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Low relative mechanical power in older adults: An operational definition and algorithm for its application in the clinical setting

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ABSTRACT

Introduction: The assessment and treatment of low relative muscle power in older people has received little attention in the clinical setting when compared to sarcopenia. Our main goal was to assess the associations of low relative power and sarcopenia with other negative outcomes in older people.

Methods: The participants were 1189 subjects (54% women; 65–101 years old) from the Toledo Study for Healthy Aging. Probable sarcopenia was defined as having low handgrip strength, while confirmed sarcopenia also included low appendicular skeletal muscle index (assessed by dual energy X-ray absorptiometry) (EWGSOP2's definition). Low relative (i.e. normalized to body mass) muscle power was assessed with the 5-repetition sit-to-stand power test (which uses an equation that converts sit-to-stand performance into mechanical power) and diagnosed in those subjects in the lowest sex-specific tertile. Low usual gait speed (UGS), frailty (according to Fried's criteria and the Frailty Trait Scale), limitations in basic (BADL) and instrumental activities of daily living (IADL) and poor quality of life were also recorded.

Results: Age-adjusted logistic regression analyses demonstrated that low relative muscle power was associated with low UGS (odds ratio (OR) = 1.9 and 2.5), frailty (OR = 3.9 and 4.7) and poor quality of life (OR = 1.8 and 1.9) in older men and women, respectively, and with limitations in BADL (OR = 1.6) and IADL (OR = 3.8) in older women (all $p < 0.05$). Confirmed sarcopenia was only associated with low UGS (OR = 2.5) and frailty (OR = 5.0) in older men, and with limitations in IADL in older women (OR = 4.3) (all $p < 0.05$).

Conclusions: Low relative muscle power had a greater clinical relevance than low handgrip strength and confirmed sarcopenia among older people. An operational definition and algorithm for low relative muscle power case finding in daily clinical practice was presented.

1. Introduction

The deterioration of functional capacity is one of the main hallmarks and negative consequences of aging. Notably, presenting functional limitations increases costs associated with falls and hospitalization, and mortality risk to a greater extent than multimorbidity (Grundstrom et al., 2012; Kumar et al., 2017; Landi et al., 2010). Thus, building and maintaining functional ability and intrinsic capacity are key healthy aging goals that must be adopted by health systems (Steves et al., 2012; Thiyagarajan et al., 2019; World Health Organization, 2015).

Sarcopenia has progressively received increased attention due to its association with increased risk of disability and mobility limitations (Baumgartner et al., 1998; Janssen et al., 2002) and their associated heath care costs (Pinedo-Villanueva et al., 2019). Sarcopenia is defined as the age-related loss of muscle mass and strength and its assessment is strongly encouraged in the clinical setting (Cruz-Jentoft et al., 2019).

Abbreviations: ASMI, appendicular skeletal muscle index; BADL, basic activities of daily living; BMI, body mass index; DXA, dual energy X-ray absorptiometry; FTS, frailty trait scale; IADL, instrumental activities of daily living; SMI, skeletal muscle index; STS, sit-to-stand; TSHA, Toledo Study for Healthy Aging; UGS, usual gait speed.

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However, there are other components of the neuromuscular system that may be more relevant for the older adults' functional ability. Mechanical power (or muscle power in humans) declines with age at a higher rate than muscle mass and strength, and has also shown a higher association with functional limitations and mortality than sarcopenia (Akima et al., 2001; Doherty, 2003; Lauretani et al., 2003; Pearson et al., 2002; Reid et al., 2014; Siglinsky et al., 2015; Skelton et al., 1994). Early reports demonstrated the major relevance of muscle power in older people (Bassey et al., 1992; Skelton et al., 1994), but its assessment and utilization has not been adequately encouraged and addressed in the clinical setting. This contrasts with the progressively increased attention that the definition and evaluation of sarcopenia has received during the last decade. One reason for this might be that the traditional instruments and procedures employed to measure muscle power may inherently present several technical and economic barriers that may restrain their use in the clinical setting and in large cohort studies (Alcazar et al., 2017). In this sense, a recent position paper pointed out that the assessment of muscle power cannot be indicated in the clinical setting due to the lack of feasible and standardized protocols (Beaudart et al., 2019).

Interestingly, as recently reported, the assessment of muscle power may be feasible in the clinical setting by means of the sit-to-stand (STS) muscle power test (Alcazar et al., 2020b; Alcazar et al., 2018a). This procedure uses a validated equation that converts STS performance into muscle power and only requires a stopwatch and a chair. Notably, STS muscle power showed a larger association with physical and cognitive function than STS performance and handgrip strength among older people (Alcazar et al., 2020b; Alcazar et al., 2018a). However, the use of the STS muscle power test has not been compared to the assessment of sarcopenia in terms of their associations with other negative outcomes in older men and older women. Finally, it must be considered that the normalization of muscle power to body mass (i.e. relative muscle power) strengthens the relationship of muscle power with physical performance (Alcazar et al., 2018a; Alcazar et al., 2018b; Skelton et al., 1994). Thus, the main goals of the present study were to provide an operational definition and algorithm of low relative muscle power in older people and to assess the ability of sarcopenia and low relative muscle power (evaluated by the STS muscle power test) to associate with impaired gait speed, frailty, disability and poor quality of life. Our hypothesis was that the provided operational definition of low relative muscle power will be more strongly related with the above-mentioned negative outcomes than sarcopenia. In addition, relative muscle power has previously been observed to decline after the fourth decade of life due to age- and sex-specific changes in its contributing factors: allometric power, body mass index, specific power and legs skeletal muscle index (Alcazar et al., 2020). Thus, a second goal of the present investigation was to assess the impact that the different components accounting for relative muscle power have in physical function and frailty.

2. Methods

2.1. Participants

The Toledo Study for Healthy Aging (TSHA) is a prospective cohort study involving men and women over 65 years of age (Garcia-Garcia et al., 2011). Older subjects participating in the TSHA were selected by a two-stage random sampling of the municipal census of the province of Toledo (Spain) (Garcia-Garcia et al., 2011). In total, 1189 older adults (53.7% women) completed all the required examinations and participated in the current investigation (Table 1). The main characteristics of the participants were assessed by the Mini-mental State Examination questionnaire (cognitive function) (Folstein et al., 1975) and the Short Physical Performance Battery (physical performance) (Guralnik et al., 1994). All the study participants signed a written informed consent, and the study protocol was approved by the Clinical Research Ethics Committee of the Complejo Hospitalario de Toledo (Spain).

Table 1
Main characteristics of the study participants.

	Men (n = 550)	Women (n = 639)	*p* value	All (n = 1189)
Age (years)	75.7 ± 5.9	76.0 ± 5.9	0.381	75.8 ± 5.9
Body mass (kg)	76.5 ± 11.9	68.9 ± 12.0	<0.001	72.4 ± 12.5
Height (m)	1.64 ± 0.07	1.50 ± 0.06	<0.001	1.56 ± 0.09
BMI ($kg{\cdot}m^{-2}$)	28.5 ± 3.9	30.5 ± 5.1	<0.001	29.6 ± 4.7
MMSE score	24.9 ± 4.0	23.9 ± 4.2	<0.001	24.4 ± 4.1
SPPB score	9.3 ± 2.0	8.3 ± 2.3	<0.001	8.8 ± 2.2
Katz index	5.9 ± 0.3	5.8 ± 0.4	<0.001	5.9 ± 0.4
Lawton index	6.6 ± 1.6	7.5 ± 1.2	<0.001	7.1 ± 1.5

Note: BMI, body mass index. MMSE, mini-mental state examination. SPPB, short physical performance battery. *p* values denote significant differences between men and women according to unpaired *t*-tests.

2.2. Anthropometrics

Height and body mass were assessed, respectively, with a portable stadiometer (Medizintechnikseit 1890, KaWe, Germany) and a precision scale (SECA 884 floor scale, Germany). Participants removed shoes, socks and heavy clothes prior to these assessments. Body mass index (BMI) was calculated as the ratio between body mass and height^2 ($kg{\cdot}m^{-2}$).

2.3. Sarcopenia

Sarcopenia was defined according to the last report provided by the European Working Group on Sarcopenia in Older People (EWGSOP) (Cruz-Jentoft et al., 2019). Lean mass was assessed by dual energy X-ray absorptiometry (DXA) (Hologic, Serie Discovery QDR, Bedford, USA). DXA scans were analyzed using commercially available software (Physician's Viewer, APEX System Software Version 3.1.2, Bedford, USA) and appendicular lean mass was obtained. Then, appendicular skeletal muscle index (ASMI) was calculated as the ratio between appendicular lean mass and height^2 ($kg{\cdot}m^{-2}$). In addition, a hand held dynamometer (Jamar Preston, Jackson, MI, USA) was utilized to measure handgrip strength. As previously reported, cut-off points for low ASMI were <7.0 $kg{\cdot}m^{-2}$ for men and <5.5 $kg{\cdot}m^{-2}$ for women, while cut-off points for low handgrip strength were <27 kg for men and <16 kg for women (Cruz-Jentoft et al., 2019). Finally, probable sarcopenia was defined as having low handgrip strength and confirmed sarcopenia was defined as having both low handgrip strength and low ASMI.

2.4. Relative muscle power

The STS muscle power test was used to assess mechanical power (Alcazar et al., 2018a). Participants were instructed to perform 5 timed STS repetitions after the cue "ready, set, go!", as fast as possible, on a standardized armless chair (height = 0.43 m) with arms crossed over the chest. Importantly, from the sitting position, they had to fully extend their knees and hips to the standing position, and descend to the sitting position until at least touching the chair with their buttocks. The test was repeated when any of these instructions was broken. The time (±0.01 s) needed to perform 5 STS repetitions was recorded using a stopwatch. Absolute STS muscle power (W) was calculated using the following equation (Alcazar et al., 2018a):

$$STS power\,(W) = \frac{Body\,mass \times 0.9 \times 9.81 \times [Body\,height \times 0.5 - Chair\,height]}{Five\,STS\,time \times 0.1}$$

where body mass is indicated in kg, body height and chair height in m, and five STS time in s. This equation is based on several biomechanical principles that have been clarified elsewhere (Alcazar et al., 2018a). Briefly, 0.9 is a coefficient applied to body mass to calculate the body mass that is displaced during the STS task (whole body mass minus shank and feet mass), 0.5 is a coefficient applied to body height to

calculate leg length, and 0.1 is a coefficient applied to total 5-rep STS time to calculate the average duration of the concentric phase of 1 STS repetition. Then, absolute STS power was normalized to body mass to calculate relative STS power ($W \cdot kg^{-1}$), which denotes the ability to produce mechanical power per unit of body mass. Allometric STS power ($W \cdot m^{-2}$), a scaled measure of mechanical power, was obtained by normalizing absolute STS power to height^2. Finally, specific STS power ($W \cdot kg^{-1}$) was obtained from the ratio between absolute STS power and legs lean mass, and indicates the ability to exert lower-limb mechanical power per unit of lower-limb muscle mass. Legs lean mass was derived from regional analyses conducted on whole body DXA scans. Please note that allometric muscle power can also be obtained from the product of relative muscle power and BMI, while specific muscle power can also be obtained from the ratio between allometric muscle power and legs skeletal muscle index (SMI; ratio between legs lean mass and height^2). Therefore, these components must be part of the operational algorithm to detect low relative muscle power and their causes. Sex-specific tertiles were used to determine low, medium and high levels of relative STS power and its main components (Fig. 1).

2.5. Usual gait speed

Usual gait speed (UGS) was assessed over a 3-m distance. The subjects were asked to walk at their habitual velocity and instructed to continue beyond the 3-m distance to avoid everyone from stopping or slowing down before reaching the 3-m distance. A stopwatch was used to measure the time (s) needed to complete the task, and velocity ($m \cdot s^{-1}$) was calculated. Low UGS was defined as the lowest sex-specific tertile in our sample ($<0.68\ m \cdot s^{-1}$ for men and $<0.55\ m \cdot s^{-1}$ for women).

2.6. Frailty

Two different scales were used to assess frailty: the Fried's frailty syndrome (Fried et al., 2001) and the Frailty Trait Scale (FTS) (García-García et al., 2014). Frailty syndrome was assessed using the procedures presented in the original study (Fried et al., 2001), so it was defined as presenting at least 3 of the following frailty criteria: unintentional weight loss (>4.5 kg in prior year), weakness (sex- and BMI-specific low handgrip strength), slowness (sex- and height-specific low usual gait speed), fatigue (self-reported exhaustion) and physical inactivity (self-reported walking time $<2.5\ h \cdot week^{-1}$ in men and $<2.0\ h \cdot week^{-1}$ in women). The FTS evaluates 7 different dimensions (nutrition, balance of energy, nervous system, physical activity, vascular system, endurance, strength, and gait speed) that in turn are recorded throughout 12 items (García-García et al., 2014). Each of the FTS items scores from 0 to 4 points, with a higher score indicating a higher level of frailty. The items include, among other tests, the assessment of serum albumin levels, verbal fluency, brachial-ankle index (Doppler ultrasonography) and knee extension strength (Lafayette dynamometer). The FTS items are described in further detail in the original publication (García-García et al., 2014). FTS's frailty was defined as scoring ≥50 points (García-García et al., 2014).

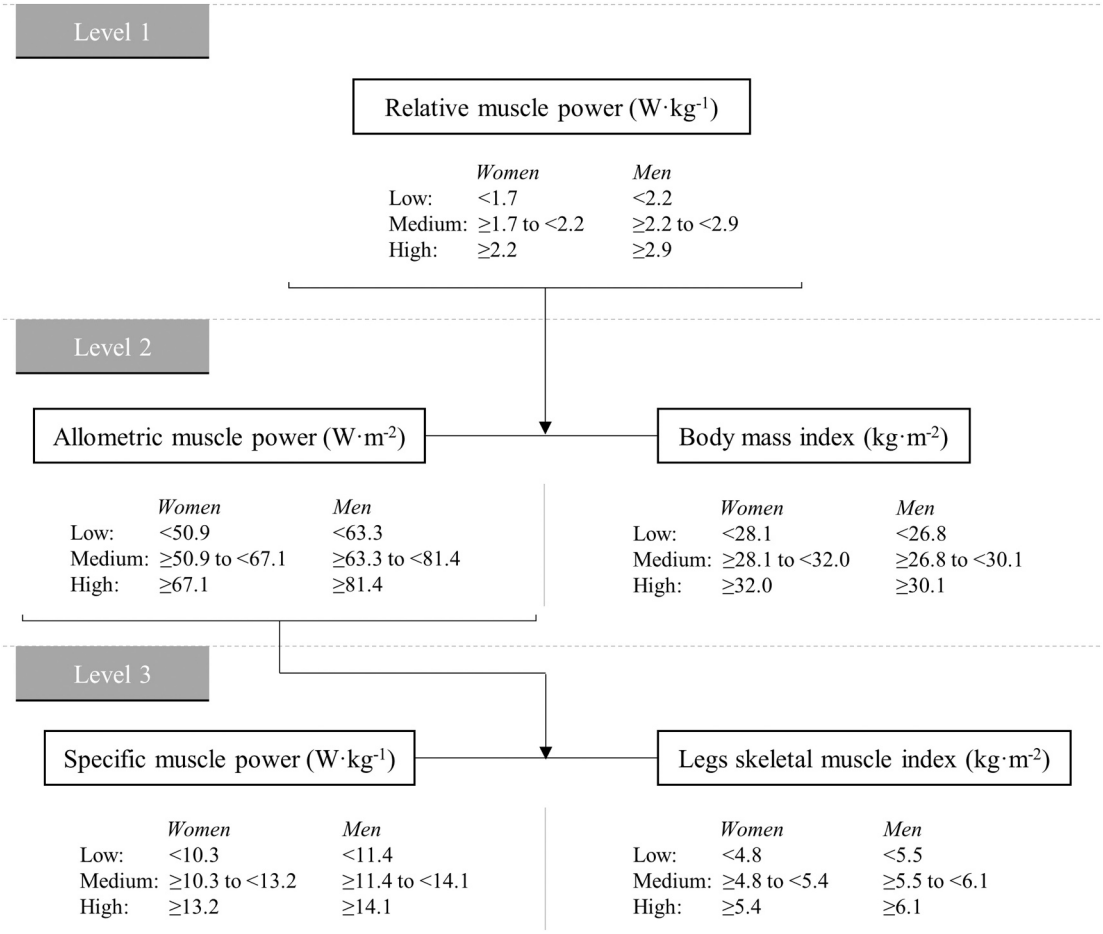

Fig. 1. Hierarchical classification of variables accounting for relative muscle power. Relative muscle power is dependent of allometric muscle power and body mass index. In turn, allometric muscle power is dependent of specific muscle power and legs skeletal muscle index. Low, medium and high levels of each component were calculated based on sex-specific tertiles.

2.7. Disability

Disability in basic and instrumental activities of daily living (BADL and IADL) was assessed by the Katz index (Katz et al., 1970) and the Lawton and Brody Scale (Lawton and Brody, 1969), respectively. In these questionnaires, limitations in BADL (bathing, continence, feeding, toilet use, dressing, and chair/bed transfer) and IADL (cooking, doing laundry, handling medications, using the telephone, housekeeping, shopping, use of transportation, and handling finances) are self-reported by the participants.

2.8. Health-related quality of life

Health-related quality of life was assessed by the EQ-5D-5L questionnaire (Herdman et al., 2011). This questionnaire registers the participants' self-reported information on 5 different dimensions (mobility, pain/discomfort, self-care, anxiety/depression, and usual activities) and health status (Herdman et al., 2011). Poor quality of life was declared in those older adults in the lowest sex-specific tertiles of both EQ-index (<1.00 for men and <0.91 for women) and EQ-visual analogue scale (<70 for men and <50 for women).

2.9. Statistical analysis

Continuous variables were presented as mean ± standard deviation unless otherwise stated. Normality of distribution was confirmed for continuous variables by Shapiro-Wilk's tests. All analyses were performed in women and men separately due to the sex-related differences that have been previously reported regarding the effects of aging on anthropometrics, body composition and muscle function (Alcazar et al., 2020). Logistic regression analyses (odds ratio (OR) [95% confidence intervals (CI)]) adjusted for age were used to assess the associations of sarcopenia and low relative STS power with low UGS, frailty, limitations in BADL and IADL, and poor quality of life. To check the influence of the variables accounting for relative muscle power, differences in UGS and FTS-based frailty among groups of older people presenting various combinations of 1) allometric STS muscle power and BMI and 2) specific STS muscle power and legs SMI were assessed by one-way ANOVA. Pairwise comparisons (vs. reference group) were carried out using Bonferroni's tests in case of homogeneity of variances, and Games-Howell's tests in case of heterogeneity of variances. The reference group was declared to be the group with higher values of relative muscle power and allometric muscle power, respectively: 1) combination of high allometric STS power and low BMI; and 2) combination of high specific STS power and high legs SMI. Finally, to extend the applicability of our proposed algorithm to those contexts in which body composition analysis and legs SMI determination are limited, optimal cut-off points for the recognition of older adults with low legs SMI were assessed by receiver operator characteristic (ROC) curves. Cur-off values of BMI were selected for older men and older women based on the best trade-off between sensitivity and specificity according to the highest product of both. All analyses were carried out with SPSS v22 (SPSS Inc., Chicago, Illinois). The level of significance was set at $\alpha = 0.05$.

3. Results

3.1. Impact of sarcopenia and low relative muscle power on usual gait speed, frailty, disability and quality of life

The age-adjusted associations of probable (low handgrip strength) and confirmed (low handgrip strength plus low ASMI) sarcopenia and low relative muscle power with low UGS, frailty, disability and quality of are shown in Table 2.

Among men, either probable or confirmed sarcopenia augmented the ORs for low UGS and Fried's frailty, while only probable sarcopenia augmented the OR for FTS-based frailty. Confirmed sarcopenia had no impact on FTS-based frailty, limitations in BADL or IADL and quality of life. On the other hand, men experiencing low relative STS muscle power had increased ORs for low UGS, Fried's and FTS-based frailty, and poor quality of life, while no effect on limitations in BADL or IADL was noted.

Among women, probable sarcopenia increased the odds for FTS-based frailty and confirmed sarcopenia increased the odds for having limitations in IADL, but no significant effects were found for any of the other variables. On the other hand, women with a low relative STS power presented increased ORs for low UGS, FTS-based frailty, limitations in BADL and IADL and poor quality of life. However, low relative STS power was not associated with Fried's frailty in women.

3.2. Impact of various combinations of allometric muscle power and body mass index on usual gait speed and frailty

In men, the groups with medium or low allometric STS power displayed lower UGS (all $p \leq 0.002$ and $p < 0.001$, respectively) and higher FTS-based frailty values (all $p < 0.001$) when compared to the reference group independently of BMI levels (Fig. 2A and B). In addition, frailty was higher in the groups with high allometric STS power combined with medium or high BMI (both $p < 0.001$).

In women, lower UGS values were noted in the groups exhibiting low

Table 2
Logistic regression analysis comparing the associations of sarcopenia and low relative sit-to-stand power with other negative outcomes.

	Probable sarcopenia (low handgrip strength)			Confirmed sarcopenia (both low handgrip strength and low ASMI)			Low relative STS power		
	OR	(95% CI)[a]	*p*	OR	(95% CI)[a]	*p*	OR	(95% CI)[a]	*p*
Men									
Low UGS	**2.1**	**(1.3–3.3)**	**0.002**	**2.5**	**(1.2–4.9)**	**0.010**	**1.9**	**(1.2–3.0)**	**0.006**
Frailty (Fried)	**18.4**	**(2.2–155.3)**	**0.007**	**5.0**	**(1.2–20.0)**	**0.023**	**4.5**	**(1.1–18.0)**	**0.036**
Frailty (FTS)	**3.5**	**(2.1–5.9)**	**<0.001**	1.7	(0.8–3.7)	0.157	**3.9**	**(2.4–6.3)**	**<0.001**
≥1 limitation in BADL	1.6	(0.8–2.9)	0.159	2.2	(1.0–4.9)	0.064	1.5	(0.8–2.8)	0.157
≥1 limitation in IADL	1.4	(0.9–2.0)	0.140	1.2	(0.6–2.5)	0.526	1.2	(0.8–1.7)	0.433
Poor quality of life	1.0	(0.6–1.7)	0.927	0.9	(0.4–2.1)	0.874	**1.8**	**(1.1–2.8)**	**0.016**
Women									
Low UGS	1.4	(0.9–2.2)	0.179	2.2	(0.9–5.6)	0.084	**2.5**	**(1.6–3.9)**	**<0.001**
Frailty (Fried)	5.0	(0.9–29.2)	0.072	6.7	(1.0–42.4)	0.055	4.2	(0.8–24.2)	0.110
Frailty (FTS)	**3.2**	**(2.2–4.7)**	**<0.001**	0.6	(0.2–1.5)	0.260	**4.7**	**(3.2–6.9)**	**<0.001**
≥1 limitation in BADL	1.4	(0.9–2.2)	0.140	2.4	(1.0–5.7)	0.052	**1.6**	**(1.1–2.5)**	**0.026**
≥1 limitation in IADL	1.5	(1.0–2.4)	0.052	**4.3**	**(1.6–11.4)**	**0.003**	**3.8**	**(2.5–5.7)**	**<0.001**
Poor quality of life	1.3	(0.9–1.8)	0.204	1.1	(0.5–2.6)	0.797	**1.9**	**(1.3–2.6)**	**0.001**

Note: ASMI, appendicular skeletal muscle index. OR, odds ratio. CI, confidence interval. BADL, basic activities of daily living. UGS, usual gait speed. IADL, instrumental activities of daily living. Bold values and * indicate $p < 0.05$.

[a] All the analyses were adjusted by age.

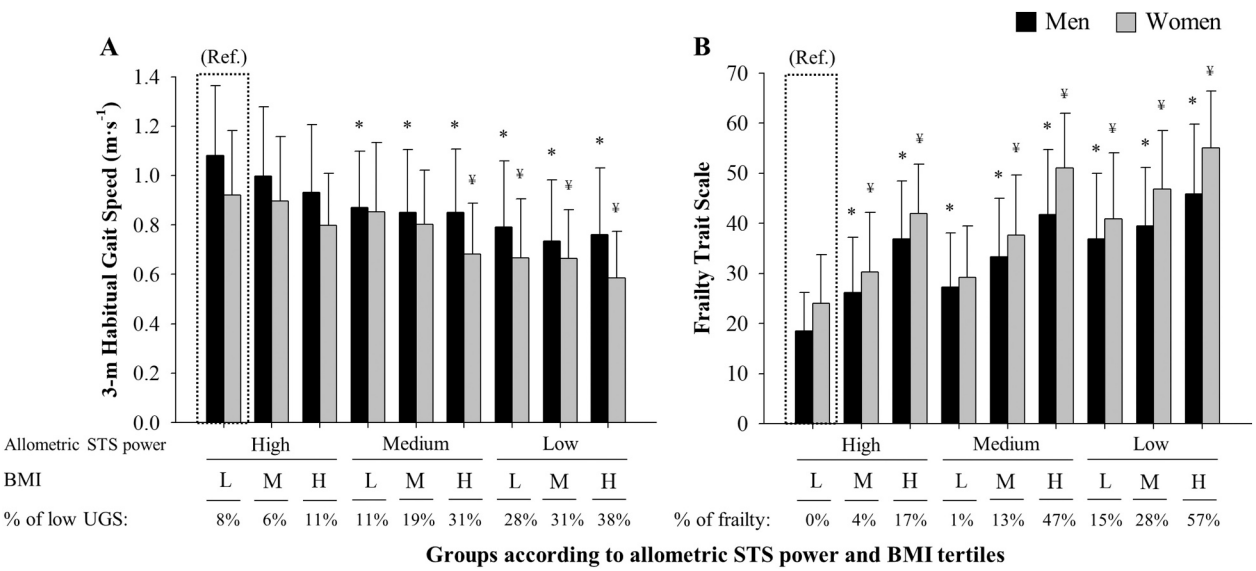

Fig. 2. Comparison of usual gait speed (UGS) (A) and frailty (B) levels among various groups of older men (black bars) and women (grey bars) combining different levels of allometric sit-to-stand (STS) power and body mass index (BMI). Percentages (%) of older people with low UGS (A) and frailty (B) are shown below the bars. Significant differences compared with the reference group are denoted by * in men and ¥ in women ($p < 0.05$). The reference group is H-L (i.e. high allometric STS power and low BMI). Note: H, high. M, medium. L, low.

allometric STS power regardless of BMI (all $p < 0.001$), and also in the group showing a medium allometric STS power in combination with a high BMI ($p < 0.001$) (Fig. 2A). Moreover, FTS-based frailty was higher in women presenting low allometric STS power independently of BMI levels (all $p < 0.001$), in women with medium allometric STS power in combination with medium or high BMI (both $p < 0.001$), and in women exhibiting high allometric STS power plus either medium or high BMI ($p = 0.017$ and $p < 0.001$, respectively) (Fig. 2B).

The percentages of older men and older women experiencing low UGS and frailty are presented in detail at the bottom of Fig. 2.

3.3. Impact of various combinations of specific muscle power and legs skeletal muscle index on usual gait speed and frailty

Men with low specific STS power presented lower values of UGS independently of legs SMI levels (all $p \leq 0.02$). Moreover, men with medium specific STS power combined with either medium or low legs SMI also presented lower UGS levels than the reference group ($p = 0.022$ and $p = 0.002$, respectively) (Fig. 3A). Regarding frailty, the male group with high specific STS power and low legs SMI displayed decreased FTS values ($p = 0.049$), while higher FTS values were noted in the male group with low specific STS power and either high or low legs SMI

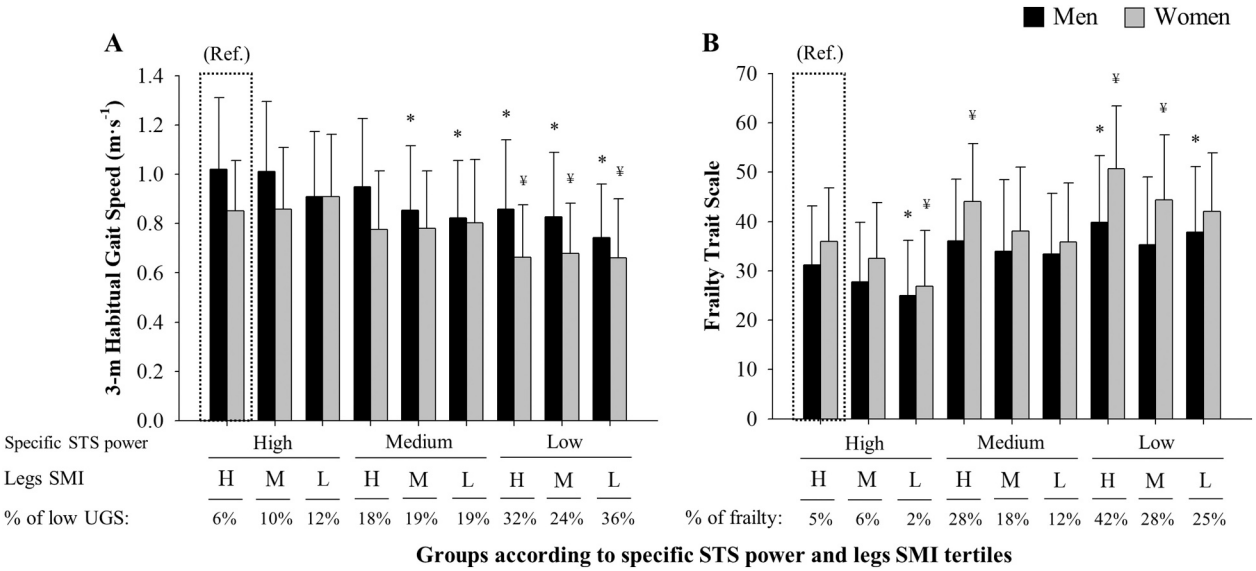

Fig. 3. Comparison of usual gait speed (UGS) (A) and frailty (B) levels among various groups of older men (black bars) and women (grey bars) combining different levels of specific STS power and legs skeletal muscle index (SMI). Percentages (%) of older people with low UGS (A) and frailty (B) are shown below the bars. Significant differences compared with the reference group are denoted by * in men and ¥ in women ($p < 0.05$). The reference group is H-H (i.e. high specific STS power and high legs SMI). Note: H, high. M, medium. L, low.

(Fig. 3B) ($p = 0.002$ and $p = 0.044$, respectively).

In women, UGS was lower in the group exhibiting low specific STS power independently of legs SMI (all $p < 0.001$) (Fig. 3A). Regarding frailty, lower FTS values were noted in women presenting high specific STS power combined with low legs SMI ($p < 0.001$), but frailty augmented in the female group with low specific STS power combined with either high or medium legs SMI ($p < 0.001$ and $p = 0.002$, respectively) (Fig. 3B).

Further details on the percentages of older men and older women with low UGS and frailty can be observed at the bottom of Fig. 3.

3.4. Operational algorithm for low relative muscle power detection

An operational algorithm for the detection of low relative muscle power and the underlying factors that contribute to low relative muscle power is presented in Fig. 4. Cut-off points of BMI below which low legs SMI is probable were 27.9 kg·m^{-2} in men (AUC [95% CI] = 0.87 [0.81–0.93], sensitivity = 83%, specificity = 80%) and 28.5 kg·m^{-2} in women (AUC [95% CI] = 0.88 [0.82–0.94], sensitivity = 81%, specificity = 81%).

4. Discussion

The main findings of the present investigation were: i) low relative muscle power evaluated with the STS muscle power test increased the odds for having low gait speed, frailty and poor quality of life in older men and women, and the odds for having limitations in BADL and IADL in older women alone; ii) probable sarcopenia (low handgrip strength) only augmented the odds for having frailty in older men and women, and the odds for having low gait speed in men alone; iii) confirmed sarcopenia (low handgrip strength plus low ASMI) only increased the odds for having low gait speed and frailty in older men, and the odds for having limitations in IADL in older women; and iv) the negative consequences of low relative muscle power were modulated by the different combinations of allometric muscle power and BMI, and specific muscle power and legs SMI.

Although the relevance of the assessment of sarcopenia in the management of functional trajectories with aging must be acknowledged (Cruz-Jentoft and Sayer, 2019), muscle power has been reported to be of higher relevance for older people's functional ability (Foldvari et al., 2000; Martinikorena et al., 2016; Metter et al., 2004). The superiority of low relative muscle power over sarcopenia in terms of being associated with physical performance, frailty, disability and poor quality of life among older men and women may be due to the fact that muscle power reflects the ability of the motor system to perform mechanical work per unit of time, while other factors such as muscle mass or strength are partial contributors to this ability. However, interestingly low relative muscle power was associated with disability in activities of daily living among older women, but not in older men. Other study in the past reported similar findings regarding the sex-specific association of low muscle function with disability in activities of daily living (Kozicka and Kostka, 2016). Perhaps this fact is related to the unbalance that

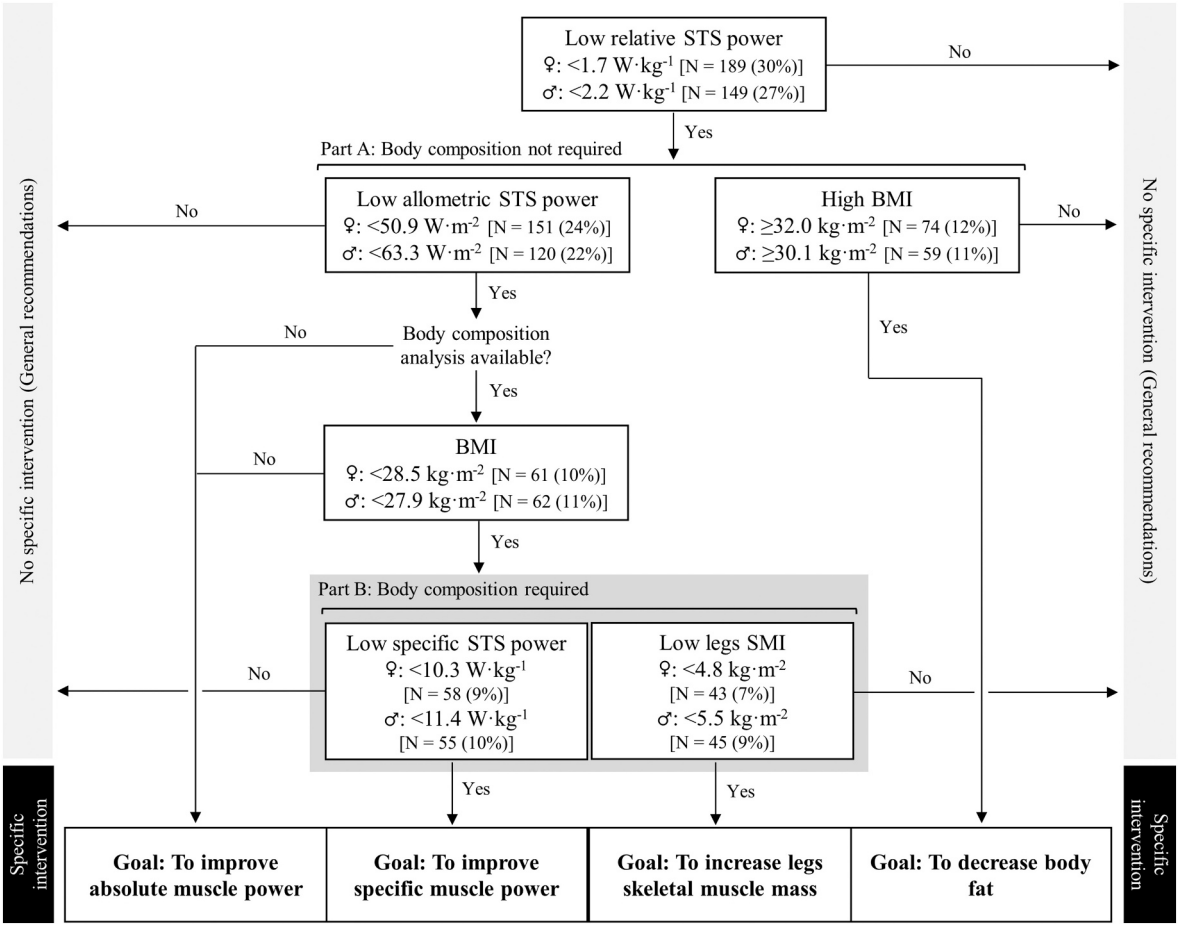

Fig. 4. Algorithm to detect low relative muscle power and their causes. Older adults presenting low relative muscle power should participate in a supervised intervention designed to improve the physiological components accounting for low relative muscle power. Part A of the algorithm can be accomplished without body composition examination. In addition, in those older subjects with low allometric muscle power and low BMI (according to the provided cut-off values), body composition examination (DXA or other validated instrument) should be performed when available in order to determine the specific causes leading to low allometric power. Note: STS, sit-to stand. BMI, body mass index. SMI, skeletal muscle index.

traditionally exists between women and men with respect to participation in household activities (Cerrato and Cifre, 2018). In order to overcome the traditional methodological issues related to muscle power assessment (Beaudart et al., 2019), the STS muscle power test may provide an opportunity to assess muscle power in older people in a feasible, valid and inexpensive way, given that only a chair and a stopwatch are required (Alcazar et al., 2018a). Of note, the traditional repetition- or time-based STS performance measures that are sometimes recommended as a measure of lower-body strength or power are indeed measures of physical performance. The interpretation of STS performance as a measure of muscle strength or power should be strongly discouraged simply because STS performance is not expressed in any strength- or power-related unit (i.e. N or W). The STS muscle power test provides an equation that allows the calculation of legs extensor power from traditional STS data. The STS power test was effectively reported to improve the ability of traditional STS measures to predict physical and cognitive function in older adults (Alcazar et al., 2018a). In addition, as confirmed in the current study, the STS muscle power test was more strongly related to functional performance in older adults than other frequently used measures, such as handgrip strength or muscle power assessed with the Nottingham power rig (Alcazar et al., 2020b). Therefore, this procedure may be truly adequate and feasible in daily clinical practice as well in large cohort studies (Alcazar et al., 2018a).

Accordingly, a flowchart to guide health professionals in evaluating low relative muscle power and determining its causes in their daily practice is proposed in Fig. 4. First, older subjects with low relative muscle power should be identified after conducting the STS muscle power test. In those older adults with low relative muscle power, part A of the proposed algorithm helps to determine whether it is related to low allometric STS power, high BMI, or both. Importantly, DXA scanning is not required in part A. Then, specific interventions aimed to improve allometric STS power, decrease BMI or both, can be appropriately prescribed. In addition, in case of low allometric STS power, whether it is related to low specific STS power, low legs SMI, or both, can be elucidated in part B of the proposed algorithm, which requires of body composition analysis. However, when the costs associated with legs muscle mass determination prevent its application, leg muscle mass might be only recommended in older subjects at risk for low leg SMI according to BMI values (men: BMI <27.9 kg·m^{-2}; and women: BMI <28.5 kg·m^{-2}).

The presented approach has various advantages when compared to the current sarcopenia definition (Cruz-Jentoft et al., 2019). First, the mechanisms accounting for low relative muscle power can be identified and accordingly treated. It is noteworthy that the mechanisms contributing to the loss of relative muscle power with age differ among various stages in life (Alcazar et al., 2020). Throughout the fifth and sixth decades of life (40–60 years old) it seems to be related to the loss of specific muscle power and the increase in BMI, while it is related to the loss of specific muscle power and leg SMI approximately during the seventh and eighth decades of life in men and women, respectively (Alcazar et al., 2020). Thus, older people with low relative power may require different strategies addressing their specific needs, and this can be accomplished with the help of the proposed algorithm. Second, unlike for sarcopenia diagnosis (Cruz-Jentoft et al., 2019), body composition analysis is not imperative to determine low relative muscle power, which may potentially augments its utilization in the clinical setting. In any case, when body composition analysis is available, we provided sex-specific cut-off points to better identify older people with low allometric STS power requiring body composition analysis to discern whether or not it may be related to low legs SMI. This filtering procedure reduces the proportion of older people requiring body composition analysis (11% of older men and 10% of older women) and its associated costs when compared with the percentage of older men and women that would require body composition analysis according to the current sarcopenia definition (i.e. older people from the present study with handgrip strength below the cut-off points proposed by the EWGSOP (Cruz-Jentoft et al., 2019): 25% of older men and 27% of older women).

Most importantly, once all the deficits related with low relative muscle power are identified, these can be treated according to the existing evidence in order to revert this negative condition. For instance, a low relative muscle power related to an excessive BMI can be treated with interventions combining adequate nutrition and exercise training that achieve an appropriate negative energy balance (Villareal et al., 2011). In older adults with low allometric STS power and low specific STS power a power-oriented resistance training program should be prescribed (Byrne et al., 2016; Losa-Reyna et al., 2019). Finally, interventions aiming to increase low legs SMI should include adequate nutrient intake (overall including essential amino acid and β-hydroxy β-methylbutyric acid supplementation, and at least 1.2 g of protein per kg of body mass) and resistance training (Bauer et al., 2013; Cruz-Jentoft et al., 2014).

Definitely, it must be clarified that the differences in gait speed and frailty observed among the different groups of allometric power and BMI, and specific power and legs SMI were due to the underlying differences in relative muscle power among groups. Obviously, having a greater allometric power combined with a lower BMI leads to a greater relative muscle power, which is positively associated with gait speed and negatively associated with frailty. Furthermore, having greater specific power and legs SMI leads to greater allometric power, which in turn should lead to greater relative power. Nevertheless, greater levels of frailty were surprisingly associated with high legs SMI. This fact may be related to older people with high legs SMI having greater BMI as well, leading to less relative muscle power. Indeed, when we conducted a secondary analysis considering normal-weight and obese subjects (i.e. below and above 30 kg·m^{-2}, respectively), there was no relation between legs SMI and frailty. These findings point out that clinical care models for older people require consideration of muscle function, muscle mass and BMI. All these components are regarded within the algorithm proposed in the present study. It should be noted that the application of more clinically relevant tools related with older people's functional ability is supported by the recently encouraged necessity of redesigning care for older people to preserve physical and cognitive performance (Thiyagarajan et al., 2019). Several studies have shown that exercise interventions provide substantial and clinical benefits to either healthy, chronically or acutely ill older people (Cadore et al., 2014; García-Hermoso et al., 2020; Martínez-Velilla et al., 2019; Sáez de Asteasu et al., 2019). In this scenario, our proposed algorithm may help improve the identification of patients needing an exercise intervention and optimize exercise dosing.

There are several limitations that should be acknowledged. This is a cross-sectional study, and thus we cannot establish cause-effect relationships. However, low muscle power has already demonstrated its prognostic value in terms of cognitive decline (Steves et al., 2016), incident disability (Hicks et al., 2012) and mortality (Metter et al., 2004). Moreover, low relative muscle power was established according to sex-specific tertiles in the present study. Thus, further studies should be conducted to find optimal cut-off points based on their ability to detect older adults at an increased risk for frailty and disability.

5. Conclusions

Low relative STS muscle power showed a greater clinical relevance than probable (low handgrip strength) and confirmed (low handgrip strength plus low ASMI) sarcopenia among older men and women. Specifically, low relative STS muscle power was significantly associated with low UGS, frailty and poor quality of life in both older men and women, and with limitations in BADL and IADL in older women; while confirmed sarcopenia was only associated with low UGS and frailty among older men, and with limitations in IADL among older women. The STS muscle power test and the proposed algorithm provides health professionals the opportunity to assess and diagnose low relative muscle power in their daily practice. Additionally, the main determinants of low

relative muscle power can be identified and specific interventions can be prescribed to revert this negative condition.

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Declaration of competing interest

The authors declare no conflicts of interest.

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