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# Asociación entre la relación masa grasa/masa libre de grasa y la fuerza muscular, el equilibrio estático y la capacidad de ejercicio en adultos mayores: un estudio transversal

# Association between the fat mass/fat-free mass ratio and muscle strength, static balance and exercise capacity in older adults: a cross-sectional study

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*Asociación entre la relación masa grasa/masa libre de grasa y la fuerza muscular, el equilibrio estático y la capacidad de ejercicio en adultos mayores: un estudio transversal*

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**ABSTRACT**

**Background:** the FM/FFM ratio has been proposed as a new body composition variable. However, the association between FM/FFM ratio and physical function in older adults remains limited. Therefore, the aim of this study was to analyze the association between FM/FFM ratio and muscle strength, static balance, and exercise capacity in older adults.

**Methods:** this was a cross-sectional study involving 392 older adults from Londrina, Brazil. Subjects underwent body composition analysis by bioelectrical impedance, and assessments for aerobic capacity, muscle strength and static balance including the 6-minutes walking test, handgrip strength and one-legged stance test. Statistical analysis was conducted using correlation tests and lineal regression models adjusted for age and gender. The statistical significance considered was $p < 0.05$.

**Results:** a total of 392 older adults participated (mean age = 69.77 years; women: 74.7 %). The FM/FFM ratio was significantly associated with muscle strength (β = -22.779, 95 % CI: -26.741 to -18.818; $p < 0.001$), static balance (β = -14.335, 95 % CI: -19.980 to -8.690; $p < 0.001$), and exercise capacity (β =-98.937, 95 % CI: -152.286 to -45.588, $p < 0.001$). After adjusting for age and gender, FM/FFM ratio was an important predictor of muscle strength (β = -4.687, 95 % CI: -8.646 to -0.728; $p = 0.020$) and static balance (β = -18.361, 95 % CI: -24.943 to -11.778; $p < 0.001$).

**Conclusions:** the FM/FFM ratio is an important clinical measure of body composition that is significantly associated with key indicators of physical performance, including muscle strength, static balance, and exercise capacity in older adults.

**Keywords:** Body composition. Muscle strength. Electric impedance. Ageing.

**RESUMEN**

**Antecedentes**: la relación entre masa grasa (MG) y masa libre de grasa (MLG) (MG/MLG) se ha propuesto como nueva variable de la composición corporal. Sin embargo, la asociación entre MG/MLG y otras variables clínicas como la función física en los adultos mayores sigue siendo limitada. Por lo tanto, el objetivo de este estudio fue analizar la asociación entre el MG/MLG y la fuerza muscular, el equilibrio estático y la capacidad de ejercicio en adultos mayores.

**Métodos:** este fue un estudio transversal que incluyó a 392 adultos mayores de Londrina, Brasil. Se evaluaron la composición corporal mediante la impedancia bioeléctrica y la capacidad aeróbica, la fuerza muscular y el equilibrio estático mediante la prueba de la marcha de 6 minutos, la fuerza de prensión de la mano y la prueba del equilibrio en un solo pie. Se realizó un análisis estadístico utilizando pruebas de correlación y modelos de regresión lineal ajustados por edad y sexo. Se consideró un nivel de significancia estadística de $p < 0,05$.

**Resultados:** participaron un total de 392 adultos mayores (edad media = 69,77 años; mujeres: 74,7%). El MG/MLG se asoció significativamente con la fuerza muscular (β = -22,779, IC 95 %: -26,741 a -18,818; $p < 0,001$), el equilibrio estático (β = -14,335, IC 95 %: -19,980 a -8,690; $p < 0,001$) y la capacidad de ejercicio (β = -98,937, IC 95 %: -152,286 a -45,588, $p < 0,001$). Tras ajustar la edad y el sexo, MG/MLG se mantuvo como predictor importante de la fuerza muscular (β = -4,687, IC 95 %: -8,646 a -0,728; $p = 0,020$) y de equilibrio estático (β = -18,361, IC 95 %: -24,943 a -11,778; $p < 0,001$).

**Conclusiones:** MG/MLG es una medida clínica relevante de evaluación de la composición corporal que está asociada con indicadores clave del rendimiento físico, incluyendo fuerza muscular, equilibrio estático y capacidad de ejercicio en adultos mayores.

**Palabras clave:** Composición corporal. Fuerza muscular. Impedancia eléctrica. Envejecimiento.

## INTRODUCTION

As time goes on, the older adult population experiences significant growth worldwide (1). This not only involves an interest in improving life expectancy, but also in addressing and reducing the disabilities that often accompany aging process (2). Longevity comes with a series of complex changes in the body composition, physical (3) and cognitive function (4,5). These changes can contribute to an increased risk of chronic diseases and geriatric syndromes such as sarcopenia or frailty affecting the quality of life and health (4,6).

Changes in body composition, particularly shifts in fat mass (FM) and fat-free mass (FFM), are critical indicators of metabolic health, physical function and overall well-being (6). In addition, FM and FFM are predictors of hospitalization and mortality in older adults (7). Accurate measurement of body composition parameters is essential, especially in populations vulnerable to muscle loss or increased fat mass, such as older adults with chronic diseases or geriatric syndromes (8,9). The relationship between FM and FFM, expressed as FM/FFM ratio has been proposed as new variable of body composition, which currently represents a crucial measurement unit for understanding overall health (6,10). Additionally, this relationship describes two aspects: metabolic load, which refers to the fat accumulated in the body, and metabolic capacity, which encompasses the body's ability to use energy and maintain proper physiological functions (11). In the elderly population, these values reflect a significant increase in FM, accompanied by a decrease in FFM, which have related to the presence of sarcopenic obesity (12). Scientific evidence suggests that FM/FFM ratio is associated with metabolic and fatty liver clinical variables (12). Among the few studies conducted, the FM/FFM ratio has been related to conditions such as sarcopenia, chronic obstructive pulmonary disease (COPD), osteoporosis, and sarcopenic obesity (13). These comorbidities are often accompanied by reductions in grip strength, higher fracture incidence, increased fall risk, and decreased exercise capacity (6,14). However, studies specifically examining the association between FM/FFM ratio and physical function in older adults remain limited (6). Despite existing evidence, further research is needed to clarify the clinical significance of FM/FFM ratio in relation to other functional and clinical variables in older adults, helping to establish its relevance for routine clinical assessments. Therefore, the aim of this study was to analyze the association between FM/FFM ratio and muscle strength, static balance, and exercise capacity in older adults.

## METHODS

### Population study

The present study is a cross-sectional analysis from the study on aging and longevity (ELLO data from 2009 to 2018) from the community of Londrina, Paraná, Brazil (15). The total sample of the EELO Project was 508 subjects, which is representative of the 43,610 citizens over 60 years of age who live in Londrina city. The inclusion and exclusion criteria and characteristics of the population were published previously. It is mentioned that adults aged 60 or older, who present a level 3 or 4 of physical independence (according to the Functional Status Scale), have a normal mental state (scoring more than 17 points on the Mini-Mental State Examination), and reside in an urban community of the city of Londrina, were included. Additionally, adults who exhibited severe dysfunction in the respiratory, neurological, or musculoskeletal systems, including amputations or the use of prosthetics were excluded (15). From the EELO program database, we included older adults of both sexes who have measured the body composition. The research was approved by the Research Ethics Committee of Universidade Norte do Paraná (UNOPAR) for both study designs (PP/0070/09 and PP 1,168,693). The collections and tests were performed at the UNOPAR. All participants signed an informed consent form.

**Body composition**

FM and FFM were measured using bioelectrical impedance of multi-frequency (Bio-dynamics 310TM; Biodynamics Corp., USA), after 10-hour of fasting. The assessment was performed on the dominant side of the individual with the patient in a supine position, the arms and legs were separated by approximately 30 degrees from a midline. The electrode placement sites were cleaned with alcohol. One electrode was placed in the hand and the other in the foot. FM/FFM ratio was estimated considering a previous study (16).



**Muscle strength**

Muscle strength was assessed via Hand Grip Strength (HGS) (17,18) assessed in a seated position with a Jamar hydraulic dynamometer (Sammons Preston Inc, Saint Paul, MN). The forearm and wrist were supported on the chair's armrests. Participants completed three trials with each hand, alternating between hands, with a 30-second rest between attempts. The highest value obtained was recorded for analysis.

**Static balance**

Static balance was assessed by the One-Legged Support Test (OLST) (19). Participants stood on one leg on a stable surface with their eyes open. The best result from three attempts using the dominant leg was recorded for analysis and the maximum time of 30 seconds was considered for the test (20)

**Exercise capacity**

Exercise capacity was assessed by the 6-Minute Walk Test (6MWT) (21,22). Participants walked along a 30-meter linear course, marked by two cones, for a duration of six minutes to cover the maximum possible distance. Standardized incentive phrases and information on the remaining time were provided throughout the test. Two assessments were conducted, with a 30-minute rest interval between them (23).

**Comorbidities**

Charlson's comorbidity index was assessed to quantify the overall burden of comorbidities, which is an index with 19 medical conditions along with the corresponding weights Comorbidities were weighted and scored using an algorithm proposed by Charlson et al. (24,25).

**Statistical analysis**

Descriptive statistics were calculated for all variables, and data normality was assessed using the Kolmogorov-Smirnov test and the graphical procedures (normal probability plot). Continuous variables (age, body mass index, FM, etc.) were presented as the mean and standard deviation (SD), and categorical variables (gender and prevalence of comorbidities) were presented as the number and percentage. Pearson’s correlation coefficients were used to evaluate the linear relationships between the FM/FFM ratio and the dependent variables: muscle strength, static balance, and exercise capacity. To explore the associations between FM/FFM ratio and muscle strength, static balance, and exercise capacity, linear regression models were constructed. First, a crude model (unadjusted) was fitted to assess the univariate associations between the FM/FFM ratio (independent variable) and each outcome variable (HGS, OLST, and 6MWT). Subsequently, multivariable linear regression models were performed, adjusting for potential confounders, including age and gender.

Regression coefficients (β) with corresponding 95 % confidence intervals (CIs) and *p*-values were reported to quantify the strength and significance of the associations. The statistical significance was considered as $p < 0.05$, and the analysis was performed using SPSS software (IBM Co., USA) and GraphPad Prism 6.0 (GraphPad Software, San Diego, CA, USA).

## RESULTS

A total of 392 older adults were included in the study. The clinical characteristics of the individuals included in this study are reported in table I. The mean age of the participants was 69.77 ± 6.348 years and 74.7 % were female. The prevalence of diabetes was 63.8 %, arterial hypertension 63.7 %, and dyslipidemia 33.7 %. The average for FM/FFM ratio was 0.551 ± 0.169.

### Correlation and regression analyses between FM/FFM ratio and muscle strength, static balance and exercise capacity

Pearson's correlation analysis revealed significant negative associations between the FM/FFM ratio and all three physical performance measures: muscle strength (HGS: $r = -0.498$; $p < 0.001$), static balance (OLST: $r = -0.244$; $p < 0.001$), and exercise capacity (6MWT: $r = -0.182$; $p < 0.001$). The correlation between the FM/FFM ratio and muscle strength, static balance and exercise capacity in older adults is presented in figure 1 (A, B and C, respectively).

In the non-adjusted linear regression analysis (Model 1), the FM/FFM ratio was significantly associated with muscle strength (HGS: β = -22.779, 95 % CI: -26.741 to -18.818, $p < 0.001$, $R^2 = 0.247$), static balance (OLST: β = -14.335, 95 % CI: -19.980 to -8.690, $p < 0.001$, $R^2 = 0.060$), and exercise capacity (6MWT: β = -98.937, 95 % CI: -152.286 to -45.588, $p < 0.001$, $R^2 = 0.033$). After adjusting for age and gender in Model 2, FM/FFM ratio continues to be an important predictor of muscle strength (HGS: β = -4.687, 95 % CI: -8.646 to -0.728, $p = 0.020$, $R^2 = 0.539$) and static balance (OLST: β = -18.361, 95 % CI: -24.943 to -11.778, $p < 0.001$, $R^2 = 0.218$). However, the association with exercise capacity was no longer significant (6MWT: β = -32.518, 95 % CI: -97.965 to 32.929, $p = 0.329$, $R^2 = 0.109$). The associations between the FM/FFM ratio and the dependent variables: muscle strength, static balance, and exercise capacity were presented in table II. In addition, a regression analysis was performed to examine the association between gender and HGS, OLST, 6MWT, and the FM/FFM ratio in older adults. Older women exhibited lower HGS (β = -11.4, 95 % CI: -12.6 to -10.3, $p < 0.001$), OLST (β = -1.6, 95 % CI: -3.6 to -0.5, $p < 0.001$), and 6MWT performance (β = -42.7, 95 % CI: -60.8 to -24.5, $p < 0.001$), as well as a higher FM/FFM ratio (β = 0.2, 95 % CI: 0.19 to 0.25, $p < 0.001$) compared to older men. Similar results were observed in the model adjusted for age (Supplementary Table I).

## DISCUSSION

The present study demonstrates a significant association between the FM/FFM ratio and muscle strength, static balance, and exercise capacity in older adults. These findings underscore the importance of assessing body composition and suggest that a higher FM/FFM ratio is strongly associated with reduced physical function in older adults.

The negative correlation between FM/FFM ratio with muscle strength and balance is particularly noteworthy, as both muscle variables are well-established predictor of frailty, disability, and overall quality of life in aging populations (26). We observed that higher FM/FFM ratio was strongly associated with lower muscle strength and poorer static balance, even after adjusting for age and gender. This suggests that the detrimental effects of a higher FM/FFM ratio on these physical performance measures are not merely a function of age or gender differences but may reflect underlying physiological mechanisms such as sarcopenic obesity (27). Although the FM/FFM ratio itself is not a diagnostic criterion for sarcopenic obesity, this index may serve as a proxy, as low fat-free mass commonly associated with sarcopenia can occur alongside either normal or elevated fat mass, indicative of sarcopenic obesity (28). Sarcopenic obesity, defined by the simultaneous presence of increased fat mass and decreased muscle mass, is widely implicated in reduced physical performance and heightened risk of falls and fractures in older adults (29). The observed association between a higher FM/FFM ratio and poorer static balance further supports the idea that elevated body fat, particularly when coupled with lower lean mass, may impair the neuromuscular control needed to maintain stability. This aligns with previous studies that emphasize the adverse impact of increased adiposity on physical function in aging populations (30).

The relationship between body composition and exercise capacity is more complex and influenced by additional factors, which were reported in this and in a current study (31). For this reason, the association between FM/FFM ratio and exercise capacity was no longer significant after adjusting for age and gender in this study. Previous research has also suggested that exercise capacity may be more sensitive to other markers of physical fitness, rather than body composition alone (32).

Our findings underscore the potential value of incorporating the FM/FFM ratio into clinical assessments as an integrated measure of body composition that can provide additional insights into the physical health of older adults. Future studies should explore the mechanisms underlying these associations and investigate the effects of targeted exercise and nutritional interventions on FM/FFM ratio and physical performance. Furthermore, reference values for FM/FFM ratio have been proposed for populations outside of Latin America (33) highlighting the need for studies to establish region-specific reference values and assess their association with clinical outcomes in diverse populations.

Finally, this study has several limitations that should be considered. First, its cross-sectional design limits the findings to an exploratory perspective, precluding conclusions about causality. Second, we did not include additional measurements of physical function, such as the sit-to-stand test or the timed up and go test, commonly used in clinical practice with older adults. However, the study also has notable strengths, including a large sample size and the use of standardized protocols for measurements which has been extensively investigated in older adult populations worldwide, recommended by international guidelines and validated in Brazilian population (17-19,21,22). Future research with a longitudinal design, incorporating other key functional variables and examining the predictive capacity of FM/FFM ratio to identify risks of falls, fractures, hospitalizations, or mortality in older adults, is warranted.

## CONCLUSION

In conclusion, FM/FFM ratio is a crucial clinical measure of body composition that is significantly associated with key indicators of physical performance, including muscle strength, static balance, and exercise capacity in older adults. A higher FM/FFM ratio is linked to decreased muscle strength and poorer static balance, even after adjusting for confounders, highlighting the importance of body composition in maintaining functional capacity during aging. These results emphasize the need to incorporate the FM/FFM ratio into daily clinical practice, which will allow for the implementation of personalized programs to reduce the risks of falls and loss of mobility, through exercises focused on increasing muscle mass and improving balance.

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Table I. Characteristics of the individuals

| **Variables** | **Total (*n* = 392)** |
|---|---|
| Age (years) | 69.77 ± 6.348 |
| Female, *n* (%) | 293 (74.745%) |
| *Comorbidities* | |
| Diabetes | 105 (26.786 %) |
| Arterial hypertension | 250 (63.776 %) |
| Dyslipidemia | 132 (33.673 %) |
| Charlson comorbidity index, score | 2.1 ± 1.7 |
| *Body composition* | |
| BMI (kg/m$^2$) | 27.789 ± 4.665 |
| FM (kg) | 24.158 ± 7.399 |
| FFM (kg) | 44.798 ± 8.757 |
| FM/FFM ratio | 0.551 ± 0.169 |
| *Muscle strength, static balance and exercise capacity* | |
| HGS (kg) | 26.143 ± 7.748 |
| OLST (sec) | 12.789 ± 9.899 |
| 6MWT (m) | 523.23 ± 91.330 |
| | |

Data are expressed as mean and standard deviation. BMI: body mass index; FM: fat mass; FFM: fat-free mass; HGS: hand grip strength; OLST: one-legged stance test; 6MWT: 6-minute walking test.

Table II. Association between FM/FFM ratio and muscle strength, static balance and exercise capacity in older adults

| Variable | Muscle strength (HGS) | | Static balance (OLST) | | Exercise capacity (6MWT) | |
|---|---|---|---|---|---|---|
| | **Coef. β (CI: 95 %)** | ***p*** | **Coef. β (CI: 95 %)** | ***p*** | **Coef. β (CI: 95 %)** | ***p*** |
| Model 1 | -22.779 (-26.741 to -18.818) | < 0.001* <br> $R^2$ = 0.247 | -14.335 (-19.980 to -8.690) | < 0.001* <br> $R^2$ = 0.060 | -98.937 (-152.286 to -45.588) | < 0.001* <br> $R^2$ = 0.033 |
| Model 2 | -4.687 (-8.646 to -0.728) | 0.020* <br> $R^2$ = 0.539 | -18.361 (-24.943 to -11.778) | < 0.001* <br> $R^2$ = 0.218 | -32.518 (-97.965 to 32.929) | 0.329 <br> $R^2$ = 0.109 |

FM: fat mass; FFM: fat-free mass; HGS: hand grip strength; OLST: one-legged stance test; 6MWT: 6-minute walking test. Model 1: unadjusted analysis; Model 2: adjusted model by age and gender. Statistical significance, *$p < 0.05$. Analysis with 392 individuals.

Supplementary Table I. Association between gender and HGS, OLST, 6MWT and FM/FFM ratio in older adults

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **FM/FFM ratio** | | **HGS** | | **OLST** | | **6MWT** | |
| | **Coef. β (CI: 95 %)** | ***p*** | **Coef. β (CI: 95 %)** | ***p*** | **Coef. β (CI: 95 %)** | ***p*** | **Coef. β (CI: 95 %)** | ***p*** |
| Male | **Ref.** | **-** | **Ref.** | | **Ref.** | | **Ref.** | |
| Female Model 1 | 0.22 (0.19 to 0.25) | < 0.001 | -11.4 (-12.6 to -10.3) | < 0.001 | -1.6 (-3.6 to -0.5) | < 0.001 | -42.7 (60.8 to 24.5) | < 0.001 |
| Female Model 2 | 0.22 (0.20 to 0.25) | < 0.001 | -11.9 (-13.1 to -10.9) | < 0.001 | -2.7 (-4.5 to -0.8) | 0.005 | -48.9 (66.7 to 31.2) | < 0.001 |

FM: fat mass; FFM: fat-free mass; HGS: hand grip strength; OLST: one-legged stance test; 6MWT: 6-minute walking test; Ref: reference. Model 1: unadjusted analysis; Model 2: adjusted model by age. Statistical significance, *$p < 0.05$. Analysis with 392 individuals.

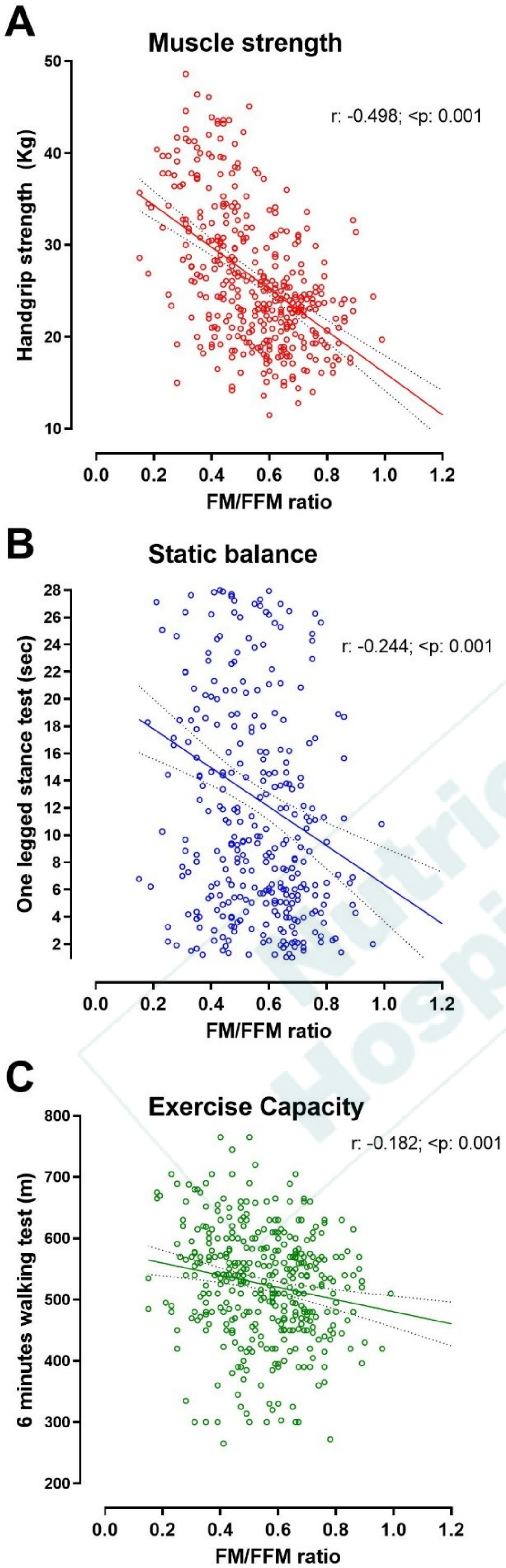


Figure 1. Correlation between FM/FFM ratio and muscle strength, static balance and exercise capacity in older adults.