Correlations between physical performance and muscle mass, strength, and quality in obese and normal-weight community-dwelling older Japanese women

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ABSTRACT

Background. Muscle strength correlates with physical performance and depends on muscle mass and quality, which may differ between obese and normal-weight older women. We aimed to compare obese and normal-weight older women in terms of muscle strength, mass, and quality to determine the correlation between physical performance and these muscle characteristics.

Methods. A total of 170 community-dwelling older women were categorised into normal-weight (n=137) or obese (n=33) group. Their knee extension strength ratio, leg muscle mass ratio and muscle quality, and physical performance (30-second chair stand test and timed up and go test) were assessed.

Results. Compared with the normal-weight group, the obese group had lower muscle strength ratio (0.32 vs 0.39, $p<0.001$) and muscle mass ratio (92.36 vs 107.82, $p<0.001$) but similar muscle quality and physical performance. The muscle strength ratio moderately correlated with physical performance in both groups, whereas the muscle mass ratio weakly to moderately correlated or tended to correlate with physical performance, except for 30-second chair stand test result in the normal-weight group. Muscle quality correlated with physical performance in the normal-weight group but not in the obese group.

Conclusions. Obese older women had lower muscle strength ratio and muscle mass ratio but similar muscle quality, compared with normal-weight older women. In obese older women, physical performance tended to correlate with muscle mass ratio rather than muscle quality.

Key words: Aged; Muscle strength; Obesity; Physical functional performance

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INTRODUCTION

Muscle strength decreases with ageing,¹ and its maintenance reduces the prevalence of functional limitation.² Among community-dwelling older adults, leg function is highly predictive of

subsequent disability.³ Knee extension strength and its impairment are associated with physical performance.^{4,5} The risk of falling (and possible subsequent fractures) is associated with a decline in the musculoskeletal function.⁶ Therefore, muscle strength is important for the health of older adults.

Age-related loss of muscle strength refers to loss of both neuromuscular function and muscle mass and is the primary cause for muscle decline.⁷⁻⁹ However, other factors may contribute to the loss of muscle strength with ageing.¹⁰ In addition to muscle quantity, muscle quality (muscle strength relative to muscle mass) may be another determinant of loss of muscle strength with ageing.¹¹

Body mass index (BMI) is associated with muscle mass and muscle quality. Obese individuals (BMI, ≥ 25 kg/m²) tend to have greater muscle mass than normal-weight individuals (BMI, 18.5-22.9 kg/m²).¹² Muscle strength is expected to be greater in obese individuals than in normal-weight individuals. However, one study reported similar muscle strength in obese (BMI, ≥ 29 kg/m²) and normal-weight (BMI, 24-29 kg/m²) individuals.¹³ This conflicting evidence may be due to the association between low muscle mass and high muscle quality.¹⁴ There are treatment strategies to improve muscle mass and muscle quality.¹⁵ Given that muscle strength is associated with physical performance,⁵ we hypothesised that the correlations between muscle mass or quality and physical performance differ between obese and normal-weight individuals. This study aimed to determine the correlation between physical performance and muscle characteristics (strength,

mass, and quality) in obese and normal-weight community-dwelling older women.

METHODS

This cross-sectional study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of the Kyoto Tachibana University (approval number: 18-26). Written informed consent was obtained from each participant. 253 community-dwelling older adults were recruited from Yasu City, Japan, through public information papers. Inclusion criteria were: (1) age >60 years, (2) no cognitive impairment (Mini-Mental State Examination score of ≥ 24), and (3) ability to perform all measurements. Exclusion criteria were: (1) underweight (BMI, <18.5 kg/m²) and (2) cardiac pacemaker implanted. Of 253 community-dwelling older adults, 170 women were included for analysis (FIGURE). They were categorised to normal-weight (BMI, 18.5-24.9 kg/m²) and obese (BMI, ≥ 25 kg/m²) groups, according to the Japanese criteria. The number of comorbidities under medical treatment in each participant was recorded.

Knee extension strength was measured. Participants were instructed to sit upright with their arms folded across their chest and the hip and knee

FIGURE. Flowchart of recruitment of participants

flexed at 90°, without changing posture during measurement.¹⁶ A hand-held dynamometer (μ Tas F-1; Anima, Tokyo, Japan) was placed proximal to the ankle to measure maximal isometric muscle contraction. The intra-class correlation coefficient of measurements in older adults (aged 65-79 years) was >0.8 .¹⁷ The mean value of two measurements for each leg was used for analysis. The muscle strength ratio was defined as knee extension strength in kg / body weight in kg. Muscle mass of both legs was measured using the bioelectrical impedance method with Inbody 470 (InBody Japan, Tokyo, Japan). The mean value of both legs was used for analysis. The muscle mass ratio was defined as muscle mass in kg / body weight in kg. The muscle quality of legs was defined as the ratio of muscle strength in kg to muscle mass in kg.¹⁸

Physical performance was measured using the 30-second chair stand test (CS-30)¹⁹ and timed up and go test (TUG).²⁰ For CS-30, participants were asked to sit in a chair (with the back straight, feet on the floor, and arms folded across the chest) and repeatedly rise to a full-standing position and then return to the initial seated position as fast as possible for 30 s. For TUG, participants were asked to stand up from sitting in a chair without arm rests, walk 3 m, turn around, walk back, and sit down on the chair again as fast as possible.

Using G*Power version 3.1.9.2 (Statistical Power Analyses, <http://www.gpower.hhu.de>), the sample size was calculated to be 44 based on the low correlation ($r=0.40$), with α set at 0.05 and power set at 0.80. The ratio of normal-weight group to obese group was estimated to be approximately 3:1, based on our previous study.²¹ Therefore, a sample size of 176 was needed.

The Shapiro-Wilk test was used to verify whether data were normally distributed. The normal-weight group and obese group were compared using the Mann-Whitney *U* test for non-normally distributed data (age, height, BMI, and TUG), the Levene test of homogeneity of variance for normally distributed data, the Welch *t* test for data not exhibiting homogeneous variance (muscle strength ratio), the unpaired-*t* test for data exhibiting homogeneous variance, and the Chi-squared test for the prevalence of comorbidities. Correlations between physical performance (CS-30 and TUG) and muscle

characteristics (strength, mass, and quality) were analysed using the Spearman correlation test or Pearson correlation test, as appropriate. A correlation coefficient (*r*) of 0.2-0.4, >0.4 -0.7, and >0.7 -0.9 indicated weak, moderate, and high correlations, respectively. Statistical analyses were performed using SPSS (version 24.0, IBM, USA). Statistical significance was set at $p<0.05$. For multiple between-group comparison on different muscle strength ratio, muscle mass ratio, and muscle quality, Bonferroni correction was performed with statistical significance set at $p<0.016$ ($0.05/3$).

RESULTS

There were 137 women in the normal-weight group and 33 women in the obese groups (**TABLE 1**). The two groups were comparable in terms of age, height, and the prevalence of comorbidities. Compared with the normal-weight group, the obese group had lower muscle strength ratio (0.32 vs 0.39, $p<0.001$) and muscle mass ratio (92.36 vs 107.82, $p<0.001$) but similar muscle quality and physical performance (CS-30 and TUG) [**TABLE 2**].

The muscle strength ratio moderately correlated with physical performance in both groups, whereas the muscle mass ratio weakly to moderately correlated or tended to correlate with physical performance, except for CS-30 in the normal-weight group (**TABLE 3**). Muscle quality moderately correlated with CS-30 and weakly correlated with TUG in the normal-weight group, but it did not correlate with physical performance in the obese group.

DISCUSSION

Our findings revealed that physical performance tended to correlate more with muscle strength ratio, compared with muscle mass ratio and muscle quality. Consistent with our results, muscle strength has been reported to correlate with CS-30²² and TUG.²³ Muscle strength is important in maintaining or improving physical performance in both obese and normal-weight older women.

Upper leg muscle quality has been reported to moderately correlate with TUG ($r=-0.47$).²⁴ In our study, physical performance correlated with muscle quality in the normal-weight group but not in the obese group. Although obesity has been reported

TABLE 1
Characteristics of normal-weight and obese older women

Variable	Normal-weight group (n=137)*	Obese group (n=33)*	p Value
Age, y	74.7±5.2	74.2±5.8	0.893
Height, cm	151.4±5.2	149.4±6.2	0.098
Weight, kg	49.1±5.1	61.1±5.4	<0.001
Body mass index, kg/m ²	21.1±5.1	27.4±1.6	<0.001
Comorbidities			
Hypertension	58 (42.3)	17 (51.5)	0.340
Hyperlipidaemia	23 (16.8)	5 (17.9)	0.820
Orthopaedic diseases	24 (17.5)	7 (21.2)	0.622
Stroke	1 (0.7)	0 (0.0)	0.623
Diabetes mellitus	8 (5.8)	5 (38.5)	0.071
Rheumatoid arthritis	3 (2.2)	0 (0.0)	0.391
Cardiovascular disease	5 (3.6)	2 (6.1)	0.531
Pulmonary disease	3 (2.2)	0 (0.0)	0.391
Renal disease	2 (1.5)	0 (0.0)	0.485
Cancer	3 (2.2)	0 (0.0)	0.391
Others	26 (19.0)	5 (15.2)	0.609

* Data are presented as mean ± standard deviation or No. (%) of patients

TABLE 2
Leg muscle strength ratio, muscle mass ratio, muscle quality and physical performance in normal-weight and obese older women

Variable	Normal-weight group (n=137)*	Obese group (n=33)*	p Value
Muscle strength ratio	0.39±0.09	0.32±0.06	<0.001
Muscle mass ratio	107.82±10.11	92.36±8.49	<0.001
Muscle quality	3.60±0.88	3.50±0.68	0.570
30-second chair stand test, repetition/30 sec	21.44±6.22	21.85±5.23	0.731
Timed up and go test, sec	5.76±1.00	5.90±0.98	0.431

* Data are presented as mean ± standard deviation

TABLE 3
Correlations between physical performance and leg muscle strength ratio, muscle mass ratio, and muscle quality

Variable	30-second chair stand test		Timed up and go test	
	Normal-weight group	Obese group	Normal-weight group	Obese group
Muscle strength ratio	$r=0.500$ ($p<0.001$)	$r=0.518$ ($p=0.002$)	$r=-0.466$ ($p<0.001$)	$r=-0.486$ ($p=0.004$)
Muscle mass ratio	$r=0.096$ ($p=0.268$)	$r=0.391$ ($p=0.024$)	$r=-0.203$ ($p=0.018$)	$r=-0.569$ ($p=0.001$)
Muscle quality	$r=0.435$ ($p<0.001$)	$r=0.343$ ($p=0.051$)	$r=-0.385$ ($p<0.001$)	$r=-0.248$ ($p=0.164$)

to be associated with lower muscle quality,²⁵ our findings reported similar muscle quality in obese and normal-weight older women. The discrepancy may be due to (1) obese individuals have greater weight-

bearing stress and thus higher muscle quality than normal-weight individuals, and (2) the muscle mass ratio is lower in obese than normal-weight individuals, and low muscle mass ratio increases

weight-bearing stress to the muscle. Knee extensor muscle quality has been reported to increase after 12 weeks of strength training.²⁶ Therefore, lower muscle mass ratio increases stress on the legs and hence increases muscle quality in obese individuals.

Thigh muscle volume (estimated by an equation that included age, sex, body weight, and thigh circumference) has been reported to weakly correlate with TUG ($r = -0.224$) in older adults.²⁷ Nonetheless, muscle thickness of the quadriceps femoris measured by ultrasonography was not correlated with TUG in older adult women.²⁸ These findings suggest that correlation between muscle mass and TUG was low or absent. On the contrary, our study showed that the muscle mass ratio correlated or tended to correlate with both CS-30 and TUG in the obese group. Some obese older individuals do not have parallel growth of muscle mass with increasing weight.²⁹ Therefore, the muscle mass ratio tended to correlate with physical performance in obese older women but not in normal-weight older women.

Assessment of muscle strength rather than muscle mass or muscle quality is effective in identifying older women at risk of developing impaired mobility in later life.³⁰ Decline of muscle strength with ageing is a determinant of loss of muscle mass and muscle quality.^{9,11} Understanding the correlations between physical performance and muscle mass or muscle quality in obese and normal-weight older women may help them to maintain or improve their physical performance.

There are some limitations to this study. The cross-sectional design cannot determine causality. Men were excluded because of the small sample size. The muscle quality should have assessed through both muscle histological study and nervous system evaluation.

CONCLUSION

Obese older women had lower muscle strength ratio and muscle mass ratio but similar muscle quality, compared with normal-weight older women. In obese older women, physical performance tended to correlate with muscle mass ratio rather than muscle quality. Obese older adults should perform aerobic exercises to prevent muscle mass decrease and to reduce body weight so as to increase muscle mass

ratio to maintain or improve physical performance.

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DECLARATION

The authors have no conflict of interest to disclose.

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