Experimental Gerontology 212 (2025) 112961

Contents lists available at ScienceDirect

Experimental Gerontology

journal homepage: www.elsevier.com/locate/expgero

Predictive value of different muscle power normalization methods for mobility limitations in community-dwelling older adults: A cross-sectional analysis from the longevity check-up 8+ study

Stefano Cacciatore [a,b,*,1], Matteo Tosato [b,1], Riccardo Calvani [a], Hélio José Coelho-Júnior [a,b], Emanuele Marzetti [a,b], Francesco Landi [a,b], on Behalf of the Lookup8+ Study Group

[a] Department of Geriatrics, Orthopedics and Rheumatology, Università Cattolica del Sacro Cuore, Rome, Italy
[b] Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Rome, Italy

ARTICLE INFO

Section Editor: Carel Meskers

Keywords:
Sarcopenia
Frailty, muscle strength
Sit-to-stand test
Mobility limitation
Physical performance
Community-dwelling
Aging

ABSTRACT

Background: Lower limb muscle power is a critical determinant of mobility in older adults. However, its optimal normalization method remains uncertain. The aim of this cross-sectional study is to compare different normalization approaches for muscle power in predicting self-reported 400 m walking difficulty, used as a proxy of mobility limitation, in community-dwelling older adults (≥65 years old) from the Longevity Check-Up 8+ Study.
Methods: Lower limb muscle power was estimated using five-repetition sit-to-stand equations and expressed as i) absolute (W), ii) relative (W/kg), iii) allometric (W/m^2), and iv) specific power (W/kg of appendicular skeletal muscle mass). 400-m walking difficulty was self-reported and dichotomized. Discriminative ability was assessed through receiver operating characteristic curves. Associations were tested using logistic regression models.
Results: Among the 4614 participants (mean age 72.8 ± 5.8 years; 53.2 % women), 25.1 % reported difficulty walking 400 m. Individuals reporting difficulty were older, more frequently female, had higher body mass index, and lower physical activity levels (all $p < 0.001$). Relative muscle power demonstrated the highest discriminative ability [area under the curve 0.70; 95 % confidence interval (CI) 0.68–0.72], outperforming other indices. Optimal cut-offs for relative muscle power identified using the Youden index were 3.1 W/kg in women and 3.8 W/kg in men. Low relative muscle power was significantly associated with greater odds of walking difficulty (odds ratio 2.07; 95 % CI 1.78–2.42; $p < 0.001$).
Conclusions: Relative muscle power showed superior predictive performance for self-reported walking difficulty, as an indicator of mobility limitation, compared to other normalization methods. Future longitudinal studies are needed to confirm these findings and explore their relevance for other clinically meaningful outcomes.

1. Introduction

Age-related decline in physical function is a major public health concern, contributing to disability, falls, institutionalization, and increased mortality in older adults (Cacciatore et al., 2024; Yuan and Larsson, 2023). Mobility, often described as the “sixth vital sign,” represents a core dimension of functional ability and healthy aging (Beauchamp et al., 2023). Among the various indicators of functional limitation, self-reported difficulty in walking 400 m is a simple yet clinically meaningful measure that strongly correlates with performance-based tests (Lauretani et al., 2003), and has been proposed as an early marker of muscle strength decline (Salini et al., 2022). Approximately one-third of community-dwelling older adults experience mobility limitations, with prevalence rising sharply with advancing age (Freiberger et al., 2020; Herbert et al., 2020; Wang et al., 2024). Although prevalence estimates vary depending on the definition and assessment method used, the burden remains consistently high across aging populations (Cummings et al., 2014). The unified World Health Organization framework for mobility measurement (Beauchamp et al., 2023) further emphasizes its multidimensional nature, encompassing

* Corresponding author at: Department of Geriatrics, Orthopedics and Rheumatology, Università Cattolica del Sacro Cuore, Largo F. Vito 1, 00168, Rome, Italy.
E-mail address: stefano.cacciatore01@icatt.it (S. Cacciatore).
[1] Equal contribution.

https://doi.org/10.1016/j.exger.2025.112961
Received 18 July 2025; Received in revised form 17 October 2025; Accepted 4 November 2025
Available online 7 November 2025

perceived, actual, and locomotor facets, and provides a standardized foundation for its assessment in older adults. Evidence from the studies examining large cohorts (e.g., LIFE study, InCHIANTI) has shown that self-reported difficulty walking a quarter mile (~400 m) closely parallels objective measures of physical performance (Chen et al., 2018; Lauretani et al., 2003). Importantly, the onset of self-reported difficulty typically precedes objectively measured decline, suggesting that a single question about walking ability may capture an early phase of mobility limitation, particularly when performance testing is not feasible (Chen et al., 2018).

Deteriorations in muscle function are a main determinant of changes in mobility with aging (Bernabei et al., 2014). Muscle strength refers to the maximal force a muscle or muscle group can generate against resistance, whereas muscle power describes the rate at which that force can be produced, combining both strength and speed of contraction (Hunter et al., 2016). While muscle strength declines at a rate of roughly 1–2 % per year after age 50, with a steeper acceleration after 70 years of age (Landi et al., 2020), muscle power may decline at nearly double that rate, starting as early as the fourth decade of life (Coelho-Junior et al., 2024b). This accelerated loss of power is believed to precede and contribute to strength and mass losses, making it a valuable early marker of functional decline. The pathophysiological basis for the loss of muscle power lies in age-related neuromuscular changes, particularly the selective atrophy and denervation of type II (fast-twitch) muscle fibers, which are critical for rapid and forceful movements (Horwath et al., 2025; Hunter et al., 2016). Given its functional relevance, muscle power has been increasingly recognized as a more robust predictor of mobility than muscle strength or mass alone (Alvarez-Bustos et al., 2025; Araujo et al., 2025; Losa-Reyna et al., 2022; Travaglini et al., 2025).

Normalization of muscle power to anthropometric variables is essential for accurate inter-individual comparisons and for establishing clinically meaningful thresholds each reflecting different physiological assumptions. Absolute muscle power (expressed in watts, W) represents the raw output of mechanical power during a functional task, independent of body size or composition. While useful, it tends to favor individuals with larger body mass, potentially underestimating functional impairment in smaller or leaner individuals (Alcazar et al., 2021c; Tomlinson et al., 2016). Relative muscle power (W/kg) adjusts for body weight, providing an estimate of power per unit of mass. This normalization improves comparability between individuals and reflects the functional capacity to move the body mass of the individual, which is particularly relevant for weight-bearing activities like walking or standing (Alcazar et al., 2021b). Allometric muscle power (W/m^2) scales power to height squared, based on principles of geometric similarity. This method may reduce bias associated with variations in body size and is less influenced by excess adiposity, though it remains less commonly adopted in clinical settings (Folland et al., 2008). Specific muscle power (W/kg of appendicular skeletal muscle mass, ASM) represents power normalized to muscle quantity, offering insight into muscle quality and neuromuscular efficiency. This index reflects how effectively an individual can translate muscle mass into functional output (da Costa Teixeira et al., 2024; Kirk et al., 2024).

Despite the growing consensus on the importance of muscle power, evidence on the optimal normalization method for predicting functional limitations in older populations is sparse. Therefore, the aim of this study is to compare different normalization approaches for muscle power in predicting self-reported difficulty in walking 400 m in community-dwelling older adults enrolled in the Longevity Check-Up 8+ (Lookup8+) Study.

2. Materials and methods

2.1. Study design and sample selection

This cross-sectional analysis was conducted using data from the Lookup 8+ project, a population-based initiative coordinated by the Department of Geriatrics at Università Cattolica del Sacro Cuore, in collaboration with the Fondazione Policlinico Universitario "Agostino Gemelli" IRCCS in Rome, Italy. Participant recruitment was carried out in public venues across various Italian cities to ensure broad geographic representation, encompassing both mainland and insular regions. In metropolitan areas with populations exceeding 250,000 inhabitants, multiple events were organized across different districts to enhance sociodemographic diversity.

For the present analysis, we included participants aged 65 years or older. Participants were excluded from the analysis if they had missing data in the following variables: self-reported walking difficulty, five-time sit-to-stand test time, body mass index (BMI), and calf circumference measurements. The study protocol was approved by the Ethics Committee of Università Cattolica del Sacro Cuore (protocol number A.1220/CE/2011), and written informed consent was obtained from all participants prior to data collection. The study procedures were conducted in accordance with the principles outlined in the Declaration of Helsinki. Further methodological details have been described elsewhere (Landi et al., 2018).

2.2. Data collection

All participants underwent a comprehensive assessment including a structured questionnaire, clinical evaluation, and anthropometric measurements. Smoking status was categorized as current, former, or never smoker; for analytical purposes, individuals were classified as either current or never/former smokers. Body weight was measured using an analog scale, while standing height was assessed with a portable stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Dietary intake was assessed via a brief food frequency questionnaire evaluating weekly consumption of 12 main food groups, including fish, meat and derivatives (e.g., cured meats), eggs, milk and dairy products (e.g., yogurt, cheese), pasta and baked goods (e.g., bread, breadsticks, biscuits), rice, legumes, vegetables, and other cereals (e.g., spelt, rye, oat), based on standard Italian portion sizes (Landi et al., 2017). A healthy diet was defined as the intake of at least three to four servings of fruits and/or vegetables per day. Daily protein intake (in grams) was estimated by summing the protein content of consumed standard portions and dividing by seven. Protein content was derived from the Italian Center for Research on Foods and Nutrition online database (CREA Centro di Ricerca Alimenti e Nutrizione, *n.d.*). Protein intake was normalized to body weight and categorized as low (<1.0 g/kg/day) or adequate (≥1.0 g/kg/day), based on recommendations for older adults by the PROT-AGE Study Group (Bauer et al., 2013).

Physical activity was defined as engaging in any form of exercise for at least 30 min on two or more days per week during the preceding year. Participants were classified as physically active or inactive for analytical purposes.

Capillary total cholesterol and blood glucose levels were measured using the MultiCare-In system (Biomedical Systems International srl, Florence, Italy). Hypercholesterolemia was defined as total cholesterol >200 mg/dL or ongoing lipid-lowering therapy. Diabetes was defined as fasting blood glucose ≥126 mg/dL, random glucose ≥200 mg/dL, or a self-reported physician diagnosis (American Diabetes Association Professional Practice, 2025). Blood pressure was measured with an electronic sphygmomanometer, and hypertension was defined as systolic pressure ≥ 140 mmHg, diastolic pressure ≥ 90 mmHg, or current antihypertensive treatment (McEvoy et al., 2024).

Calf circumference (in cm) was measured using a non-elastic anthropometric tape with the participant seated, the foot flat on the floor, and the knee flexed at 90 degrees. The measurement was taken at the point of maximum calf girth, without compressing the subcutaneous tissue. ASM was estimated using a calf circumference-based equation developed by the COCONUT study group (Santos et al., 2019). The skeletal muscle index (SMI) was calculated as ASM divided by height squared (kg/m^2). Low ASM was identified as <20 kg in men and < 15 kg in women, while low SMI was defined as <7.0 kg/m^2 in men and < 5.5 kg/m^2 in women, in accordance with the EWGSOP2 criteria (Cruz-Jentoft et al., 2019).

2.3. Estimation of muscle power

Lower limb muscle power was estimated using five-time sit-to-stand equations, according to the results of the five-time sit-to-stand performance test, body mass, stature, and chair height. For testing, participants were requested to rise from a chair (43–47 cm) five times as fast as possible with their arms crossed in front of the body. Then, absolute muscle power (expressed in W) was calculated based on a validated equation (Alcazar et al., 2018):

$$Absolute\ muscle\ power\ (W) = \frac{body\ weight\ (kg) \times 0.9 \times g \times [height\ (m) \times 0.5 - chair\ height\ (m)]}{\frac{5STS\ test\ (s)}{no.of\ 5STS\ repetitions} \times 0.5}$$

In this equation, gravitational acceleration (g) is set at 9.81 m/s^2, and the abbreviation “5STS” is used in the equation to identify the five-time sit-to-stand task. From the calculated absolute power, three derived indices were computed to account for individual differences in body size and composition:

- Relative power (W/kg): absolute power divided by body weight.
- Allometric power (W/m^2): absolute power divided by height squared.
- Specific power (W/kg ASM): absolute power divided by ASM.

These derived indices were used to explore different normalization methods and their ability to predict functional limitations.

2.4. Self-reported walking difficulty

Perceived mobility was evaluated through a single-item interview question: “Do you experience any difficulty walking 400 meters?”. To enhance clarity and ensure participant understanding, interviewers provided concrete reference points, such as the approximate distance between two urban bus stops. Response options included: “No difficulty”, “A little difficulty”, “A lot of difficulty”, and “Unable to walk this distance”. For analytical purposes, responses were dichotomized: participants reporting any level of difficulty or inability were classified as having walking difficulty, whereas those indicating no difficulty were categorized as not experiencing walking limitations.

2.5. Statistical analysis

Continuous variables were expressed as means and standard deviations, while categorical variables were summarized as absolute frequencies and percentages. Between-group differences, comparing participants with and without self-reported walking difficulty, were assessed using independent-samples *t*-tests for continuous variables and chi-square tests for categorical variables, as appropriate. To evaluate the discriminative capacity of each muscle power index in identifying individuals with walking difficulty, receiver operating characteristic (ROC) curve analysis was performed. The area under the curve (AUC) and corresponding 95 % confidence intervals (CIs) were calculated for the overall sample and separately by sex. Optimal threshold values were determined using the Youden index, with associated sensitivity and specificity reported. Comparisons between AUCs were conducted using the DeLong test. The association between low relative muscle power, defined as <3.1 W/kg in women and < 3.8 W/kg in men, and walking difficulty was examined using binary logistic regression models. Odds ratios (ORs) with 95 % CIs were reported for both unadjusted and adjusted models. The multivariable model included the following covariates: age, sex, BMI, physical activity, and the presence of hypertension and diabetes. Hypertension was considered as a proxy of vascular aging and microcirculatory impairment potentially affecting muscle perfusion and performance (Quan et al., 2023). Multicollinearity was evaluated using the variance inflation factor (VIF), with all values below 2, indicating no meaningful collinearity among predictors. All analyses were conducted using R software, version 4.2.3 (R Core Team, Vienna, Austria), with statistical significance defined as a two-tailed *p*-value <0.05.

3. Results

Between 1st June 2015 and 1st November 2024, a total of 6395 individuals aged 65 years or older were recruited. After excluding 1781 participants due to missing data on the variables of interest (including 1334 for self-reported walking difficulty, 311 for five-time sit-to-stand test time, 84 for BMI values, and 108 without calf circumference measurements), the final sample consisted of 4614 individuals (mean age 72.8 ± 5.8 years; 53.2 % women). No significant differences were observed in demographic or anthropometric characteristics between included and excluded participants.

General characteristics of the study population stratified by walking ability are presented in Table 1. Self-reported difficulty walking 400 m was addressed by 1159 participants (25.1 %). Compared to those without reported difficulty, individuals reporting 400 m difficulty were approximately two years older (74.6 ± 6.2 vs. 72.2 ± 5.6 years, $p < 0.001$) and more frequently female (63.6 % vs. 49.7 %, $p < 0.001$). Furthermore, participants with walking difficulty had a higher BMI (27.4 ± 4.1 vs. 25.5 ± 3.4 kg/m2, p < 0.001) and slightly greater calf circumference (35.4 ± 3.3 vs. 35.2 ± 3.2 cm, $p = 0.024$). Among men, ASM did not differ significantly between groups (22.8 ± 2.4 vs. 22.7 ± 2.4 kg, $p = 0.371$), whereas in women ASM was significantly lower in those with walking difficulty (13.8 ± 2.3 vs. 14.2 ± 2.6 kg, $p < 0.001$). However, no significant differences were observed in low ASM between participants with and without self-reported walking difficulty. Participants with walking difficulty were less likely to be physically active (33.8 % vs. 61.5 %, $p < 0.001$) and reported healthy dietary habits less frequently (68.7 % vs. 74.0 %, p < 0.001). Hypertension and diabetes were more prevalent among participants with walking difficulty (both p < 0.001), Regarding physical performance, individuals reporting difficulty required significantly more time to complete the sit-to-stand test (10.3 ± 2.9 vs. 8.7 ± 2.3 s, p < 0.001).

As shown in Table 2, all muscle power indices, i.e., absolute, relative, allometric, and specific, were significantly lower in participants reporting walking difficulty compared to those without difficulty (all p < 0.001). Among women, mean relative muscle power was 3.1 ± 0.8 W/kg in those with walking difficulty versus 3.6 ± 0.9 W/kg in those without (p < 0.001); corresponding values for men were 3.8 ± 1.1 W/kg and 4.5 ± 1.2 W/kg, respectively (p < 0.001).

Figs. 1–4 illustrate the ROC curves for each muscle power index. Among the four indices, relative muscle power demonstrated the highest

Table 1
Baseline characteristics of the study population according to self-reported difficulty in walking 400 m.

	Self-reported walking difficulty (n = 1159)	No self-reported walking difficulty (n = 3455)	Total sample (n = 4614)	p
General characteristics				
Age, years	74.6 ± 6.2	72.2 ± 5.6	72.8 ± 5.8	<0.001
Sex, women	737 (63.6 %)	1717 (49.7 %)	2454 (53.2 %)	<0.001
General anthropometry				
Weight, kg	72.3 ± 12.8	70.0 ± 12.4	70.6 ± 12.5	<0.001
Height, m	1.6 ± 0.1	1.7 ± 0.1	1.6 ± 0.1	<0.001
BMI, kg/m2	27.4 ± 4.1	25.5 ± 3.4	25.9 ± 3.7	<0.001
Calf circumference, cm	35.4 ± 3.3	35.2 ± 3.2	35.2 ± 3.2	0.024
Muscle mass and skeletal muscle index				
ASM, kg				
Men	22.8 ± 2.4	22.7 ± 2.4	22.7 ± 2.4	0.371
Women	14.2 ± 2.6	13.8 ± 2.3	14.0 ± 2.4	<0.001
Low ASM	502 (43.3 %)	1391 (40.3 %)	1893 (41.0 %)	0.073
Skeletal muscle index, kg/m2				
Men	7.9 ± 1.0	7.7 ± 0.9	7.7 ± 0.9	0.004
Women	5.7 ± 1.1	5.5 ± 0.9	5.5 ± 1.0	<0.001
Low skeletal muscle index	407 (35.0 %)	1257 (36.4 %)	1664 (36.1 %)	0.500
Lifestyle factors				
Current smoking	156 (13.5 %)	468 (13.5 %)	624 (13.5 %)	–
Physically active	392 (33.8 %)	2125 (61.5 %)	2517 (54.6 %)	<0.001
Healthy diet	796 (68.7 %)	2558 (74.0 %)	3354 (72.7 %)	<0.001
Daily protein intake, g/kg	0.8 ± 0.2	0.8 ± 0.2	0.8 ± 0.2	0.131
≥ 1.0 g/kg daily	177 (15.3 %)	585 (16.9 %)	762 (16.5 %)	0.194
<1.0 g/kg daily	963 (83.1 %)	2807 (81.2 %)	3770 (81.7 %)	–
Comorbidities				
Hypertension	848 (73.2 %)	2246 (65.0 %)	3094 (67.1 %)	<0.001
Diabetes	237 (20.4 %)	436 (12.6 %)	673 (14.6 %)	<0.001
Hypercholesterolemia	779 (67.2 %)	2292 (66.3 %)	3071 (66.6 %)	0.600
Physical performance				
Sit to stand test, seconds	10.3 ± 2.9	8.7 ± 2.3	9.1 ± 2.6	<0.001

Continuous variables are presented as mean ± standard deviation, and categorical variables as absolute frequencies and percentages. P-values are derived from t-tests (continuous variables) or chi-squared tests (categorical variables). Abbreviations: ASM, appendicular skeletal muscle mass; BMI, body mass index; SMI: skeletal muscle index (ASM/height^2).

discriminative performance in identifying self-reported walking difficulty, with an AUC of 0.70 (95 % CI: 0.68–0.72). This outperformed absolute power (AUC 0.63; 95 % CI: 0.62–0.65), allometric power (AUC 0.62; 95 % CI: 0.61–0.64), and specific power (AUC 0.61; 95 % CI: 0.59–0.63). Sex-stratified analyses confirmed the superiority of relative power in both women (AUC 0.68; 95 % CI: 0.65–0.70) and men (AUC 0.69; 95 % CI: 0.66–0.72). Cut-off values maximizing both sensitivity and specificity were identified as 3.6 W/kg for the overall population, 3.1 W/kg for women, and 3.8 W/kg for men. Corresponding sensitivity and specificity estimates are reported in Table 3. Supplementary Table S1 provides alternative thresholds optimized for higher sensitivity levels (≥90 % and ≥ 95 %) in both sexes.

Table 4 summarizes the results of unadjusted and adjusted logistic regression models assessing the association between relative muscle power and self-reported walking difficulty. In the unadjusted model, low relative muscle power was significantly associated with walking difficulty (OR 3.18; 95 % CI: 2.77–3.65; $p < 0.001$). The association remained significant after adjustment for age and sex (Model 1: OR 2.68; 95 % CI: 2.32–3.10; p < 0.001), and in the fully adjusted model (Model 2: OR 2.07; 95 % CI: 1.78–2.42; p < 0.001), which included BMI, physical activity, hypertension, and diabetes. In the final model, older age, female sex, higher BMI, and diabetes were positively associated with walking difficulty, while regular physical activity was inversely associated (OR 0.40; 95 % CI: 0.35–0.47; p < 0.001). Hypertension was not significantly associated.

4. Discussion

This study demonstrated that relative lower-limb muscle power, estimated through the five-time sit-to-stand test and normalized to body weight, was the most accurate index for identifying self-reported difficulty in walking 400 m among community-dwelling older adults. Indeed, compared to absolute, allometric, and specific muscle power indices, relative power exhibited the highest discriminative ability, in total sample and in both men and women. Optimal thresholds were identified as 3.1 W/kg for women and 3.8 W/kg for men. Individuals below these cut-offs had significantly greater odds of reporting walking difficulty, even after adjusting for age, sex, BMI, physical activity, diet quality, and comorbidities. These findings support the clinical value of relative muscle power as a feasible and informative indicator of early functional limitation in later life.

To date, relatively few studies have directly compared different normalization methods of muscle power in relation to adverse health outcomes in older adults. Coelho-Junior et al. (2024a) found that specific muscle power, but not other muscle power indices, was significantly associated with mortality among older adults who lived in a mountain community in Central Italy. These findings were expanded by Losa-Reyna et al. (2022), who found significant associations between relative muscle power and both hospitalization and death after examining a population of Spanish community-dwelling older adults. Another study of the same group (Alcazar et al., 2021a) indicated that relative muscle power is critical determinant of mobility in older adults. More recently, Alvarez-Bustos et al. (2025) evaluated the prognostic value of muscle power indices in predicting adverse outcomes in older adults, including falls, disability, frailty, and hospitalization across multiple clinical settings. According to the authors, relative muscle power showed the strongest associations with frailty and adverse events, particularly when specific frailty tools or contexts were considered.

Although cut-offs for low relative muscle power vary slightly across studies, recent literature converges on clinically meaningful thresholds that are consistently associated with mobility limitations and adverse outcomes. For instance, Alcazar et al. (2021b) found that relative muscle power performance <2.6 W/kg for men and < 2.1 W/kg for women was significantly associated with increased risk of mobility impairment and adverse events in a cohort of older adults from four European countries (Belgium, Denmark, Portugal, and Spain), Similarly, Baltasar-Fernandez et al. (2021), after examining data from the Toledo Study for Healthy Aging, proposed <2.5 W/kg in men and < 1.9 W/kg in women as cut-offs linked to frailty, reduced gait speed, disability, and poorer quality of life. In a Turkish cohort, Bahat et al. (Bahat et al., 2021) reported

Table 2
Comparison of absolute, relative, allometric, and specific muscle power between participants with and without self-reported difficulty in walking 400 m, stratified by sex.

	Women				Men			
	Self-reported walking difficulty ($n = 737$)	No self-reported walking difficulty ($n = 1717$)	Overall ($n = 2454$)	*p*	Self-reported walking difficulty ($n = 422$)	No self-reported walking difficulty ($n = 1738$)	Overall ($n = 2160$)	*p*
Absolute muscle power, W	207.9 ± 66.5	229.1 ± 70.7	222.8 ± 70.1	<0.001	305.2 ± 102.8	349.9 ± 104.9	341.2 ± 105.9	<0.001
Relative muscle power, W/kg	3.1 ± 0.8	3.6 ± 0.9	3.5 ± 0.9	<0.001	3.8 ± 1.1	4.5 ± 1.2	4.4 ± 1.2	<0.001
Allometric muscle power, W/m^2	83.3 ± 25.1	89.8 ± 24.7	87.9 ± 25.0	<0.001	104.3 ± 32.7	118.0 ± 32.4	115.3 ± 32.9	<0.001
Specific muscle power, W/kg ASM	14.8 ± 4.5	16.7 ± 4.9	16.1 ± 4.8	<0.001	13.4 ± 4.4	15.4 ± 4.3	15.1 ± 4.4	<0.001

Values are reported as mean ± standard deviation. *P*-values are derived from independent samples *t*-tests. Abbreviation: ASM, appendicular skeletal muscle mass.

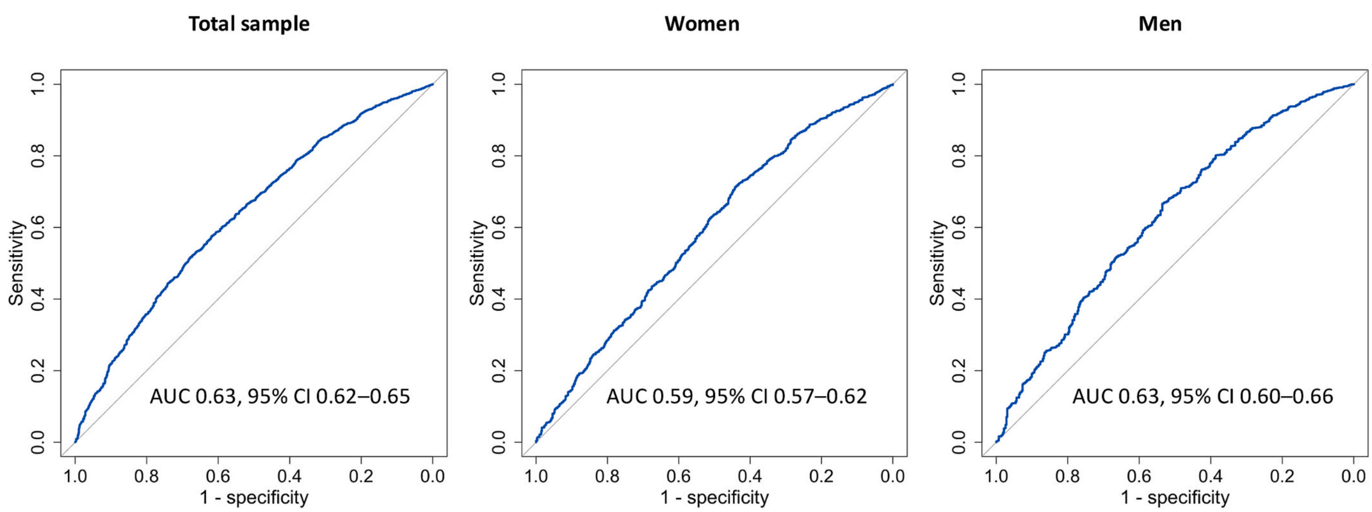

Fig. 1. Receiver operating characteristic curves for the association between absolute lower limb muscle power and self-reported difficulty in walking 400 m in the total sample, women, and men. Abbreviations: AUC, area under the curve; CI: confidence interval.

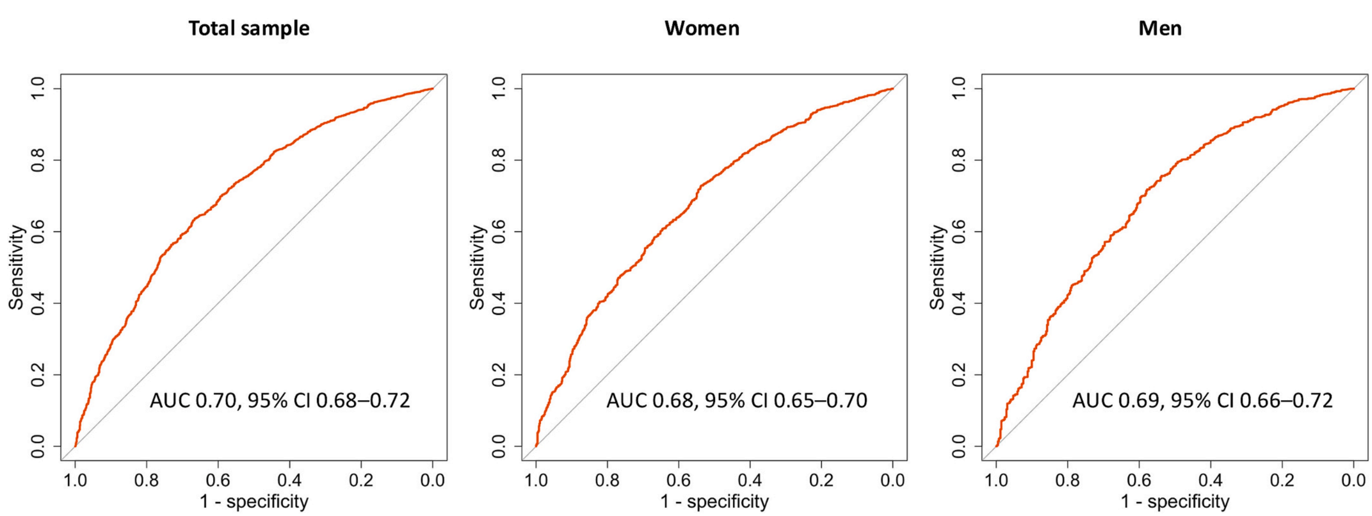

Fig. 2. Receiver operating characteristic curves for the association between relative lower limb relative muscle power and self-reported difficulty in walking 400 m in the total sample, women, and men. Abbreviations: AUC, area under the curve; CI: confidence interval.

thresholds of <2.6 W/kg in men and < 1.9 W/kg in women, derived from the lowest tertile of distribution, which were likewise associated with functional disability. A study conducted in older adults from Colombia proposed slightly lower cutoff points, ranging from <1.30 to 2.38 W/kg in men and < 1.21 to 1.79 W/kg in women, with values below one standard deviation from the mean correlating with increased

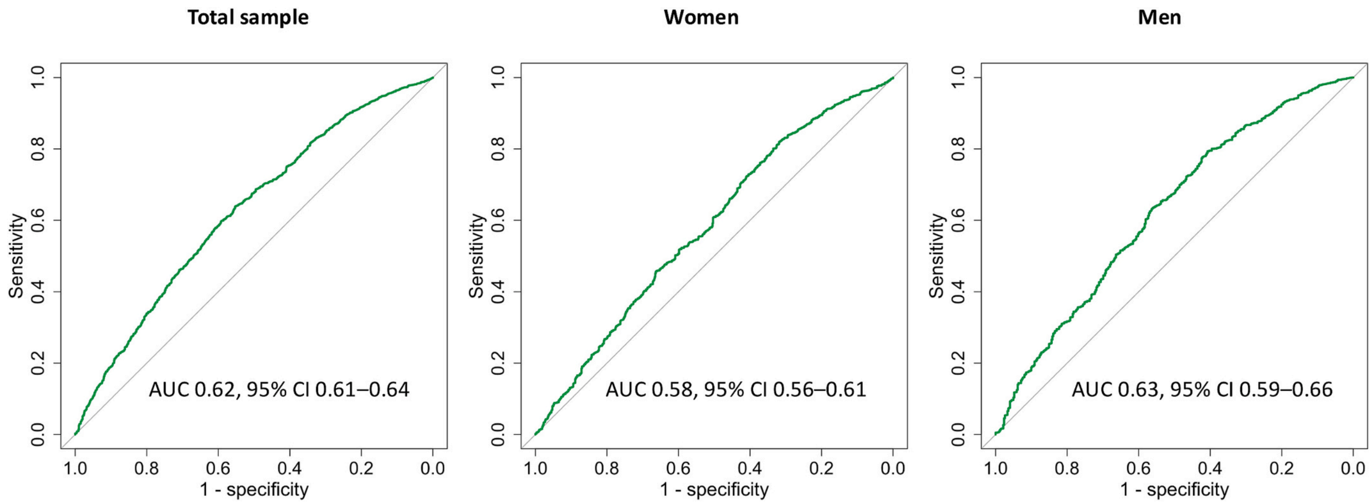

Fig. 3. Receiver operating characteristic curves for the association between allometric lower limb relative muscle power and self-reported difficulty in walking 400 m in the total sample, women, and men. Abbreviations: AUC, area under the curve; CI: confidence interval.

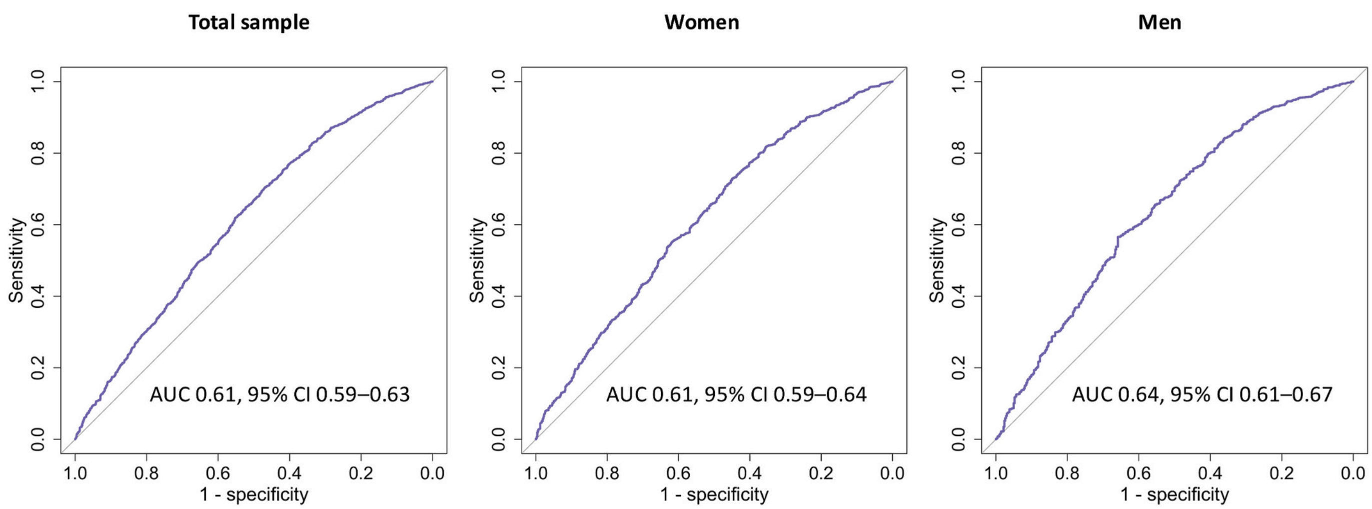

Fig. 4. Receiver operating characteristic curves for the association between specific lower limb relative muscle power and self-reported difficulty in walking 400 m in the total sample, women, and men. Abbreviations: AUC, area under the curve; CI: confidence interval.

risk of adverse outcomes (Ramirez-Velez et al., 2022). The slightly higher thresholds identified in our study may reflect population-specific factors, such as body composition or habitual physical activity. Notably, 54.6 % of participants in our cohort were classified as physically active, a proportion substantially higher than that reported in recent regional and national data for older adults in Italy (40.1 %; 95 % CI 31.8 %–48.8 %) and high-income Western countries (41.5 %; 95 % CI 37.8 %–45.3 %) in general (Strain et al., 2024). This higher prevalence of physical activity may have contributed to more favorable functional reserve, thereby influencing test performance and threshold estimates.

Importantly, these thresholds were derived using self-reported difficulty walking 400 m as the reference outcome, which, despite being a valid proxy for major mobility disability, may anticipate the onset of objectively measurable impairment. Indeed, the LIFE study demonstrated that individuals often report mobility limitations prior to failing the 400 m walk test, suggesting that self-reported difficulty might capture an earlier phase of functional decline (Chen et al., 2018). From a clinical perspective, such elevated cut-off values could be instrumental in identifying older adults at an intermediate risk stage, what may be conceptualized as a “pre-impairment” of muscle power, where preventive strategies such as targeted lower-limb power training could still be effective. Given that power training requires a minimal functional reserve and is particularly challenging for individuals already experiencing marked muscle power loss (Balachandran et al., 2022), early intervention may be essential. Consistent evidence indicates that the benefits of muscle-strengthening activities on lower-limb strength and mobility tend to diminish in older age groups, reflecting an age-dependent attenuation of muscle adaptation (Prokopidis et al., 2025). Nevertheless, further research is needed to validate these thresholds across diverse cohorts and to examine their associations with clinically relevant outcomes, including disability, institutionalization, and mortality.

The five-time sit-to-stand test, when combined with body weight, offers a rapid, low-cost, and non-invasive method to estimate lower-limb muscle power, making it suitable for widespread use in clinical and public health settings. Given its feasibility and strong predictive performance, relative muscle power could be incorporated into routine functional assessments to enable early identification of older adults at risk of mobility decline and to guide timely, targeted interventions (Hetherington-Rauth et al., 2022). In this context, our findings contribute to the growing body of evidence supporting a refined understanding of sarcopenia and muscle health in aging, one that

Table 3
Area under the receiver operating characteristic curve and 95 % confidence intervals for absolute, relative, allometric, and specific muscle power in predicting self-reported difficulty in walking 400 m.

	AUC (95 % CI)	Optimal threshold	Sensitivity	Specificity
Total sample				
Absolute muscle power, W	0.63 (0.62–0.65)	269.5	0.52	0.68
Relative muscle power, W/kg	0.70 (0.68–0.72)	3.6	0.64	0.67
Allometric muscle power, W/m^2	0.62 (0.61–0.64)	89.9	0.64	0.55
Specific muscle power, W/kg ASM	0.61 (0.59–0.63)	13.4	0.71	0.47
Women				
Absolute muscle power, W	0.59 (0.57–0.62)	189.7	0.71	0.44
Relative muscle power, W/kg	0.68 (0.65–0.70)	3.1	0.73	0.54
Allometric muscle power, W/m^2	0.58 (0.56–0.61)	68.7	0.82	0.32
Specific muscle power, W/kg ASM	0.62 (0.59–0.64)	13.8	0.73	0.45
Men				
Absolute muscle power, W	0.63 (0.60–0.66)	298.1	0.67	0.54
Relative muscle power, W/kg	0.69 (0.66–0.72)	3.8	0.72	0.58
Allometric muscle power, W/m^2	0.63 (0.59–0.66)	92.7	0.79	0.41
Specific muscle power, W/kg ASM	0.64 (0.61–0.67)	14.3	0.57	0.66

Abbreviations: AUC, area under the receiver operating characteristic curve. CI, confidence interval.

prioritizes clinically meaningful measures and seeks to capture the underlying biological substrate of physical frailty.

While the present findings offer important insights into the predictive value of muscle power normalization, several limitations should be taken into account when interpreting the results. First, the cross-sectional design precludes any inference of causality between relative muscle power and walking difficulty. Second, ASM was estimated indirectly using calf circumference. Although calf circumference is practical and validated proxy in large-scale studies, it lacks the precision of imaging-based techniques such as dual-energy X-ray absorptiometry or bioimpedance analysis. Third, muscle power was estimated via the five-time sit-to-stand test, an indirect method that does not capture true maximal power output. Fourth, the study population consisted of community-dwelling volunteers recruited in public settings, which may introduce selection bias and limit the generalizability of findings to more vulnerable or institutionalized older adults. Finally, residual confounding cannot be excluded, as detailed information on chronic comorbidities, medications affecting muscle performance, and vigorous physical activity was not available for adjustment.

5. Conclusions

Relative lower-limb muscle power, estimated through the five-time sit-to-stand test and normalized to body weight, proved to be the most effective index for identifying self-reported walking difficulty among community-dwelling older adults. The cut-off values identified in our study, 3.1 W/kg for women and 3.8 W/kg for men, are slightly higher than those traditionally reported in the literature and may reflect earlier stages of functional decline. These values could possibly provide as clinically meaningful thresholds for the early detection of mobility risk. Incorporating a sit-to-stand-based relative muscle power assessment into routine geriatric evaluations may facilitate timely, targeted interventions aimed at preserving mobility, preventing disability, and promoting healthy aging. However, further longitudinal studies are warranted to determine the most appropriate normalization method and to clarify its relationship with clinically meaningful outcomes.

CRediT authorship contribution statement

Stefano Cacciatore: Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Matteo Tosato:** Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **Riccardo Calvani:** Writing – review & editing, Validation, Methodology, Investigation, Conceptualization. **Hélio José Coelho-Júnior:** Writing – review & editing, Validation, Methodology. **Emanuele Marzetti:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Francesco Landi:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Università Cattolica del Sacro Cuore, Rome, Italy (protocol #A.1220/CE/2011).

Table 4
Unadjusted and adjusted logistic regression models exploring the association between the relative muscle power and difficulty in walking 400 m.

	Unadjusted OR (95 % CI)	*p*	Model 1 OR (95 % CI)	*p*	Model 2 OR (95 % CI)	*p*
Relative muscle power						
High	1.00 (reference)	–	1.00 (reference)	–	1.00 (reference)	–
Low	3.18 (2.77–3.65)	<0.001	2.68 (2.32–3.10)	<0.001	2.07 (1.78–2.42)	<0.001
Age			1.05 (1.04–1.06)	<0.001	1.06 (1.05–1.08)	<0.001
Sex, women			1.85 (1.60–2.14)	<0.001	2.18 (1.87–2.55)	<0.001
BMI					1.13 (1.11–1.16)	<0.001
Physically active					0.40 (0.35–0.47)	<0.001
Hypertension					1.02 (0.86–1.20)	0.800
Diabetes					1.49 (1.22–1.81)	<0.001

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.
Model 1: age- and sex-adjusted.
Model 2: adjusted for age, female sex, BMI, physical activity, hypertension and diabetes.

Funding

This work was supported by the Università Cattolica del Sacro Cuore (D1.2024 and D1.2025), the Italian Ministry of Health (Ricerca Corrente 2025), and the nonprofit research foundation "Centro Studi Achille e Linda Lorenzon" (N/A). E.M. received support from the European Union's Next Generation EU PRIN (2022YNENP3). The authors also acknowledge co-funding from Next Generation EU, in the context of the National Recovery and Resilience Plan, Investment PE8—Project Age-It: "Ageing Well in an Ageing Society". This resource was co-financed by the Next Generation EU (DM 1557 11.10.2022). The views and opinions expressed are only those of the authors and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgments

Members of the Lookup 8+ project team are listed in the Supplementary File S1.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2025.112961.

Data availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to their containing information that could compromise the privacy of the research participants.

References

Alcazar, J., Losa-Reyna, J., Rodriguez-Lopez, C., Alfaro-Acha, A., Rodriguez-Manas, L., Ara, I., Garcia-Garcia, F.J., Alegre, L.M., 2018. The sit-to-stand muscle power test: an easy, inexpensive and portable procedure to assess muscle power in older people. Exp. Gerontol. 112, 38–43. https://doi.org/10.1016/j.exger.2018.08.006.

Alcazar, J., Alegre, L.M., Suetta, C., Judice, P.B., E, V.A.N.R., Gonzalez-Gross, M., Rodriguez-Manas, L., Casajus, J.A., JP, M.A., Nielsen, B.R., Garcia-Garcia, F.J., Delecluse, C., Sardinha, L.B., Ara, I., 2021a. Threshold of relative muscle power required to rise from a chair and mobility limitations and disability in older adults. Med. Sci. Sports Exerc. 53 (11), 2217–2224. https://doi.org/10.1249/MSS.0000000000002717.

Alcazar, J., Alegre, L.M., Van Roie, E., Magalhaes, J.P., Nielsen, B.R., Gonzalez-Gross, M., Judice, P.B., Casajus, J.A., Delecluse, C., Sardinha, L.B., Suetta, C., Ara, I., 2021b. Relative sit-to-stand power: aging trajectories, functionally relevant cut-off points, and normative data in a large European cohort. J. Cachexia. Sarcopenia Muscle 12 (4), 921–932. https://doi.org/10.1002/jcsm.12737.

Alcazar, J., Navarrete-Villanueva, D., Manas, A., Gomez-Cabello, A., Pedrero-Chamizo, R., Alegre, L.M., Villa, G., Gusi, N., Gonzalez-Gross, M., Casajus, J.A., Vicente-Rodriguez, G., Ara, I., 2021c. 'Fat but powerful' paradox: association of muscle power and adiposity markers with all-cause mortality in older adults from the EXERNET multicentre study. Br. J. Sports Med. 55 (21), 1204–1211. https://doi.org/10.1136/bjsports-2020-103720.

Alvarez-Bustos, A., Coelho-Junior, H.J., Carnicero, J.A., Molina-Hermosilla, I., Alfonso-Lopez, B., Peinado, I., Checa-Lopez, M., Rodriguez-Manas, L., 2025. Muscle power predicts frailty and other adverse events across different settings. J. Nutr. Health Aging 29 (6), 100555. https://doi.org/10.1016/j.jnha.2025.100555.

American Diabetes Association Professional Practice, C, 2025. 2. Diagnosis and classification of diabetes: standards of Care in Diabetes-2025. Diabetes Care 48 (1 Suppl 1), S27–S49. https://doi.org/10.2337/dc25-S002.

Araujo, C.G.S., Kunutsor, S.K., Eijsvogels, T.M.H., Myers, J., Laukkanen, J.A., Hamar, D., Niebauer, J., Bhattacharjee, A., de Souza, E.S.C.G., Franca, J.F., Castro, C.L.B., 2025. Muscle power versus strength as a predictor of mortality in middle-aged and older men and women. Mayo Clin. Proc. https://doi.org/10.1016/j.mayocp.2025.02.015.

Bahat, G., Kilic, C., Eris, S., Karan, M.A., 2021. Power versus sarcopenia: associations with functionality and physical performance measures. J. Nutr. Health Aging 25 (1), 13–17. https://doi.org/10.1007/s12603-020-1544-8.

Balachandran, A.T., Steele, J., Angielczyk, D., Belio, M., Schoenfeld, B.J., Quiles, N., Askin, N., Abou-Setta, A.M., 2022. Comparison of power training vs traditional strength training on physical function in older adults: A systematic review and Meta-analysis. JAMA Netw. Open 5 (5), e2211623. https://doi.org/10.1001/jamanetworkopen.2022.11623.

Baltasar-Fernandez, I., Alcazar, J., Manas, A., Alegre, L.M., Alfaro-Acha, A., Rodriguez-Manas, L., Ara, I., Garcia-Garcia, F.J., Losa-Reyna, J., 2021. Relative sit-to-stand power cut-off points and their association with negatives outcomes in older adults. Sci. Rep. 11 (1), 19460. https://doi.org/10.1038/s41598-021-98871-3.

Bauer, J., Biolo, G., Cederholm, T., Cesari, M., Cruz-Jentoft, A.J., Morley, J.E., Phillips, S., Sieber, C., Stehle, P., Teta, D., Visvanathan, R., Volpi, E., Boirie, Y., 2013. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE study group. J. Am. Med. Dir. Assoc. 14 (8), 542–559. https://doi.org/10.1016/j.jamda.2013.05.021.

Beauchamp, M.K., Hao, Q., Kuspinar, A., Amuthavalli, Thiyagarajan J., Mikton, C., Diaz, T., Raina, P., 2023. A unified framework for the measurement of mobility in older persons. Age Ageing 52 (Suppl. 4), iv82–iv85. https://doi.org/10.1093/ageing/afad125.

Bernabei, R., Martone, A.M., Vetrano, D.L., Calvani, R., Landi, F., Marzetti, E., 2014. Frailty, physical frailty, sarcopenia: A new conceptual model. Stud. Health Technol. Inform. 203, 78–84. https://www.ncbi.nlm.nih.gov/pubmed/26630514.

Cacciatore, S., Calvani, R., Marzetti, E., Picca, A., Russo, A., Tosato, M., Landi, F., 2024. Physical performance is associated with long-term survival in adults 80 years and older: results from the ilSIRENTE study. J. Am. Geriatr. Soc. 72 (8), 2585–2589. https://doi.org/10.1111/jgs.18941.

Chen, H., Rejeski, W.J., Gill, T.M., Guralnik, J., King, A.C., Newman, A., Blair, S.N., Conroy, D., Liu, C., Manini, T.M., Pahor, M., Ambrosius, W.T., Miller, M.E., Study, L., 2018. A comparison of self-report indices of major mobility disability to failure on the 400-m walk test: the LIFE study. J. Gerontol. A Biol. Sci. Med. Sci. 73 (4), 513–518. https://doi.org/10.1093/gerona/glx153.

Coelho-Junior, H.J., Calvani, R., Alvarez-Bustos, A., Tosato, M., Russo, A., Landi, F., Picca, A., Marzetti, E., 2024a. Physical performance and negative events in very old adults: a longitudinal study examining the ilSIRENTE cohort. Aging Clin. Exp. Res. 36 (1), 33. https://doi.org/10.1007/s40520-024-02693-y.

Coelho-Junior, H.J., Marzetti, E., Picca, A., Tosato, M., Calvani, R., Landi, F., 2024b. Sex- and age-specific normative values of lower extremity muscle power in Italian community-dwellers. J. Cachexia. Sarcopenia Muscle 15 (1), 45–54. https://doi.org/10.1002/jcsm.13301.

CREA Centro di Ricerca Alimenti e Nutrizione. Retrieved 20 June 2025 from. https://www.alimentinutrizione.it/.

Cruz-Jentoft, A.J., Bahat, G., Bauer, J., Boirie, Y., Bruyere, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A.A., Schneider, S.M., Sieber, C.C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., Writing Group for the European Working Group on Sarcopenia in Older, P, the Extended Group for, E, 2019. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 48 (1), 16–31. https://doi.org/10.1093/ageing/afy169.

Cummings, S.R., Studenski, S., Ferrucci, L., 2014. A diagnosis of dismobility–giving mobility clinical visibility: a Mobility Working Group recommendation. JAMA 311 (20), 2061–2062. https://doi.org/10.1001/jama.2014.3033.

da Costa Teixeira, L.A., Soares, L.A., da Fonseca, S.F., Goncalves, G.T., Dos Santos, J.M., Viegas, A.A., Parentoni, A.N., Figueiredo, P.H.S., Mendonca, V.A., Lacerda, A.C.R., 2024. Analysis of body composition, functionality and muscle-specific strength of older women with obesity, sarcopenia and sarcopenic obesity: a cross-sectional study. Sci. Rep. 14 (1), 24802. https://doi.org/10.1038/s41598-024-76417-7.

Folland, J.P., Mc Cauley, T.M., Williams, A.G., 2008. Allometric scaling of strength measurements to body size. Eur. J. Appl. Physiol. 102 (6), 739–745. https://doi.org/10.1007/s00421-007-0654-x.

Freiberger, E., Sieber, C.C., Kob, R., 2020. Mobility in older community-dwelling persons: A narrative review. Front. Physiol. 11, 881. https://doi.org/10.3389/fphys.2020.00881.

Herbert, R.D., Taylor, J.L., Lord, S.R., Gandevia, S.C., 2020. Prevalence of motor impairment in residents of New South Wales, Australia aged 55 years and over: cross-sectional survey of the 45 and up cohort. BMC Public Health 20 (1), 1353. https://doi.org/10.1186/s12889-020-09443-5.

Hetherington-Rauth, M., Magalhaes, J.P., Alcazar, J., Rosa, G.B., Correia, I.R., Ara, I., Sardinha, L.B., 2022. Relative sit-to-stand muscle power predicts an older adult's physical Independence at age of 90 Yrs beyond that of relative handgrip strength, physical activity, and sedentary time: A cross-sectional analysis. Am. J. Phys. Med. Rehabil. 101 (11), 995–1000. https://doi.org/10.1097/PHM.0000000000001945.

Horwath, O., Moberg, M., Edman, S., Philp, A., Apro, W., 2025. Ageing leads to selective type II myofibre deterioration and denervation independent of reinnervative capacity in human skeletal muscle. Exp. Physiol. 110 (2), 277–292. https://doi.org/10.1113/EP092222.

Hunter, S.K., Pereira, H.M., Keenan, K.G., 2016. The aging neuromuscular system and motor performance. J. Appl. Physiol. (1985) 121 (4), 982–995. https://doi.org/10.1152/japplphysiol.00475.2016.

Kirk, B., Cawthon, P.M., Arai, H., Avila-Funes, J.A., Barazzoni, R., Bhasin, S., Binder, E. F., Bruyere, O., Cederholm, T., Chen, L.K., Cooper, C., Duque, G., Fielding, R.A., Guralnik, J., Kiel, D.P., Landi, F., Reginster, J.Y., Sayer, A.A., Visser, M., Global Leadership Initiative in Sarcopenia, g, 2024. The conceptual definition of sarcopenia: Delphi consensus from the global leadership initiative in sarcopenia (GLIS). Age Ageing 53 (3). https://doi.org/10.1093/ageing/afae052.

Landi, F., Calvani, R., Tosato, M., Martone, A.M., Picca, A., Ortolani, E., Savera, G., Salini, S., Ramaschi, M., Bernabei, R., Marzetti, E., 2017. Animal-derived protein consumption is associated with muscle mass and strength in community-dwellers:

results from the Milan EXPO survey. J. Nutr. Health Aging 21 (9), 1050–1056. https://doi.org/10.1007/s12603-017-0974-4.

Landi, F., Calvani, R., Picca, A., Tosato, M., Martone, A.M., Ortolani, E., Salini, S., Pafundi, T., Savera, G., Pantanelli, C., Bernabei, R., Marzetti, E., 2018. Cardiovascular health metrics, muscle mass and function among Italian community-dwellers: the lookup 7+ project. Eur. J. Pub. Health 28 (4), 766–772. https://doi.org/10.1093/eurpub/cky034.

Landi, F., Calvani, R., Martone, A.M., Salini, S., Zazzara, M.B., Candeloro, M., Coelho-Junior, H.J., Tosato, M., Picca, A., Marzetti, E., 2020. Normative values of muscle strength across ages in a 'real world' population: results from the longevity check-up 7+ project. J. Cachexia. Sarcopenia Muscle 11 (6), 1562–1569. https://doi.org/10.1002/jcsm.12610.

Lauretani, F., Russo, C.R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., Corsi, A. M., Rantanen, T., Guralnik, J.M., Ferrucci, L., 2003. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J. Appl. Physiol. (1985) 95 (5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003.

Losa-Reyna, J., Alcazar, J., Carnicero, J., Alfaro-Acha, A., Castillo-Gallego, C., Rosado-Artalejo, C., Rodriguez-Manas, L., Ara, I., Garcia-Garcia, F.J., 2022. Impact of relative muscle power on hospitalization and all-cause mortality in older adults. J. Gerontol. A Biol. Sci. Med. Sci. 77 (4), 781–789. https://doi.org/10.1093/gerona/glab230.

McEvoy, J.W., McCarthy, C.P., Bruno, R.M., Brouwers, S., Canavan, M.D., Ceconi, C., Christodorescu, R.M., Daskalopoulou, S.S., Ferro, C.J., Gerdts, E., Hanssen, H., Harris, J., Lauder, L., McManus, R.J., Molloy, G.J., Rahimi, K., Regitz-Zagrosek, V., Rossi, G.P., Sandset, E.C., Group, E.S.C.S.D., 2024. 2024 ESC guidelines for the management of elevated blood pressure and hypertension. Eur. Heart J. 45 (38), 3912–4018. https://doi.org/10.1093/eurheartj/ehae178.

Prokopidis, K., Cacciatore, S., Piaggi, P., Vetrano, D.L., Schlögl, M., 2025. Muscle strengthening activities: cross-sectional associations with skeletal muscle outcomes in adults aged 50–64 and 65 years and above. Eur Geriatr Med. https://doi.org/10.1007/s41999-025-01327-4.

Quan, Y., Wang, C., Wang, L., Li, G., 2023. Geriatric sarcopenia is associated with hypertension: A systematic review and meta-analysis. J. Clin. Hypertens. (Greenwich) 25 (9), 808–816. https://doi.org/10.1111/jch.14714.

Ramirez-Velez, R., Izquierdo, M., Garcia-Hermoso, A., Ordonez-Mora, L.T., Cano-Gutierrez, C., Campo-Lucumi, F., Perez-Sousa, M.A., 2022. Sit to stand muscle power reference values and their association with adverse events in Colombian older adults. Sci. Rep. 12 (1), 11820. https://doi.org/10.1038/s41598-022-15757-8.

Salini, S., Russo, A., Calvani, R., Covino, M., Martone, A.M., Tosato, M., Damiano, F.P., Picca, A., Marzetti, E., Landi, F., 2022. Self-reported difficulty in walking 400 meters: the "red flag" for probable sarcopenia. BMC Geriatr. 22 (1), 530. https://doi.org/10.1186/s12877-022-03231-z.

Santos, L.P., Gonzalez, M.C., Orlandi, S.P., Bielemann, R.M., Barbosa-Silva, T.G., Heymsfield, S.B., Group, C.S., 2019. New prediction equations to estimate appendicular skeletal muscle mass using calf circumference: results from NHANES 1999-2006. JPEN J. Parenter. Enteral Nutr. 43 (8), 998–1007. https://doi.org/10.1002/jpen.1605.

Strain, T., Flaxman, S., Guthold, R., Semenova, E., Cowan, M., Riley, L.M., Bull, F.C., Stevens, G.A., Author, Country Data, G., 2024. National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: a pooled analysis of 507 population-based surveys with 5.7 million participants. Lancet Glob. Health 12 (8), e1232–e1243. https://doi.org/10.1016/S2214-109X(24)00150-5.

Tomlinson, D.J., Erskine, R.M., Morse, C.I., Winwood, K., Onambele-Pearson, G., 2016. The impact of obesity on skeletal muscle strength and structure through adolescence to old age. Biogerontology 17 (3), 467–483. https://doi.org/10.1007/s10522-015-9626-4.

Travaglini, S., Bonvicini, M., Bandinelli, S., Ferrucci, L., Antonelli Incalzi, R., Pedone, C., 2025. Has muscle power better discriminative capacity compared to muscle strength in predicting worsening disability in older adults? J. Gerontol. A Biol. Sci. Med. Sci. 80 (3). https://doi.org/10.1093/gerona/glaf003.

Wang, G., Zhou, Y., Zhang, L., Li, J., Liu, P., Li, Y., Ma, L., 2024. Prevalence and incidence of mobility limitation in Chinese older adults: evidence from the China health and retirement longitudinal study. J. Nutr. Health Aging 28 (3), 100038. https://doi.org/10.1016/j.jnha.2024.100038.

Yuan, S., Larsson, S.C., 2023. Epidemiology of sarcopenia: prevalence, risk factors, and consequences. Metabolism 144, 155533. https://doi.org/10.1016/j.metabol.2023.155533.