Muscle strength in obese elderly women: effect of recreational physical activity in a cross-sectional study

Yves Rolland, Valérie Lauwers-Cances, Marco Pahor, Judith Fillaux, Hélène Grandjean, and Bruno Vellas

ABSTRACT

Background: Muscle strength (MS) may be impaired in obese persons, and this impairment may be a consequence of both obesity and low physical fitness.

Objective: We investigated whether MS differed between obese [body mass index (BMI; in kg/m²) > 29], normal-weight (BMI = 24–29), and lean (BMI < 24) elderly subjects and compared the MS of sedentary and active subjects according to their BMI group.

Design: The study included 215 obese (x ± SD age: 80.0 ± 3.5 y; BMI: 31.9 ± 2.6), 630 normal-weight (age: 80.2 ± 3.7 y; BMI: 26.3 ± 1.4), and 598 lean (age: 80.7 ± 3.5 y; BMI: 21.6 ± 1.8) women with good functional ability. A cross-sectional design was used. Anthropometric measures (weight, height); measures of appendicular skeletal muscle mass (by dual-energy X-ray absorptiometry), isometric knee and elbow extension (by statergometer), and isometric handgrip strength (by dynamometer); and data on health status and self-reported recreational physical activity (RPA: walking, gymnastics, cycling, swimming, gardening) were collected.

Results: Absolute (unadjusted) MS was higher in obese than in lean women (P < 0.01), except for handgrip strength (P > 0.05). When adjusted for age, height, RPA, pain, depression, and appendicular skeletal muscle mass, MS did not differ significantly between obese, normal-weight, and lean subjects, except for knee extension (significant interaction effect with RPA; P = 0.01). With increasing BMI, lower limb strength did not change in the sedentary women but increased in active (≥ 1 h/wk in ≥ 1 RPA for ≥ 1 mo) women. All adjusted MS measures in active participants were significantly higher (P < 0.001) than those in their sedentary peers.

Conclusion: The adjusted MS of elderly women is not associated with obesity but is higher in active subjects than in sedentary ones, especially in the lower limbs of obese subjects.

KEY WORDS Muscle strength, muscle mass, obesity, physical function, physical activity, body composition, elderly

INTRODUCTION

Obesity is a major health problem in the elderly because it is related to disability (1–3). However, less attention has been given to obesity in this age range (4). The mechanisms through which body mass may affect disability have not been identified. Current research methodology relies on physical function assessments, such as strength tests, that give objective and quantifiable results. However, these tests capture neither the specific effect of obesity on the ability to perform tasks nor muscle quality (muscle strength corrected for muscle mass).

Various factors, in addition to muscle mass, contribute to the components of strength and may play a role in functional disability (1). Among these factors, obesity and low physical fitness are frequently associated, and both may impair muscle strength (5).

Several arguments suggest that muscle strength is affected in obesity. A high amount of fat mass is frequently associated with functional incapacity, whereas a low amount of muscle mass is not (6–10). These results cast doubts on the key role of a purely quantitative loss of muscle mass in the development of disability. In fact, the contribution of muscle mass to strength seems to be relative to the amount of body fat (10). In obesity, muscle impairment may be involved independently of a lack of physical activity (11, 12). Studies of basic physiology suggest that the muscle of obese persons has specific metabolic and histologic characteristics (13–17). Obese persons usually have more muscle mass and more strength (6, 10) than do nonobese persons. However, we do not know whether muscle quality, defined as muscle strength corrected for muscle mass, is lower in obese elderly persons than in nonobese elderly persons (12).

Physical activity improves muscle strength and muscle mass (18) and has a key role in the management strategy for obesity; even without significant body-composition modifications, physical activity improves the physical performances of obese subjects (19), which suggests that their muscle strength can be improved. However, we do not know whether the effect of physical activity on muscle strength differs between obese and nonobese persons.

To answer these 2 questions, we compared muscle strength adjusted for muscle mass between obese, normal-weight, and lean elderly women. We then compared adjusted muscle strength between sedentary and active participants according to their body mass index (BMI; in kg/m²).
SUBJECTS AND METHODS
From 1992 to 1994, 1454 women aged ≥ 70 y took part in the EPIDOS (ÉPIDemiologie de l’OSTéoporose) study in Toulouse, France. EPIDOS is a prospective epidemiologic study carried out in 5 French cities (Amiens, Lyon, Montpellier, Paris, and Toulouse) to assess the risk factors for hip fracture in the healthy elderly (20).

Population and protocol
The 1454 women were recruited from electoral lists. Women were excluded if they were unable to walk independently, were living in an institution, had a previous history of hip fracture or hip replacement, or were unable to understand or answer the questionnaire. We analyzed the data collected during the inclusion visit. All participants gave written informed consent. The study was approved by the ethics committee of the Hôpital La Grave-Casselardit (Toulouse, France).

Baseline examination was performed in a clinical research center by a trained geriatric nurse. A physical examination and a health-status questionnaire were used to record comorbid diseases (hypertension, diabetes, dyslipidemia, coronary artery disease, peripheral vascular disease, cancer, stroke, Parkinson disease, and depression) and pain (pain of the back, hip, knee, ankle, or feet). The women were asked to bring all their regular medication to the clinical center. Vision was assessed with the use of a visual acuity test. Smoking (previous or current) and alcohol intake were noted.

Participants also self-reported in a structured questionnaire whether they regularly participated in recreational physical activities such as walking, gymnastics, cycling, swimming, or gardening. The type, frequency, and duration of each recreational physical activity were recorded. Women were considered physically active if they had participated in at least one recreational physical activity for ≥ 1 h/wk for at least the past month.

Anthropometry
Anthropometric measurements were performed by a trained technician using standardized techniques (21). Weight was measured with a beam balance scale, and height was measured with a wall-mounted stadiometer. Hip circumference was measured by using a tape measure at the level of the maximum posterior protrusion of the buttocks. Waist circumference was measured 1 cm above the iliac crests. Calf circumference was measured while the patient was supine, with the left knee raised and the calf at right angles to the thigh. The tape measure was placed around the calf and adjusted to obtain the maximal circumference. Subcutaneous tissues were not compressed.

A recent review of the literature suggests that the optimal range of BMI for elderly persons is 24–29 (22). In accordance with these proposed values for the elderly, women were defined as obese if their BMI was > 29, and women were defined as lean if their BMI was < 24.

Evaluation of muscle strength
Grip strength was measured in the dominant hand with a hydraulic hand dynamometer (Martin Vigorimeter; Medizin-Technik, Tuttlingen, Germany). The size of the grip was adjusted so that the participants felt comfortable. Each participant stood upright with her arm vertical and the dynamometer close to her body. The maximal peak pressure expressed in N/m² was recorded for a set of 3 contractions. Isometric elbow extension was measured as the force applied at the hand, with the participant seated and her shoulder and elbow flexed at 90°. The maximal strength (in N) of the dominant hand from the strain gauge was recorded after 3 attempts (ADCRO (Association pour le Développement de la Chirurgie Réparatrice et Orthopédique) electronic statergometer; ADCRO, Valenton, France). To measure maximum isometric knee extension, the participants were seated in an adjustable, straight-back chair with the pelvis fixed by a strap and a strength gauge attached by a strap just above the ankle (ADCRO electronic statergometer) (23). For analysis we used the mean of the highest score (in N) obtained during 3 attempts with each leg. Verbal encouragement was given each time to obtain the maximal score.

Body composition
The body composition of all participants was measured by using dual-energy X-ray absorptiometry (DXA). The DXA apparatus (Hologic QDR 4500 W; Hologic, Waltham, MA) was regularly calibrated. The DXA protocol was performed by a trained technician. We used an accurate method to quantify appendicular skeletal muscle mass (24), which corresponds to the sum of the muscle mass (in kg) of the 2 upper limbs (arm muscle mass) and the 2 lower limbs (leg muscle mass).

Statistical methods
Quantitative variables are expressed as means ± SDs. Analysis was stratified by BMI group (< 24, 24–29, and > 29). We used correlation coefficients for the associations between the quantitative variables (age; weight; height; BMI; waist, calf, and hip circumferences; fat mass; fat-free mass; appendicular skeletal muscle mass; handgrip strength; and elbow and knee extension). Variance analysis and Bonferroni multiple comparison tests were used to compare quantitative variables between the groups. The chi-square test was used to compare recreational physical activity between the groups. For accurate comparison of strength between the different BMI groups, strength measures were adjusted for muscle mass. Multiple linear regression was performed to take into consideration all confounding factors. Height was included as a potentially confounding factor because it may influence strength independently of muscle mass. Among all potentially confounding factors, age, height, Parkinson disease, depression, pain, visual impairment, osteoporosis, and recreational physical activity were associated with muscle strength to a threshold of 0.20 in bivariate analysis. These variables were taken into account for adjustment in the initial model. Pain and steroid treatment, factors that are known to influence muscle strength, were also taken into account in the initial model. Stepwise decreasing regression was done to obtain the best reduced model. Leg muscle mass (for knee extension only), arm muscle mass (for elbow extension and handgrip strength only), age, height, pain, depression, and recreational physical activity remained in the final model.

We then estimated average adjusted muscle strength measures for each BMI group and each level of recreational physical activity from each final model. Tests were two-sided, and $P<0.05$ was considered significant. Data analysis was performed by using STATA 7.0 software (Stata Corp, College Station, TX).
TABLE 1
Descriptive anthropometric measures, body-composition measures by dual-energy X-ray absorptiometry, and absolute strength measures (uncorrected for muscle mass) in lean [BMI (in kg/m\(^2\)) < 24], normal-weight (BMI = 24–29), and obese (BMI > 29) elderly women

<table>
<thead>
<tr>
<th></th>
<th>Lean (n = 598)</th>
<th>Normal weight (n = 630)</th>
<th>Obese (n = 215)</th>
<th>Obese compared with normal</th>
<th>Obese compared with lean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>80.7 ± 4.1(^2)</td>
<td>80.2 ± 3.7</td>
<td>80.0 ± 3.5</td>
<td>1.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>50.9 ± 5.6</td>
<td>61.1 ± 5.8</td>
<td>73.4 ± 7.7</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>Height (cm)</td>
<td>153.4 ± 5.7</td>
<td>152.4 ± 6.1</td>
<td>151.5 ± 5.9</td>
<td>0.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>21.6 ± 1.8</td>
<td>26.3 ± 1.4</td>
<td>31.9 ± 2.6</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>77.4 ± 6.3</td>
<td>87.9 ± 6.1</td>
<td>99.6 ± 7.7</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Calf circumference (cm)</td>
<td>32.8 ± 2.4</td>
<td>35.5 ± 2.3</td>
<td>38.7 ± 2.7</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hip circumference (cm)</td>
<td>92.6 ± 4.7</td>
<td>101.6 ± 4.9</td>
<td>113.0 ± 6.9</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fat-free mass (%)</td>
<td>65.8 ± 7.3</td>
<td>57.4 ± 5.0</td>
<td>52.1 ± 4.0</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>Fat-free mass (kg)</td>
<td>33.3 ± 3.6</td>
<td>35.0 ± 3.6</td>
<td>38.0 ± 4.1</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>Appendicular skeletal muscle mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total (kg)</td>
<td>14.0 ± 1.6</td>
<td>15.1 ± 1.8</td>
<td>16.8 ± 2.2</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Leg muscle mass (kg)</td>
<td>10.5 ± 1.3</td>
<td>11.1 ± 1.3</td>
<td>11.9 ± 1.5</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Arm muscle mass (kg)</td>
<td>3.4 ± 0.6</td>
<td>3.9 ± 0.7</td>
<td>4.9 ± 0.9</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Handgrip strength (N/m(^2))</td>
<td>50.6 ± 12.6</td>
<td>51.9 ± 13.6</td>
<td>52.2 ± 12.6</td>
<td>1.0</td>
<td>0.445</td>
</tr>
<tr>
<td>Elbow extension (N)</td>
<td>93.5 ± 28.4</td>
<td>96.8 ± 31.2</td>
<td>102.8 ± 32.9</td>
<td>0.048</td>
<td>0.001</td>
</tr>
<tr>
<td>Knee extension (N)</td>
<td>169.4 ± 45.6</td>
<td>176.6 ± 50.1</td>
<td>181.2 ± 54.9</td>
<td>0.614</td>
<td>0.008</td>
</tr>
<tr>
<td>Active women(^3) (%)</td>
<td>43.2</td>
<td>36.4</td>
<td>23.8</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

\(^1\) Bonferroni multiple comparison test.
\(^2\) ± SD (all such values).
\(^3\) Women who participated in at least one recreational physical activity (hiking, gymnastics, cycling, swimming, or gardening) for ≥ 1 h/wk for at least the past month.

RESULTS
The EPIDOS population in Toulouse included 1454 women. Eleven women were excluded because of stroke sequelae. The mean age of the sample was 80.4 ± 3.9 y, 41.5% of the subjects were lean, and 15% were obese. The 75–85-y-old patients represented 87% of the population.

The obese women did not differ significantly in age from the women in the other 2 BMI groups (Table 1). The obese women had significantly more fat mass than did the normal-weight and lean women, and all the anthropometric measures (except for height) of the obese women were significantly higher than those of the normal-weight and lean women. The obese women also had significantly more fat-free mass, total appendicular skeletal muscle mass, leg muscle mass, and arm muscle mass. Except for handgrip strength, absolute strength measures were significantly higher in the obese women than in the lean women. The obese women reported significantly less recreational physical activity than did the lean women or those with normal BMI.

Muscle masses (leg, arm, or appendicular skeletal muscle mass) were positively and significantly (P < 0.001) correlated (Pearson correlations) with elbow and knee extensor strength and handgrip strength in the normal-weight and lean women. In the obese women, there were no or only weakly positive significant (P < 0.05) correlations between muscle masses and muscle strength measures.

The 3 BMI groups did not differ significantly in adjusted muscle strength for handgrip and elbow extension (Table 2). For knee extensor strength, a significant interaction was found between BMI group and participation in a recreational physical activity (P < 0.01). Because of this interaction effect, a stratified

TABLE 2
Strength measures adjusted for age, height, recreational physical activity, pain, depression, and muscle masses (arm muscle mass for handgrip strength and elbow extension and leg muscle mass for knee extension) in lean [BMI (in kg/m\(^2\)) < 24], normal-weight (BMI = 24–29), and obese (BMI > 29) women\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>Lean (n = 598)</th>
<th>Normal weight (n = 630)</th>
<th>Obese (n = 215)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handgrip strength (N/m(^2))</td>
<td>50.8 ± 0.6</td>
<td>52.2 ± 0.6</td>
<td>52.1 ± 1.2</td>
<td>NS</td>
</tr>
<tr>
<td>Elbow extension (N)</td>
<td>94.5 ± 1.4</td>
<td>97.34 ± 1.2</td>
<td>99.5 ± 2.6</td>
<td>NS</td>
</tr>
<tr>
<td>Knee extension (N)</td>
<td></td>
<td></td>
<td></td>
<td>0.01(^2)</td>
</tr>
<tr>
<td>Sedentary</td>
<td>168.0 ± 2.8</td>
<td>169.0 ± 2.3</td>
<td>168.9 ± 4.0</td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>177.8 ± 3.0</td>
<td>188.7 ± 2.9</td>
<td>198.4 ± 6.0</td>
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</table>

\(^1\) All values are ± SD. Body composition was measured by using dual-energy X-ray absorptiometry.
\(^2\) For interaction between BMI group and participation in recreational physical activity.
analysis was performed for knee extensor strength. The adjusted knee extensor strength of the sedentary women did not differ significantly between the 3 BMI groups. Among the active women, adjusted knee extensor strength was significantly lower in the lean women than in the obese women ($P < 0.01$).

**DISCUSSION**

This cross-sectional study found no BMI-related decrease in adjusted muscle strength. The obese and nonobese elderly women did not differ significantly in adjusted muscle strength independently of recreational physical activity. In contrast, we found that recreational physical activity was a significant determinant of muscle strength in the elderly women irrespective of BMI, and this was especially true among obese women. Indeed, we found a significant interaction between recreational physical activity and adjusted knee extensor strength. This significant interaction suggests that for the active women, lower limb strength increased with increasing BMI.

The obese women had significantly more fat mass, fat-free mass, and leg and arm muscle mass and stronger knee and elbow extensors. Compared with lean subjects, obese subjects have higher weight and consequently more fat-free mass (12). In the general population, there is a well-known relation between muscle mass and strength (25). Consequently, weight is positively associated with muscle strength. However, although the obese women in the present study had significantly more arm muscle mass than did the normal-weight and lean women, the obese women did not have significantly higher handgrip strength. Hulens et al (12) found lower grip strength in obese adults than in lean adults despite equal physical activity levels. These results confirm that factors other than those related to muscle size contribute to strength measures.

Many factors, including strength and diminished exercise tolerance, probably contribute to disability in the elderly obese. A previous cross-sectional study found no relation between BMI group and muscle strength in a population of women (26). The approach used in that study was based on physical function assessment and thus provided information about absolute muscle strength and its consequences on the ability to perform tasks that simulated activities of daily living. However, such tests cannot provide information about muscle quality. Epidemiologic information concerning the muscle quality (muscle strength corrected for muscle mass) of elderly obese persons is scarce (11, 12). Because we did not find an association between BMI group and muscle strength adjusted for muscle mass in the present study, our results do not confirm the previous data concerning muscle quality in elderly obese subjects. Indeed, the negative effect of fat mass on physical performance was suggested in the Health, Aging and Body Composition Study, in which a high percentage of fat mass was associated with low muscle quality (defined as the ratio of muscle strength to muscle mass) in the lower limbs (11). Using an allometric approach, Hulens et al (12) also found lower muscle quality in obese women than in lean women. Muscle impairment in obese persons could be related to metabolic changes or to changes in muscle architectural components, such as fat infiltration. One important limitation of studies that compare muscle strength between obese and nonobese subjects is that many factors other than BMI or fat mass can influence the performance measures. Osteoarthritis, knee and hip pain, the use of many medications, and comorbid diseases are very common in obese subjects and may induce lower strength performances. Other major factors such as low motivation or lack of willpower might also explain the results of previous studies. To avoid confounding factors in the present study, we made adjustments for some variables like pain, which were found to be associated with physical performance measures. The design of previous studies may explain the observed association between muscle quality and obesity.

The second aim of the present study was to compare adjusted muscle strength between the active and sedentary participants according to their BMI group. A high level of recreational physical activity was positively associated with the likelihood of being in the normal or lean range of BMI values. Numerous studies have suggested the same cross-sectional association between a high level of physical activity and BMI or body fat (27–29), but information concerning large elderly populations in epidemiologic studies is scarce (26, 27, 30, 31).

Our results also confirm those of previous reports suggesting that physical activity is a major determinant of muscle strength and muscle quality (32, 33). Moreover, our study adds further information to previous findings on the link between recreational physical activity and muscle strength in obese persons. We found a significant interaction between BMI group and recreational physical activity for knee extensor strength. This result suggests that the positive effect of recreational physical activity on lower limb strength (knee extensor strength adjusted for leg muscle mass) increases from lean to obese women. This unique finding gives rise to various hypotheses.

First, the effect of weight-bearing training is greater in obese than in lean subjects. Because of the larger body mass of obese persons, the physiologic muscular response to a given level of physical activity is probably not the same in obese and lean women, especially in the lower limbs. Thus, a given level of weight-bearing activity, such as walking, gymnastics, or gardening, may be strength training for obese persons but still be endurance training for lean subjects. Although physical activity is an important predictor of muscle mass in the elderly (34), several studies reported greater relative increases in strength than in muscle mass after strength training in older subjects (32, 33, 35). In contrast, endurance training in the elderly has little or no effect on muscle strength (36). These physiologic adaptations of the neuromuscular system to different stimuli involved in body weight bearing in recreational activities, which mainly require lower limb muscle strength, could explain our results. This explanation is reinforced by the fact that in our study, muscle strength of the legs was the only physical variable affected by this significant interaction. In contrast, the effect of physical activity on arm strength may have been underestimated because gardening, walking, cycling, and gymnastics are activities that are focused less on the upper extremities than on the lower ones.

Second, data suggest that histochemically determined muscle fiber composition is partially predictive of obesity (13, 37). If muscle fiber type is related to obesity, it is tempting to speculate that the effects of physical activity on muscle strength differ between lean and obese women. However, it is unclear whether these histochemical characteristics are intrinsic phenomena of muscle in obese persons or whether they develop during the course of the obese state.

Third, obesity is influenced by both nongenetic and genetic determinants (38), and evidence of significant genetic influences on the level of physical activity have been reported (38, 39). The
The present study had several limitations. One specific limitation was the reliance on self-reported evaluation of physical activity in a selected population. The validity and reliability of this questionnaire in our selected population, especially in obese elderly women, is unknown. Such evaluation is prone to reporting bias, such as social desirability or recall (40). Moreover, because of the cross-sectional nature of the study, the causal nature of the association between muscle strength and recreational physical activity in the obese participants cannot be addressed. Physical activity may promote more muscle strength, but more muscle strength may also encourage physical activity. In fact, both probably reinforced each other. A potential limitation is that DXA does not exclude all intermuscular fat from the muscle mass measured. However, overestimation of the muscle mass of the obese women may have reduced the adjusted muscle strength but does not explain our results.

In conclusion, the present study did not find a trend toward decreasing muscle strength with increasing BMI, and our results suggest the importance of physical activity in elderly obese subjects. Physical activity is associated with an increase in muscle strength adjusted for muscle mass and may prevent disability in elderly obese subjects. We suggest that treatment of obese subjects should be focused on recreational physical activity to improve strength and to control weight.

YR, MP, and BV contributed to the conception of the study and the writing of the manuscript. VL-C and HG contributed to the design of the experiment, data analysis, and the writing of the manuscript. JF contributed to analysis. None of the authors had any conflicts of interest in the preparation or submission of the manuscript.

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