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Muscle strength, adiposity, and health-related quality of life in older adults: a cross-sectional study

Fuerza muscular, adiposidad y calidad de vida relacionada con la salud en adultos mayores: estudio transversal

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Abstract

Muscle strength is a key factor influencing health-related quality of life (HRQoL) in older adults, yet its relationship with body fat remains understudied. This cross-sectional study examined associations between muscle strength, adiposity, and HRQoL in 253 community-dwelling participants aged 65 years or older from the GMOVE project. Assessments included sociodemographic characteristics, handgrip strength, body composition, and HRQoL measured with the SF-36v2 questionnaire. Linear regression models, adjusted for age, sex, and socioeconomic status, were used to explore the associations. Results showed that higher muscle strength was significantly associated with better HRQoL, independent of body fat levels. Participants with greater strength consistently reported higher HRQoL scores than those with lower strength, regardless of adiposity. These findings highlight the potential importance of maintaining or improving muscle strength to support well-being in older adults. The results suggest that interventions targeting muscle strength may mitigate some negative effects of excess adiposity on HRQoL. Future research should incorporate comprehensive body composition measures, larger samples, and longitudinal designs to clarify causal pathways and inform evidence-based strategies for healthy aging.

Keywords: muscle strength; body composition; older adults; health-related quality of life; cross-sectional study,

Resumen

La fuerza muscular es un factor clave que influye en la calidad de vida relacionada con la salud (CVRS) en adultos mayores, pero su relación con la adiposidad corporal aún está poco estudiada. Este estudio transversal examinó las asociaciones entre fuerza muscular, adiposidad y CVRS en 253 participantes de 65 años o más residentes en la comunidad, pertenecientes al proyecto GMOVE. Se evaluaron características sociodemográficas, fuerza muscular mediante prensión manual, composición corporal y CVRS mediante el cuestionario SF-36v2. Se aplicaron modelos de regresión lineal ajustados por edad, sexo y nivel socioeconómico para analizar las asociaciones. Los resultados mostraron que mayor fuerza muscular se asoció significativamente con mejor CVRS, independientemente del nivel de grasa corporal. Los participantes con mayor fuerza reportaron consistentemente mejores niveles de CVRS que aquellos con menor fuerza, sin depender de la adiposidad. Estos hallazgos destacan la importancia potencial de mantener o mejorar la fuerza muscular para apoyar el bienestar en adultos mayores. Los resultados sugieren que intervenciones dirigidas a la fuerza muscular podrían mitigar algunos efectos negativos de la adiposidad sobre la CVRS. Futuras investigaciones deberían incluir mediciones completas de composición corporal, muestras más amplias y diseños longitudinales para esclarecer relaciones causales e informar estrategias basadas en evidencia para un envejecimiento saludable.

Palabras clave: fuerza muscular; composición corporal; adultos mayores; calidad de vida relacionada con la salud; estudio transversal



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Introduction

In recent years, the obesity paradox has gained considerable attention in health research. This concept suggests that higher body fat may confer protective effects and lower mortality in older adults and individuals with chronic diseases (Bosello & Vanzo, 2021). Initially observed in patients with coronary artery disease following percutaneous coronary interventions (Gruberg et al., 2002), the paradox has also been reported in populations with chronic heart failure (Horwich et al., 2018), chronic obstructive pulmonary disease (Ravindran et al., 2022), and diabetes (Gravina et al., 2021). These observations led to the concept of “reverse epidemiology” (Kalantar-Zadeh et al., 2004). Despite these findings, the validity of the obesity paradox remains debated due to study heterogeneity, measurement biases, and the limitations of relying solely on body mass index (BMI) as a measure of adiposity (Neeland et al., 2018). BMI does not distinguish between fat and lean mass, potentially masking important associations with health outcomes (Donini et al., 2020; Wei et al., 2022). Accurate phenotyping, including assessments of body fat percentage, lean mass, metabolic variables, and functional capacity, is crucial to better understand the interplay between adiposity, aging, and health outcomes in older adults (Agostinis-Sobrinho et al., 2025; Alcazar et al., 2021).

Aging is accompanied by progressive physiological and functional changes, including declines in muscle strength, power, balance, and physical activity, which can reduce health-related quality of life (HRQoL) and increase susceptibility to disease (Harman, 1981; Bastos et al., 2021; Koen & Yonelinas, 2014; Haynes et al., 2020). Higher levels of muscle strength are consistently associated with lower morbidity and mortality, improved functional capacity, and better HRQoL in older adults (García-Hermoso et al., 2018; Yang et al., 2020; Chagas et al., 2021). These findings suggest that maintaining or enhancing muscle strength may mitigate some of the negative consequences of aging and excess adiposity. However, despite substantial evidence on the independent roles of muscle strength and adiposity, the combined influence of these factors on HRQoL in older populations remains poorly understood (Khodadad Kashi et al., 2023; da Costa Pereira et al., 2024). Older adults who engage in regular physical activity often report enhanced HRQoL across multiple domains (Gill et al., 2013), yet the interaction between muscle strength and body fatness may modulate these benefits.

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Emerging concepts, such as the “fat but fit” hypothesis, indicate that physical fitness may offset the adverse effects of excess adiposity, but their impact on HRQoL has rarely been evaluated (Herrera et al., 2021; Qin et al., 2023). Addressing this gap is essential to inform public health strategies and individualized interventions aimed at promoting functional independence, well-being, and quality of life in aging populations.

Accordingly, the present study aimed to (i) evaluate the association between muscle strength and HRQoL, and (ii) investigate the joint influence of muscle strength and body fatness on HRQoL in older adults. By examining these associations, this study provides insights into key factors affecting quality of life and informs strategies to optimize health and well-being in later life.

Methods

Study design and sample

This cross-sectional study forms part of a larger epidemiological research initiative, known as the GMOVE project. The overarching aim of this project is to evaluate various aspects of health among community-dwelling older adults, including physical activity levels, health-related quality of life, physical fitness, clinical health status, and barriers to physical activity. Potential participants were recruited through a dissemination made at public health centers in collaboration with doctors and health professionals, as well as through poster announcements in public and commercial spaces, churches, and social networks in the district of Guarda (Portugal). Data collection was performed by a trained research team, tutored by the principal researcher of the project.

The GMOVE study adheres to the ethical principles outlined in the Helsinki Declaration for Human Studies and received approval from the Ethics Committee of the Local Health Unit of Guarda (Reference number: 11136).

A total of 253 older adults participated in the study, comprising 149 females and 104 males. The inclusion criteria required participants to be 65 years of age or older and living independently within the community. The following exclusion criteria were applied: individuals under 65 years old; participants with mobility impairments; those with cognitive limitations that could affect the comprehension or performance of psychometric tests; individuals residing in social and health care support centers. Before



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data collection commenced, all participants were thoroughly informed about the objectives and procedures of the project. Each participant provided written informed consent, ensuring they understood the nature of the study and their involvement. A post hoc power analysis was conducted to ensure the statistical validity of the study. The power was found to be higher than 0.8 for both multiple regression analysis and ANCOVA, indicating a robust sample size and sufficient power to detect meaningful effects.

Sociodemographic characteristics

Sociodemographic profiling was conducted through a questionnaire. Sex identification was based on participants' self-reporting (female or male). Age was derived from participants' date of birth and categorized into age brackets. Marital status was classified as single, married, widowed, or divorced. The variation in participant numbers across sociodemographic variables was due to missing data. Educational attainment followed the classification of the Portuguese Educational System (Fernandes, 2007) as < 4th year, = 4th year, and > 4th year. Monthly income levels were determined using average Portuguese salary standards, grouped into three categories: Low (<500€), Medium (500€-750€), and High (>750€).

Body composition and anthropometry

Participants' body composition was assessed using a multi-frequency bioelectrical impedance analyser (InBody 270, Biospace Co., Seoul, Korea), equipped with eight tactile electrodes and operating at two frequencies (20 kHz and 100 kHz). Measurements included body weight, height, and body mass index (BMI). All assessments followed the manufacturer's standardized protocol: participants were barefoot, remained motionless during the measurement, and avoided contact with electronic devices. Individuals were screened for the presence of electronic implants (e.g., pacemakers or defibrillators), and those reporting such devices were excluded from the assessment.

Body composition parameters estimated by the device, including total body mass and total fat-free mass, were exported using Lookin'Body software (Biospace Co.) for subsequent analysis. The use of multi-frequency bioimpedance analysis for body composition assessment has been previously validated, showing strong correlations with

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dual-energy X-ray absorptiometry (DXA), particularly in older age groups (Sillanpää et al., 2014; Fang et al., 2020).

Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Body fatness status was classified according to sex-specific tertiles of body fat percentage. Participants in the highest tertile were classified as having high body fatness, while those in the two lower tertiles were classified as having low body fatness, in accordance with previous studies (Kanaya et al., 2009; Agostinis-Sobrinho et al., 2025).

Muscle strength

Muscle strength was evaluated using a portable hydraulic dynamometer (Jamar®, Lafayette, LA, USA) to measure handgrip strength. This assessment was conducted in accordance with the protocol specified by the American College of Sports Medicine (Medicine, 2013). Prior to each repetition, the dynamometer's handle was customized to accommodate the size of each participant's hand, and the dial reading was reset to zero. Participants were urged to exert maximum force on the hand dynamometer for a duration of 5 seconds, with their arm fully extended in front of them, while standing upright and refraining from supporting the instrument against their body or flexing their elbow. Three consecutive trials were conducted for each hand, and the outcome yielding the highest performance was selected for analysis (Perri et al., 2025).

Health-related quality of life

The assessment of quality of life was conducted through the Health Status Questionnaire 36 (SF36v2), which has been validated for the Portuguese population (Ferreira & Santana, 2003). This questionnaire comprises 36 items, organized into eight dimensions: (i) physical functioning, (ii) role limitations due to physical health, (iii) role limitations due to emotional health, (iv) bodily pain, (v) general health perceptions, (vi) vitality, (vii) social functioning, and (viii) mental health. Additionally, the questionnaire provides scores for total physical and mental health as well as an overall score.

Statistical analysis

Descriptive data are presented as means and standard deviations. Independent two-tailed t-tests for continuous variables and chi-square tests for categorical variables



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were used to examine participant differences according to sex. Linear regression models were performed to determine the associations between muscle strength (dependent variable) and body fatness and health-related quality of life (predictor variables). Three models were tested: Model 1 was unadjusted, Model 2 was adjusted for age, sex, and socioeconomic status (education level and monthly income), and Model 3 included the adjustments in Model 2 plus an adjustment for body fatness. Unstandardized regression coefficients were used to express the B values in the linear regression analyses.

Analysis of covariance (ANCOVA) with Bonferroni post-hoc multiple comparison tests was used to assess differences in mean health-related quality of life scores across groups with different body fatness status (High vs. Low), stratified according to muscle strength level (Low and High). Covariates included age, sex, and socioeconomic status.

Data analysis was performed using the Statistical Package for the Social Sciences for Windows (Version 21.0, SPSS Inc., Chicago, IL). A p-value of < 0.05 denoted statistical significance. A post hoc power analysis was performed using G*Power software (version 3.1.9.2; Heinrich Heine University, Düsseldorf, Germany) to assess the adequacy of the sample size. Based on the linear multiple regression analysis (fixed model, R^2 deviation from zero), an observed coefficient of determination of $R^2 = 0.18$, an alpha level of 0.05, a total sample size of 253 participants, and four predictors in the fully adjusted model, the calculated statistical power ($1-\beta$) exceeded 0.99, indicating excellent power to detect the observed associations.

Results

Table 1 outlines the descriptive characteristics of the participants. Women shows the highest levels of body fatness ($37.25\% \pm 6.08$) and the lowest handgrip strength (19.9 ± 5.01 kg) when compared to males



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Table 1. Participants' characteristics.

Characteristics	Total sample (n = 253)	Female (n = 149)	Male (n = 104)
<i>Age (years)</i>	74.91 ± 8.15	74.95 ± 8.28	75.02 ± 8.02
<i>Body Mass Index</i>	27.15 ± 3.98	27.22 ± 4.27	27.09 ± 3.52
<i>Body Fatness %</i>	33.75 ± 7.84	37.25 ± 6.08	28.07 ± 6.31*
<i>Handgrip strength (kg)</i>	24.65 ± 8.67	19.9 ± 5.01	31.68 ± 8.22*
<i>Overall Score (HRQoL*)</i>	50 ± 7,71	48,40 ± 7,73	52,39 ± 7,06
Education			
< 4 th Grade (%)	17.9	19.6	16.0
4 th Grade (%)	52.7	53.6	52.8
> 4 th Grade (%)	28.2	26.8	31.1
Income			
Low (< 500 €) (%)	39.2	47.4 (70)	27.9
Average (500 € - 750 €) (%)	16.9	14.7 (23)	21.2
High (> 750 €) (%)	43.9	37.9 (60)	50.9

The descriptive data are expressed in terms of means and standard deviations. To explore sex differences, independent two-tailed t-tests were conducted for continuous variables, and Chi-square tests were employed for categorical variables.

Table 2. Unstandardized regression coefficients examining the association of muscular strength with FES-I score and Falls

Muscular strength	(Dependent variable) HRQoL score*			
	B	(95% C.I.)	P-value	R ²
Model 1	2.94	(2.07: 3.81)	<0.001	0.18
Model 2	2.21	(1.16: 3.26)	<0.001	0.18
Model 3	2.69	(-1.43: 3.9)	<0.001	0.18

B: Unstandardized coefficients;

Model 1- Unadjusted model.

Model 2 - Adjusted for age, sex, socioeconomic status

Model 3 – Full Adjusted model for age, sex, socioeconomic status, body fatness.

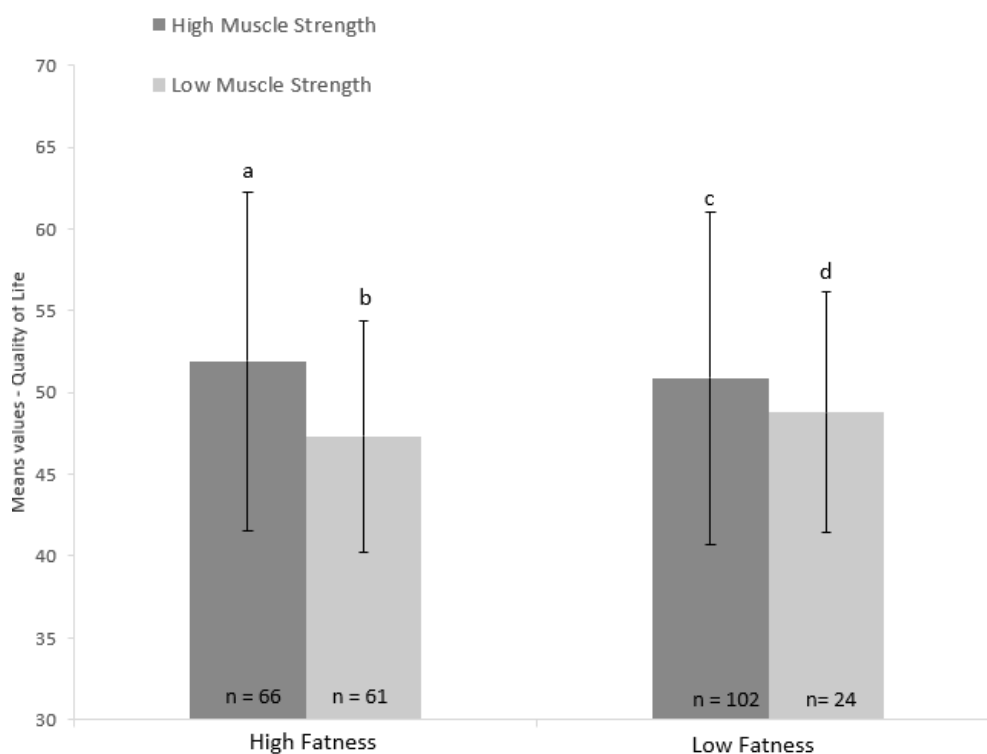
Regression analysis (**Table 2**) showed a significant and positive association between muscle strength and HRQoL score (unstandardized B = -2.69; $p < 0.001$) after **adjustments** for age, sex, socioeconomic status, body fatness (model 3).

Figure 1 presents differences in health-related quality of life (HRQoL) across combined categories of body fatness and muscle strength. Participants with high muscle strength and high body fatness (the “fat but stronger” group) exhibited significantly



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higher HRQoL scores than those with high body fatness and low muscle strength ($p < .001$). No significant differences were observed between the “fat but stronger” group and participants with low body fatness, regardless of muscle strength level. Similarly, individuals with low body fatness and high muscle strength showed significantly higher HRQoL scores compared with participants with high body fatness and low muscle strength ($p < .001$), but did not differ from the “fat but stronger” group. Overall, across body fatness categories, participants with low muscle strength consistently reported the lowest HRQoL scores.

The corrected ANCOVA model was statistically significant, $F(6, 246) = 9.46$, $p < .001$, accounting for 18.8% of the variance in HRQoL ($R^2 = .188$). Significant main effects were observed for age ($F(1, 246) = 16.06$, $p < .001$, $\eta^2p = .061$), gender ($F(1, 246) = 6.56$, $p = .011$, $\eta^2p = .026$), and combined body fatness–muscle strength groups ($F(3, 246) = 4.70$, $p = .003$, $\eta^2p = .054$).



”a”Significantly different from different from “b” group

“b”Significantly different from the different from “a” and c



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Discussion

The findings from our study contribute to the ongoing discourse surrounding the obesity paradox in older adults by explicitly disentangling the independent and joint roles of adiposity and muscle strength in relation to HRQoL. While previous research has often interpreted higher fatness as either uniformly detrimental or paradoxically protective, our results suggest that muscle strength is a key modifier of this relationship, helping to explain inconsistencies in the literature.

Specifically, our results indicate that low levels of muscle strength are associated with lower HRQoL scores, even after adjustment for age, sex, socioeconomic status, and fatness. Participants classified as “*fat but stronger*” demonstrated significantly higher HRQoL compared with individuals with low muscle strength, irrespective of fatness status. This finding contrasts with studies reporting uniformly negative associations between adiposity and HRQoL, suggesting that the adverse effects of higher fatness may be attenuated in the presence of preserved muscle function. In line with this interpretation, individuals with low fatness and high muscle strength differed significantly from those with high fatness and low muscle strength, but not from the “*fat but stronger*” group, reinforcing the notion that muscle strength may be more influential than fatness alone in shaping HRQoL outcomes.

A recent study by Mikkola et al. (2020) reported that higher fat mass was independently associated with lower HRQoL and a steeper decline over time, regardless of lean mass. At first glance, these findings appear to diverge from ours; however, important methodological differences may account for this discrepancy. Notably, Mikkola and colleagues did not assess muscle strength, and lean mass was used as a proxy for functional capacity. This distinction is critical, as greater lean mass does not necessarily translate into higher muscle strength or power, which are influenced by muscle quality, neuromuscular activation, and motor unit recruitment (Reid et al., 2014; Yaya et al., 2020). By directly measuring muscle strength, our study captures a functional dimension that may better reflect the mechanisms linking body composition to HRQoL.

The obesity paradox proposes that higher adiposity may confer protective effects in older adults or clinical populations, often reflected in lower mortality risk (Liu et al., 2023; Santo et al., 2025). However, this paradox remains controversial, with critics



Original article. Muscle strength, adiposity, and health-related quality of life in older adults: a cross-sectional study. Vol. 12, n. ° 4; p. 1-17, August 2026. <https://doi.org/10.55040/2hmqch29> highlighting substantial heterogeneity, residual confounding, and reverse causation across studies. Our findings suggest that at least part of this paradox may be explained by unmeasured differences in muscle strength or physical function, which are rarely accounted for in large epidemiological studies relying solely on BMI. BMI's inability to distinguish fat from lean tissue may therefore obscure clinically meaningful phenotypes, such as individuals with high fatness but preserved muscle strength.

Importantly, our results indicate that participants with low muscle strength consistently reported the poorest HRQoL, regardless of fatness level. This pattern supports a physiological pathway whereby muscle strength influences HRQoL through multiple mechanisms, including greater functional independence, improved mobility, enhanced metabolic health, and reduced systemic inflammation (**REF**). Stronger individuals may better tolerate the mechanical and metabolic burden associated with higher adiposity, whereas those with low muscle strength may experience compounded functional limitations, characteristic of sarcopenic obesity (Liu et al., 2023).

These findings are consistent with longitudinal evidence showing that higher muscle strength is associated with reduced all-cause mortality, independent of adiposity (Alcazar et al., 2021; García-Hermoso et al., 2018; de Souza Moreira et al., 2022). Taken together, our results help reconcile conflicting evidence in the obesity paradox literature by highlighting muscle strength as a key physiological factor that may determine whether higher adiposity is associated with adverse or neutral health outcomes.

This study has several limitations that should be acknowledged. First, the classification of body fatness and muscle strength was based on cut-points that, although supported by the literature, remain partly arbitrary due to the lack of universally accepted thresholds in older populations, which may have led to some misclassification. Second, body composition was assessed using bioelectrical impedance analysis (BIA), a feasible method for field studies but one that is less precise than reference techniques such as DXA and sensitive to hydration status. Muscle strength was evaluated using handgrip strength, which, while widely accepted, may not fully capture overall muscle power or lower-limb strength. Finally, the cross-sectional design limits causal inference, and reverse causation or selection bias cannot be excluded. Longitudinal studies using standardized definitions and more comprehensive assessments of muscle function are warranted.



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Future Directions

Our study underscores the pressing need for accurate phenotyping of patients, considering a comprehensive range of factors including body fat percentage, lean mass, muscle strength, metabolic variables, and functional status. Such an approach will enhance the precision of obesity-related research and enable the development of tailored interventions that address the specific needs of older adults. In light of our findings, interventions aimed at improving muscle strength should be prioritized in older populations, particularly those with high adiposity. Exercise programs focusing on resistance training and muscle strengthening could potentially mitigate the adverse effects of excess body fat and improve overall health outcomes.

Conclusion

Our study indicates that HRQoL in older adults is associated with the interplay between body fat and muscle strength. Participants with low muscle strength reported markedly lower HRQoL, and differences were observed across the fatness–strength subgroups, suggesting that fatness alone does not fully determine quality of life. By linking these findings to our study objective, we provide a more nuanced understanding of the “fat but stronger paradox.” This work contributes new knowledge by highlighting the potential role of muscle strength in moderating the relationship between adiposity and HRQoL. Future research using longitudinal designs and randomized controlled trials is needed to clarify causal pathways and refine strategies to promote healthy aging. Overall, maintaining or improving muscle strength may be an important factor for supporting health and quality of life in older adults.

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