ORIGINAL ARTICLE

# Muscle strength to body weight ratio is a better predictor of low physical function than absolute muscle strength in postmenopausal women

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## ABSTRACT

**Objective:** We investigated the predictive contributions and diagnostic accuracy of muscle strength (MS) and muscle strength to body weight ratio (MS/BW) on physical function in postmenopausal women (PW). **Methods:** This cross-sectional study evaluated forty-nine sedentary PW (61.7 ± 7.9 years). Body weight and height were measured with a digital scale and a stadiometer respectively. Muscle strength was determined by manual dynamometer and the left and right hand values were summed. Physical function was assessed by the six-minute walk test, short physical performance battery (SPPB) and Quality of Life Questionnaire (SF-36). A composite measure of physical function was calculated by summing the Z scores (x-μ/σ) of each individual assessment to provide a global index of physical function. **Results:** Muscle strength-specific linear regression analyses indicated that the strongest predictor of physical function was MS/BW [Beta of Z score = 0.91±0.07 (SE)] when compared to MS [Beta of Z score = 0.59±0.13 (SE)]. The ROC curve values indicated that the more accurate measure of physical function (P = 0.026) was MS/BW [AUC = 0.91±0.04 (SE)] when compared to MS [AUC = 0.75±0.08 (SE)]. **Conclusion:** The findings of this study suggest that MS/BW is more accurate and predictive measure of low physical function than absolute MS in PW.

**Keywords:** Aging, Obesity, Muscle Strength, Mobility Limitation

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## INTRODUCTION

Low physical function, defined by the Centers for Disease Control and Prevention as difficulty in performing physical tasks[1], contributes to disability, fall, fracture, low quality of life, and mortality in older adults.[1-4] Importantly, the likelihood of low physical function is greater in women than in men.[5-7] Thus, identifying the most salient contributors to physical function is critical for advancing our understanding of aging and risk for low physical function in older women. Moreover, this understanding contributes to the development of optimal prevention and treatment strategies.

Among a number of potential contributors to low physical function, age-related muscle strength loss[1-4,8] and excess of body weight (as result of high adiposity)[6,7,9-13] are particularly important in older adults. These evidences led to the hypothesis of the interaction between low muscle strength and excess of body weight on low physical function, especially in older women.[6,7,9-13] This interaction may be due, at least partially, to the capacity of body musculature to transfer load (e.g. body weight) that is affected by low muscle strength[14] and by excess of body weight.[11,15] Moreover, the menopause causes an increase of body weight (adiposity excess), and a reduction in muscle mass and strength of women.[16-19] Therefore, it seems reasonable to assume that the muscle strength to body weight ratio (MS/BW) is a more suitable predictor of low physical function than the absolute muscle strength (MS) of postmenopausal women (PW). However, predictive contributions and diagnostic accuracy of MS/BW on low physical function have not yet been explored.

Performance-based assessments are widely used to screen for low physical function.[20] Particularly, the six-minute walk test (6MWT), the short physical performance battery (SPPB) and the physical function questionnaire have been used as performance-based assessments for physical function.[20-23] Each of these tests are addressed to evaluate different aspects of physical function (6MWT, SPPB, and questionnaire as indicators of aerobic capacity, mobility and self-reported physical function, respectively); therefore, the combination of their scores have been used as an indicator of overall physical function.[11,20]

Our hypothesis was that MS/BW is a better predictor of low physical function than MS alone in PW.

## OBJECTIVE

The objective of this study was to investigate whether the MS/BW ratio is a better and more accurate predictive of overall physical function than MS alone in PW.

## METHODS

### Study design and participants

This clinical, descriptive, and cross-sectional study included 49 sedentary PW of a public Health and Physical Activity Center between February and November of 2015. All volunteers were sedentary postmenopausal women aged 45 years or older who had good overall health and spontaneous amenorrhea at least 12 months prior to the inclusion. The inclusion criteria consisted of absence of thyroid dysfunctions, myopathies, arthropathies, neuropathies and diabetes; absence of muscle, thromboembolic and gastrointestinal disorders; absence of cardiovascular and infectious diseases and ability to perform the physical function tests (Figure 1).

The volunteers were considered sedentary when they reported no leisure physical activities (e.g. supervised or unsupervised aerobic training or other type of training) besides their everyday household tasks. Participants were recruited via advertisements in newsletters, guest lectures, and flyers sent to local elderly associations. All selected women agreed with the procedures of the study and signed the free and informed consent form which had been approved by the local Research Ethics Committee (n. 1685).

The initial evaluation consisted of anamnesis. The data collected included information on age, leisure physical activities, time since menopause, diseases, cigarettes, alcohol, hormone therapy and self-reported physical function. After the initial evaluation, anthropometric and physical evaluations were provided to all participants.

### Assessments

Anthropometric measurements

Body weight and height were measured with a digital scale (Lider®, Brazil) and a stadiometer, as participants wore lightweight clothing and no shoes. Body mass index (BMI) was classified according to the World Health Organization.[24]

### Hand Grip Strength

To detect muscle strength (MS) in the right and left hands, a hand grip strength test was done with a manual dynamometer (Jamar®, Brazil). Three measures were taken and their mean was considered the valid measure. Hand grip strength values under or equal 20kg was classified as low muscle strength.[25] Left and right hand grip strength were added ($GS_{total}$) to compose MS/BW. Din. Sum = $GS_{total}$

Muscle strength to body weight ratio (MS/BW)

Muscle strength to body weight ratio was calculated by dividing the $GS_{total}$ by body weight.

### Six-minute walk test (6MWT)

The 6MWT[21] was performed indoor, along a long flat floor around a sports court. The walking course was 114m in length with marks every 3m. A starting line, which marks the beginning and end of each 114m lap, was marked on the floor by colored tape. All volunteers were advised to walk as fast as possible in the six minutes of the test. The total distance was recorded after the volunteer completed the test. The 6MWT was assisted by a trained professional. 6MWT values under or equal 500m were considered as low aerobic capacity.[21]

Short physical performance battery (SPPB)

The SPPB test consisted of three tests performed in the following order: balance test, four-meter walk test and five-time-sit-to-stand test. Each test score varied from zero to four points, and the total SPPB score varied from zero to 12 points (sum of the partial scores of the three tests).[22] The balance test consisted of three positions: Side-by-Side Stand, Semi-Tandem Stand and Tandem Stand. The scores were based on the time the volunteer stood still (10 seconds) in each position. The four-meter walk test was evaluated by the time the volunteers took to walk four meters, in which speed was not previously suggested but decided by the volunteer. Two measures were taken and the shortest time was considered as the valid measure. The five-time-sit-to-stand test was evaluated by the time the volunteer spent to perform five sit-to-stand movements with the arms crossed across the chest. The volunteer started in the sit position and was instructed to, as quickly as possible, perform the movements, which consisted of a full sit and stand. SPPB values under or equal 7 was considered as low mobility.[3]

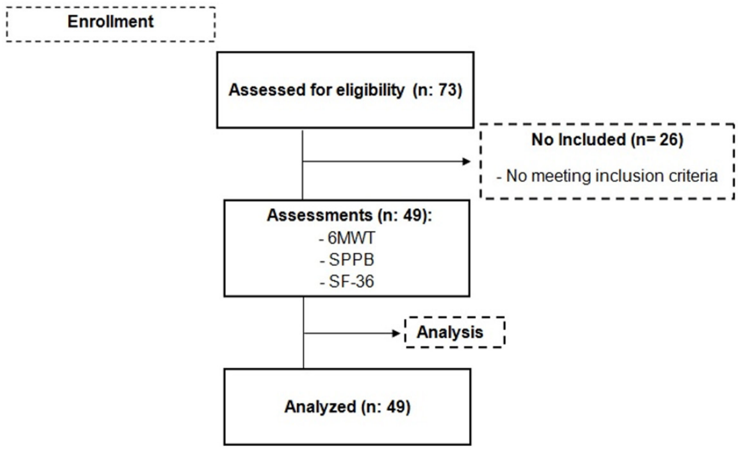


**Figure 1.** Screening, inclusion, and analysis diagram

### Quality of Life Questionnaire - SF36

The SF-36 is a multidimensional questionnaire with 36 items along eight components: functional capacity, physical aspects, pain, general health, vitality, social functioning, emotional aspects and mental health. For each component, there is a final score of zero to 100, where zero is the worst and 100 the best general health status. The sum of all components ranges from zero to 800.[23] We applied as a measure of functional capacity only the functional capacity component (FC) of the quality of life questionnaire.

### Statistical Analysis

Data was examined for normality by the Shapiro Wilk test. The continuous variables were presented as means and standard deviation, whereas the categorical variables were presented as percentage. A composite measure of physical function was calculated by adding the Z scores (x-μ/σ, where "μ" is the individual value of the variable, "x" is the mean value of the group and "σ" is the standard) of each individual assessment (6MWT, SPPB, and FC-SF36) to provide a global index of physical function.[11]

To further investigate the impact of predictor variables on physical function, we conducted linear regression analyses adjusted for hormone therapy, smoker and time after menopause to determine the relative contributions of MS and MS/BW measures over physical function. Receiver operating characteristic (ROC) curves and area under the curve (AUC) analysis were used to assess the accuracy of MS and MS/BW measures for predicting low physical function. As FC-SF36 and Z scores do not have reference values (cutoff) in literature, we used the low quartile results as an indication of low physical function. Sensitivity (expressed in percentage) was defined as the proportion of subjects with low physical function and positive results (low MS or MS/BW) out of the total subjects with the low physical function. Specificity (expressed in percentage) was defined as a proportion of subjects without low physical function and negative results (low MS or MS/BW) out of the total subjects without low physical function. The method of De Long et al.[26] was used to compare the ROC curves of sum of the Z scores. The ROC curves discrimination was classified as follows: 0.7 ≤ ROC < 0.8 = fair discrimination, 0.8 ≤ ROC < 0.9 = good discrimination and ROC ≥ 0.9 = excellent discrimination.[27] The significance level was set at $p < 0.05$.

## RESULTS

The age values were within the normal range for PW. In average, the women showed overweight (however, 11 women presented normal BMI), normal hand grip strength (however, 16 women presented low hand grip strength), and normal physical function (however, 10 women presented low 6MWT and one women presented low SPPB) as shown in Table 1.

Muscle strength specific linear regression analyses were performed to examine the relative importance of MS and MS/BW for physical function in PW. All physical function tests (6MWT, SPPB, SF36 and Sum of Z scores) were significantly associated with MS/BW. Only 6MWT, SF36 and Sum of Z scores were significantly associated with MS. The Beta values indicated that the strongest predictor of physical function was MS/BW (Table 2).

Measures of diagnostic accuracy (Sensitivity, Specificity, ROC curves) of the MS/BW and MS for low physical function along different tests are shown in Table 3. The ROC analysis indicated that the MS is an accurate measure to discriminate between low and high performance in 6MWT, SF-36, and Sum of Z score (the cutoff values are the MS values to discriminate low performance). However, the AUC values of MS were borderline or below the acceptable discrimination (AUC < 0.70). The ROC analysis also indicated that the MS/BW is an accurate measurement to discriminate between low and high performances in all physical function tests. The all AUC values of MS/BW were classified as good or excellent discrimination, differently from AUC values of MS.

Higher AUC values of MS/BW was observed in the Z score (Figure 2) when the AUC values were compared between the different muscle strength measures (Difference between AUC = 0.162, 95% Confidence interval = 0.0190 to 0.305, z statistic = 2.220 and p = 0.026).

## DISCUSSION

The most important findings from this study were that MS/BW (muscle strength to body weight ratio) is a better predictor and more accurate measure of low overall physical function than absolute muscle strength alone in postmenopausal women. To the best of our knowledge, no other study has compared the accuracy and predictive ability of different measures of muscle strength on overall physical function in PW.

It represents an important area of research owing to the implications of reduced muscle strength on the risk of low physical function, disability, fall, fracture, low quality of life, and mortality in older adults,[1-4] mainly in PW and older women.[5-7,9-13] Menopause is followed by changes in body composition, i.e. an increase in body fat concomitantly with a reduction in muscle mass and strength.[16-19] Therefore, excess of body weight and low muscle mass/strength may not coexist in same women simply by chance.

This may explain the greater likelihood of functional limitation in older women when compared to male population.[5,6,11,13] Therefore, PW should be carefully screened for interaction between muscle strength and body weight. With adequate screening for low

**Table 1.** Postmenopausal women characteristics

| Women characteristics | (n=49) |
|---|---|
| Age (yr) | 61.7±7.9 |
| Postmenopausal time (yr) | 15.4±14.0 |
| Smoker | 16.3% |
| Hormone therapy | 10.2% |
| Body Weight (kg) | 69.1±15.0 |
| Height (m) | 1.5±0.2 |
| BMI (Kg/m²) | 29.2±6.0 |
| GS. Right (kg) | 23.8±5.9 |
| GS. Left (kg) | 22.7±5.9 |
| GStotal (kg) | 46.6±11.3 |
| SM/BW (kg/kg) | 0.7±0.2 |
| 6MWT (m) | 581.1±81.6 |
| SPPB (score) | 11.1±1.3 |
| SF-36 (score) | 75.3±24.4 |
| Sum of Z scores | 0.0±3.00 |

yr: year; kg: kilogram; m: meters; m2: square meters; BMI: Body mass index; GS: grip strength by dynamometry; GStotal: sum of grip strength; 6MWT: Six minutes-walk test; SPPB: short physical performance battery; SF-36:Quality of Life Questionnaire. The continuous variables were presented as means and standard deviation. The categorical variables were presented as percentages.

**Table 2.** Strength specific linear regression analyses of physical function predictors

| | MS/BW (kg/kg) | | | MS (kg) | | |
|---|---|---|---|---|---|---|
| | Beta | SE | P | Beta | SE | P |
| 6MWT(m) | 0.65 | 0.10 | 0.000 | 0.36 | 0.14 | 0.015 |
| SPPB (scores) | 0.43 | 0.16 | 0.006 | 0.29 | 0.16 | 0.085 |
| SF-36 (scores) | 0.62 | 0.13 | 0.000 | 0.35 | 0.16 | 0.035 |
| Sum of Z scores | 0.91 | 0.07 | 0.000 | 0.59 | 0.13 | 0.000 |

m: meters; 6MWT: Six minutes-walk test; SPPB: short physical performance battery; SF-36: Quality of Life Questionnaire; MS: muscle strength; MS/BW: muscle strength to body weight ratio. All very adjusted for hormone therapy, smoker and time at menopause; SE-standard error.

**Table 3.** Roc-curve, cutoff, sensitivity and specificity values of HGS/BW and hand grip strength

| | MS/BW (kg/kg) | | | | | | MS (kg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AUC | SE | P | Cutoff | Sensitivity | Specificity | AUC | SE | P | Cutoff | Sensitivity | Specificity |
| 6MWT (m) | 0.901 | 0.043 | <0.001 | ≤0.57 | 100% | 84% | 0.673 | 0.083 | 0.037 | ≤51.3 | 100% | 30% |
| SPPB (scores) | 0.701 | 0.09 | 0.020 | ≤0.48 | 40% | 100% | 0.636 | 0.096 | 0.154 | ≤38.7 | 40% | 92% |
| SF-36 (scores) | 0.834 | 0.071 | <0.001 | ≤0.62 | 92% | 68% | 0.742 | 0.079 | 0.002 | ≤41.3 | 69% | 74% |
| Sum of Z scores | 0.909 | 0.041 | <0.001 | ≤0.62 | 100% | 71% | 0.747 | 0.076 | 0.001 | ≤41.3 | 69% | 74% |

m: meters; 6MWT: Six minutes-walk test; SPPB: short physical performance battery; SF-36: Quality of Life Questionnaire; MS: muscle strength; MS/BW: muscle strength to body weight ratio. Adjusted for hormone therapy, smoker and time at menopause; AUC-Area under the Curve; SE-standard error.

muscle strength (i.e. low muscle strength relative to body weight), those with low physical function and their adverse outcomes may be identified and prevented at an earlier stage. In our study, we found that the MS/BW was a stronger predictor of overall physical function explaining 91% of the Z scores variance, whereas the MS explicated only 59%.

Additionally, the probability that figures below the MS/BW cutoff [hand grip strength values (sum of two hands) ≤ 62% of body weight] is a positive result for low overall physical function was 100%, whereas concerning the MS cutoff (≤41.3 kg) the probability was as low as 69%.Hence, the muscle strength measure which takes into account the body weight (i.e. MS/BW) is more appropriated for predict overall function capacity than MS in PW.

Our findings suggest an interaction between low muscle strength and excess of body weight on low physical function in PW. This interaction has also been evidenced in other studies,[11,15,28,29] even though they have not evaluated the accuracy and predictive ability of different measures of muscle strength on overall physical function in PW. Stenholm et al.[28] have shown greater decline in gait speed (over a 6-year period) in elderlies with obesity and low muscle strength (17% decline) when compared to other older adults with only obesity (8% decline) or only low muscle strength (4% decline). The same authors have previously shown greater prevalence of walking limitations in older adults with excess of body weight and low muscle strength (61%) when compared to those adults with without excess of body weight and high muscle strength (7%).[29] Therefore, it seems that excess of body weight (i.e. obesity) and presence of low muscle strength synergistically contribute to low physical function in PW.

Low physical function contributes to disability, fall, fracture, low quality of life, and mortality in older adults.[1-4] Six minutes-walk test, SPPB and SF-36 have been used as performance-based assessments for physical function.[20-23] Specifically, these tests assess different dimensions of lower-extremity physical function. Even the SF-36 questions (functional capacity component) are mainly based on the lower-extremity physical function. In this sense, the combination of the test scores was used as an indicator of overall lower-extremity physical function. In present study, we explored the ratio of muscle strength to body weight (MS/BW), as this represents the capacity of the body musculature to transfer load (e.g. body mass). We found that MS/BW is a better predictor and more accurate measure of six minutes-walk test (6MWT), short physical performance battery (SPPB), physical function questionnaire and Z-score than absolute MS in PW. These findings suggest that muscle strength relative to body mass is critical to maintaining overall lower-extremity physical function and consequently to maintaining low risk for disability, fall, fracture, low quality of life, and mortality in older adults of PW.

Despite our findings showed that the MS/BW presented good clinical validity, limitations should be noted. This study was restricted to a cross-sectional approach and small sample size with no physically active PW (control group); therefore, the accuracy and predictive ability of the MS/BW may not be generalizable to different settings. In this context, future studies should consider these associations prospectively, and a larger sample should be included. However, accuracy and predictive ability can be well estimated from comparative studies. None of the other studies has

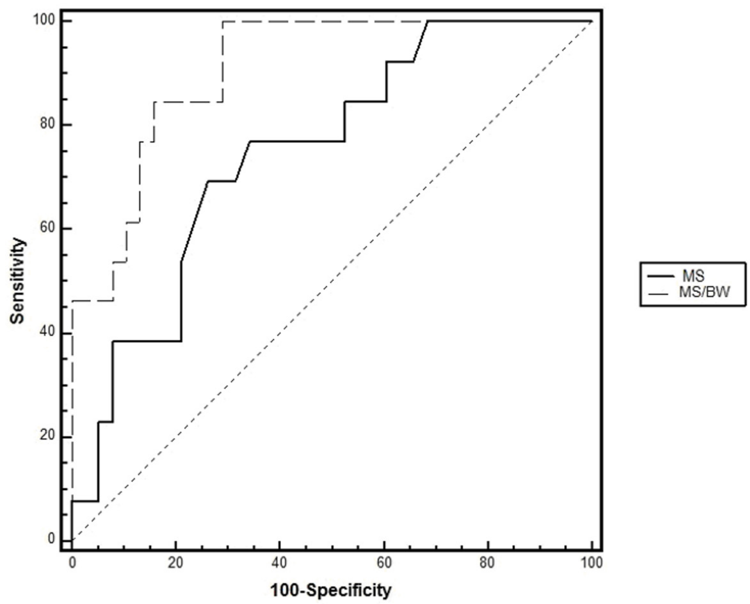


**Figure 2.** Comparison between the AUC and the sum of Z scores

been designed to determine accuracy and predictive ability of different muscle strength measures in identifying low physical function in PW, what makes our study relevant, particularly in routine clinical care.

## CONCLUSION

Muscle strength to body weight ratio is more appropriate to predict overall physical function than absolute muscle strength in postmenopausal women. Our results suggest that interventions aimed at improving the muscle strength and reducing excess of fat weight may reduce the risk of function limitation and disability. However, interventional studies are needed to show whether the positive change in muscle strength to body weight ratio leads to improvement of physical function capacity.

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