29.93 $\pm$ 6.11 and 39.43 $\pm$ 5.68; moreover, the same values in patients with small tears are 27.85 $\pm$ 4.39 and 37.63 $\pm$ 5.53. Significant differences were found between the 2 groups ($P = .004$; $P = .031$) according to both BMI and %BF (Table VI).
Discussion

Obesity is defined as an excess of body fat; it is a common disease, and its incidence is rising. Adiposity is difficult to measure; indices of relative weight are commonly used to diagnose obesity because an excess of body fat is related to an excess of total body mass.

The Quetelet index is one of the most used and approved indices of relative weight, more commonly known as body mass index (BMI). BMI (weight in kilograms divided by height in meters squared) was not originally intended as an obesity index but is now employed as such in many studies.

Some authors have considered BMI inadequate to predict %BF and that %BF is the most predictive measure to assess obesity. In our study, we considered both BMI and %BF to evaluate adiposity; we found a positive linear relationship between these two parameters. This result is in agreement with previous studies, and it may be due to the great similarity in age, sex, race, and eating habits of the study groups.

Only a few authors have concentrated their attention on the pathogenetic role of obesity in musculoskeletal disorders; however, their studies are mainly focused on the role of adiposity in lower limb and spine diseases. Nowadays, information about obesity as an etiopathogenetic factor for RCT is still scarce. In fact, only Wendelboe et al have investigated the possible association between obesity, assessed by BMI, and surgery for different shoulder diseases. It resulted that an increasing BMI is considered a risk factor for rotator cuff tendinitis and related conditions. Unfortunately, the authors did not consider whether obesity influenced the severity of RCT. To our knowledge, this is the first study of a great number of patients that investigates whether obesity is a risk factor for RCT and also for its severity.

We observed that the percentage of RCTs registered in group A was higher than that revealed in the group with a BMI < 25 kg/m². Similar findings also emerged in the Wendelboe series, which constituted a case group of patients with rotator cuff disorders and a control group of subjects with no shoulder diseases. The authors observed an association between obesity and RCT. These results might be explained by the possible role that obesity plays in rotator cuff hypovascularity.

We observed differences in the BMI and in the %BF among patients with RCT according to the tear size. Patients with massive tears have a BMI and a %BF greater than those registered in patients with small tears. We hypothesize that patients with a greater degree of obesity have a greater impairment in the microvasculature of the insertional area that might justify a wider extension of the degenerated tendon tissue. Because our results are not influenced by age, they are not affected even by the natural history of the lesion, which might be responsible for the extension of the lesion.

No statistical difference was found regarding gender; therefore, our results are applicable to both males and females.

This study has some limitations that need to be considered. It is a case-control study and so could not completely resolve issues concerning temporality. However, previous cohort studies have shown that obesity precedes musculoskeletal conditions such as osteoarthritis, as opposed to arthritis leading to an increase in obesity because of physical inactivity.

The duration of obesity and other potential risk factors for RCT (e.g., tobacco use, highest BMI ever, diabetes, Table III

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>RCT (N = 303)</td>
<td>Control (N = 137)</td>
</tr>
<tr>
<td><strong>BMI ± SD (range)</strong></td>
<td>31.18 ± 4.71 (25.16-48.55)</td>
</tr>
<tr>
<td><strong>%BF ± SD (range)</strong></td>
<td>37.64 ± 5.71 (19.55-57.41)</td>
</tr>
</tbody>
</table>

BMI, body mass index; %BF, body fat percentage; SD, standard deviation; RCT, rotator cuff tear.

Figure 2 Relationship between rotator cuff tear and body mass index according to gender.
body habitus, genetic factors, exercise habits) were not available. However, there is no evidence to suggest that both the case and control groups were different enough to account for the risk estimates found in this study. Thus, whereas some confounding is possible, it appears unlikely to account for these results.

Finally, subjects enrolled in the control group were submitted only to a physical examination and not to magnetic resonance imaging to exclude an asymptomatic RCT. We believe that because the tests we performed have a great sensitivity, accuracy, and specificity for RCT diagnosis, only a very small percentage of subjects with an asymptomatic RCT were enrolled in the study, so that results are not significantly affected.

**Table IV** Risk estimates for RCTs according to BMI for men and women

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Men (N = 283)</th>
<th>Women (N = 318)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>≤24.99</td>
<td>0.23</td>
<td>0.13</td>
</tr>
<tr>
<td>25.00-30.00</td>
<td>2.1</td>
<td>1.27</td>
</tr>
<tr>
<td>≥30</td>
<td>2.49</td>
<td>1.41</td>
</tr>
</tbody>
</table>

RCTs, rotator cuff tears; BMI, body mass index; OR, odds ratio; CI, confidence interval.
In bold, the significant P value.

**Table V** Baseline characteristics of RCT patients according to the different-sized RCTs

<table>
<thead>
<tr>
<th>RCTs</th>
<th>Mean BMI ± SD</th>
<th>95% confidence interval</th>
<th>Mean %BF ± SD</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Small (N = 112)</td>
<td>27.86</td>
<td>28.72</td>
<td>27.03</td>
<td>28.67</td>
</tr>
<tr>
<td>Large (N = 139)</td>
<td>28.50</td>
<td>29.21</td>
<td>27.80</td>
<td>29.21</td>
</tr>
<tr>
<td>Massive (N = 130)</td>
<td>29.92</td>
<td>30.98</td>
<td>28.86</td>
<td>30.98</td>
</tr>
</tbody>
</table>

RCT, rotator cuff tear; BMI, body mass index; %BF, body fat percentage; SD, standard deviation.

**Table VI** Differences in BMI and %BF among group A patients, according to different-sized RCTs

<table>
<thead>
<tr>
<th></th>
<th>Mean difference</th>
<th>Confidence intervals</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>Small vs large</td>
<td>-0.65</td>
<td>-2.17</td>
<td>0.86</td>
</tr>
<tr>
<td>%BF</td>
<td>-0.66</td>
<td>-2.32</td>
<td>0.98</td>
</tr>
<tr>
<td>Small vs massive</td>
<td>-2.07</td>
<td>3.62</td>
<td>-0.52</td>
</tr>
<tr>
<td>%BF</td>
<td>-1.80</td>
<td>-3.48</td>
<td>-0.12</td>
</tr>
<tr>
<td>Large vs massive</td>
<td>-1.42</td>
<td>-2.88</td>
<td>0.04</td>
</tr>
<tr>
<td>%BF</td>
<td>-1.13</td>
<td>-2.72</td>
<td>0.45</td>
</tr>
</tbody>
</table>

BMI, body mass index; %BF, body fat percentage.
In bold, the significant P value.

**Conclusions**

Our study shows that obesity, measured both as BMI and %BF, is a significant risk factor for both occurrence and severity of RCT for both genders.

**Disclaimer**

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**References**


