

# Relationship between muscle mass and physical performance: is it the same in older adults with weak muscle strength?

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## Abstract

**Background:** the relationship between muscle mass and physical performance has not been consistent among studies.

**Objective:** to clarify the relationship between muscle mass and physical performance in older adults with weak muscle strength.

**Design:** cross-sectional analysis using the baseline data of 542 older men and women from the Korean Longitudinal Study on Health and Aging.

**Methods:** dual X-ray absorptiometry, isokinetic dynamometer and the Short Physical Performance Battery (SPPB) were performed. Two muscle mass parameters, appendicular skeletal mass divided by weight (ASM/Wt) and by height squared (ASM/Ht<sup>2</sup>), were measured. We divided the participants into a lower-quartile (L25) group and an upper-three-quartiles (H75) group based on the knee-extensor peak torque. Correlation analysis and logistic regression models were used to assess the association between muscle mass and low physical performance, defined as SPPB scores <9, after controlling for confounders.

**Results:** in the L25 group, no correlation between mass and SPPB was detected, whereas the correlation between peak torque and SPPB was significant and higher than that in the H75 group. Results from the logistic models also showed no association between muscle mass and SPPB in the L25 group, whereas muscle mass was associated with SPPB in the H75 group.

**Conclusion:** muscle mass was not associated with physical performance in weak older adults. Measures of muscle strength may be of greater clinical importance in weak older adults than is muscle mass *per se*.

**Keywords:** sarcopenia, physical performance, muscle strength, older adults

## Introduction

The muscle strength is a determinant of physical performance, such as gait speed, in old individuals [1–3]. The relationship between strength and performance has been

shown to be non-linear, or curvilinear [3]; that is, some physiological changes may have more substantial effects on physical performance in weak older adults than in healthy older adults. Age-related loss of muscle mass, ‘sarcopenia’ [4], has been studied as another factor affecting physical

performance. Muscle mass is known to be linearly correlated with muscle strength [5, 6]; thus, the relationship between muscle mass and physical performance had been suggested to be similar to that between muscle strength and physical performance [6]. Several studies have reported a strong association between low muscle mass and limited physical function [7] or objective physical performance [8]. However, muscle mass is a weak and inconsistent predictor of physical performance compared with muscle strength [1, 9]. Despite the well-known linear correlation between mass and strength, the rate of leg strength decline was about three times greater than the rate of leg lean mass loss [10], and the muscle mass decline explained only 5% of the decline in strength [11]. Therefore, one cannot clearly conclude whether muscle mass has an effect on physical performance via its linear relationship with or independence of muscle strength.

Clinically, the goal of muscle mass evaluation is to identify older adults who are at a risk of decreased physical performance or disability and to help them by increasing muscle mass, with the assumption that muscle mass is related to physical performance. However, most mass–function relationships have been studied in healthy geriatric cohorts as a whole, and not in weak or frail older adults. The inconsistent and weak results for the mass–function relationship may be due to the difference in various subsets of people. We hypothesised that the muscle mass in weak older adults has a different relationship to physical performance than that observed among sufficiently strong adults and thus must be analysed separately. To our knowledge, no study has analysed muscle mass and physical performance focusing specifically on weak or vulnerable older adults.

This study examined the association between muscle mass and physical performance according to the level of weakness in older adults drawn from a population-based study.

## Methods

This study was a part of the Korean Longitudinal Study on Health and Aging (KLoSHA), which has been described in detail [12]. We included 542 people (279 men, 263 women) with an average age of  $74.6 \pm 7.4$  years (range, 65–97 years) for whom dual X-ray absorptiometry (DXA; Lunar Corporation, Madison, WI, USA) data were available.

The Short Physical Performance Battery (SPPB) was used to assess physical performance outcome variables [13, 14]. The appendicular skeletal muscle mass (ASM) (kg) was measured using DXA. We used ASM divided by weight (ASM/Wt) [15, 16] and by height squared (ASM/Ht<sup>2</sup>) [17] as muscle mass variables. The isokinetic muscle strength of the right knee extensors was measured using an isokinetic dynamometer (Biodex Isokinetic Tester; Biodex Medical Systems, Shirley, NY, USA). For a more detailed description, see Supplementary data available in *Age and Ageing* online.

Considering the non-linear relationship between muscle strength and physical performance [3], we divided the participants into weak and sufficient-strength groups after comparing the results of a simple linear model and one break-point models with cut-off values ranging from the 25 to 50th percentile peak torque in men and women separately. Spearman's correlation coefficients and logistic regression models adjusting for age and number of comorbid conditions were used to estimate associations between muscle mass and physical performance according to muscle strength groups. For the logistic regression analyses, SPPB was dichotomised into low (SPPB < 9) and high (SPPB ≥ 9) physical performance.

## Results

One break-point models using cut-off values equal to the 25th percentile peak torque (61.8 Nm in men and 35.1 Nm in women) provided the best fit to the relationship between muscle strength and SPPB ( $R^2 = 0.269$  and  $0.352$  in men and women, respectively), as shown in the Supplementary data available in *Age and Ageing* online, Figure S1. The slope between muscle peak torque and SPPB score in men and women was higher in the lower-quartile (L25) group than in the upper-three-quartiles (H75) group. Therefore, we based our analyses on the 25th percentile of peak torque.

Table 1 compares the baseline characteristics and muscle mass parameters between L25 and H75 groups. The mean age and Mini-Mental Status Examination and Geriatric Depression Scale scores were lower in the L25 group than in the H75 group. The number of comorbid conditions did not differ between groups, but arthritis was more prevalent in both men and women in the L25 group. Muscle mass parameters were not significantly different between the L25 and H25 group, except ASM/Ht<sup>2</sup> in men.

Correlations between muscle mass and SPPB were significant in men and women except ASM/Ht<sup>2</sup> in women, but were not as high as the correlations between strength and SPPB (Table 2). In the L25 group, the correlation between mass and SPPB was low and not significant, whereas the correlation between peak torque and SPPB was significant and even higher than that in the H75 group.

Similar to the correlation analysis results, the logistic regression analysis did not show a significant association between muscle mass and physical performance in the L25 group. Odds ratios of muscle mass parameters for low physical performance were significant in the H75 group, except ASM/Ht<sup>2</sup> in women. The Hosmer–Lemeshow goodness-of-fit test revealed that all models fitted adequately. To confirm the effect of muscle strength on the mass–performance relationship, we performed logistic regression tests for low physical performance, including the interaction terms between muscle mass parameters and the peak torque category variable by L25 and H75. Significant interaction was detected using ASM/Wt in men [OR = 0.82 (0.68–0.99)] indicating the modifying effect of the muscle strength on the mass–performance relationship.

**Table 1.** Baseline characteristics between the two groups based on the 25th percentile value of peak torque in men and women

	Men			Women		
	L25 ( <i>n</i> = 70)	H75 ( <i>n</i> = 209)	<i>P</i> -value	L25 ( <i>n</i> = 67)	H75 ( <i>n</i> = 196)	<i>P</i> -value
Age (y), mean (SD)	80.2 (8.3)	73.5 (6.8)	<0.001	77.9 (8.0)	72.7 (6.0)	<0.001
Mini-Mental Status Examination, mean (SD)	24.4 (3.8)	26.3 (2.5)	<0.001	20.9 (4.4)	24.0 (3.8)	<0.001
Geriatric depression scale, mean (SD)	11.7 (7.8)	9.7 (6.7)	<0.001	14.2 (6.5)	11.4 (7.4)	<0.001
Comorbid conditions, <i>n</i> (%)						
Hypertension	31 (44.3)	92 (44.0)	0.969	32 (47.8)	92 (46.9)	0.934
Heart diseases	8 (11.4)	32 (15.3)	0.555	10 (14.9)	36 (18.4)	0.580
Stroke or parkinsonism	7 (10.0)	7 (3.3)	0.051	6 (9.0)	8 (4.1)	0.203
Diabetes	16 (22.9)	37 (17.7)	0.379	11 (16.4)	31 (15.8)	0.920
Cancer	8 (11.4)	18 (8.6)	0.481	4 (6.0)	19 (9.7)	0.457
Chronic lung disease	7 (10.0)	16 (7.7)	0.616	4 (6.0)	22 (11.2)	0.245
Arthritis	24 (34.3)	33 (15.8)	0.002	44 (65.7)	100 (51.0)	0.047
Fracture	5 (7.1)	27 (12.9)	0.278	9 (13.4)	40 (20.4)	0.275
Number of comorbid conditions, 0–8, mean (SD)	1.5 (1.1)	1.3 (1.0)	0.068	1.8 (1.0)	1.8 (1.2)	0.924
Body mass index (kg/m <sup>2</sup> ), mean (SD)	22.7 (3.6)	24.5 (2.9)	<0.001	23.8 (2.8)	24.9 (3.2)	0.009
ASM/Wt (%), mean (SD)	30.5 (3.6)	30.9 (2.9)	0.370	25.0 (2.7)	24.4 (2.5)	0.084
ASM/Ht <sup>2</sup> (kg/m <sup>2</sup> ), mean (SD)	6.9 (0.8)	7.5 (0.8)	<0.001	5.9 (0.6)	6.0 (0.6)	0.134

L25, lower-quartile group based on the peak torque; H75, upper-three-quartiles group based on the peak torque; ASM/Wt, appendicular skeletal mass divided by weight; ASM/Ht<sup>2</sup>, appendicular skeletal mass divided by height squared.

**Table 2.** Correlation coefficients of muscle mass parameters and peak torque to the Short Physical Performance Battery score (SPPB) score and the odds ratios for low to higher physical performance by each muscle mass parameter and peak torque in men and women in the groups based on the 25th percentile value of peak torque

Models and variables	Men			Women		
	Total ( <i>n</i> = 279)	L25 ( <i>n</i> = 70)	H75 ( <i>n</i> = 209)	Total ( <i>n</i> = 263)	L25 ( <i>n</i> = 67)	H75 ( <i>n</i> = 196)
Correlation coefficient <sup>a</sup>						
ASM/Wt (%)	0.196*	0.189	0.204*	0.142*	−0.085	0.255*
ASM/Ht <sup>2</sup> (kg/m <sup>2</sup> )	0.327*	0.125	0.229*	0.080	−0.048	0.070
Peak torque	0.481*	0.477*	0.316*	0.552*	0.555*	0.439*
Odds ratio (95% CI) <sup>b</sup>						
ASM/Wt (%)	0.86* (0.78–0.95)	0.89 (0.77–1.03)	0.84* (0.73–0.97)	0.86* (0.77–0.96)	0.89 (0.71–1.11)	0.87* (0.69–0.94)
ASM/Ht <sup>2</sup> (kg/m <sup>2</sup> )	0.48* (0.32–0.71)	0.78 (0.42–1.46)	0.41* (0.23–0.73)	0.90 (0.57–1.41)	1.11 (0.44–2.76)	0.97 (0.56–1.70)
Peak torque	0.97* (0.95–0.98)	0.91* (0.86–0.97)	0.98 (0.96–1.00)	0.94* (0.92–0.96)	0.83 (0.73–0.95)	0.94* (0.91–0.98)

ASM/Wt, appendicular skeletal mass divided by weight; ASM/Ht<sup>2</sup>, appendicular skeletal mass divided by height squared; L25, lower-quartile group according to the peak torque; H75, upper-three-quartiles group according to the peak torque; CI, confidence interval.

The number of individuals with low-physical-performance was 32 (45.7%) and 41 (14.4%) in the L25 and H75 group of men, and 29 (64.2%) and 54 (27.0%) in the L25 and H75 group of women, respectively.

<sup>a</sup>Spearman's correlation coefficients to the SPPB score (we used Spearman's correlation coefficient because the SPPB score was not normally distributed).

<sup>b</sup>Models present the mean effects of each muscle mass parameter or peak torque to low physical performance (SPPB < 9) adjusted for age and number of comorbid conditions.

\**P* < 0.05.

## Discussion

In this study, we observed a consistent positive association between ASM/Wt and physical performance in older men in the H75 group; however, the association between ASM/Wt and physical performance was not clear in older men or women in the L25 group. These results support our hypothesis that muscle mass is related to physical performance in individuals who maintain muscle strength, but its relationship becomes negligible in people with weak muscle strength.

In contrast to ASM/Wt, ASM/Ht<sup>2</sup> had no significant association with physical performance in women ASM/Wt

is a measure of relative muscle mass and reflects fat mass through weight. It has been found to be a better predictor of physical performance in women [15] and to detect sarcopenic obesity, which is associated with a high risk of metabolic syndrome, better than ASM/Ht<sup>2</sup> [16]. Obesity is an important factor in physical performance, particularly in women [18]. Considering this superiority of ASM/Wt, our hypothesis was supported by the results for ASM/Wt.

Why did muscle mass have no association with physical performance in the weak older adults, whereas strength showed a significant association? In this study, there was no difference in ASM/Wt between the L25 and H75 groups. We suggest that muscle mass was maintained relative to low

muscle strength in the L25 group, resulting in decreased muscle quality (i.e. strength per unit of muscle mass). Longitudinal studies have shown that the decrease in strength was two to five times greater than the loss of the muscle size with ageing, reflecting declining muscle quality with ageing [10]. Muscle quality was reportedly a good predictor of physical performance in older adults [19, 20]. Increased intermuscular or intramuscular fat infiltration was associated with lower muscle strength after adjusting for the muscle cross-sectional area [21, 22] and with poorer physical performance [23, 24]. This indicates that the poor muscle quality is related to increased fat infiltration. Various factors related to muscle quality have been reported, but the exact mechanisms for poor associations between mass and performance in the weak group must be further investigated.

Recently, the European consensus on the definition and diagnosis of sarcopenia recommended documentation of low muscle mass plus low muscle strength or low physical performance based on recent findings that the muscle strength provides information that the muscle mass cannot [25]. Our results support this recommendation and suggest that a greater emphasis be placed on the role of muscle strength in weak or frail groups.

Despite the novel findings for the relationship between muscle mass and physical performance, the poor mass–performance relationship in the L25 group needs to be interpreted more cautiously considering the potential pitfalls revealed by the subgroup analysis, perhaps due to the relative small sample size of the L25 group. However, higher correlations between muscle strength and physical performance and a similar distribution of mass parameters in the L25 and H75 groups support our findings. Significant interaction of muscle strength on with mass–function relationship in men and not in women can be explained by relatively low levels or more homogeneous distributions of muscle strength in women compared with men.

In conclusion, muscle mass was not related to physical performance in older adults with weak muscle strength. In clinical practice, the evaluation and therapeutic approach for weak, frail older adults should focus on muscle strength rather than muscle mass.

## Key points

- Muscle mass did not show a significant association with physical performance in weak older adults.
- Whereas a significant and high association between muscle strength and physical performance was found in weak older adults.
- The clinical approach for weak or frail older adults should focus on muscle strength rather than muscle mass.

## Conflicts of interest

None declared.

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## Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

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## Values for timed limb coordination tests in a sample of healthy older adults

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### Abstract

**Background:** timed limb coordination tests are reliable measures of motor performance but many lack published reference values.

**Objective:** to determine mean values for timed tests in an older cohort, examining associations with anthropometric characteristics, handedness, gender and age.

**Design:** cross-sectional.

**Setting:** community.

**Subjects:** sixty-nine healthy adults divided into three groups: 60–69, 70–79 and 80+ years.