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Clinical Relevance of Different Muscle Strength Indexes and Functional Impairment in Women Aged 75 Years and Older

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Background. Muscle mass index has long been used as a useful index to evaluate the risks of developing functional impairments. However, there is evidence that other indexes (particularly muscle strength–based indexes) may be more relevant. Thus, the purpose of this study was to compare the association between different indexes of muscle mass or strength with self-reported and measured functional performance to determine which index would be clinically relevant to detect individuals at risk of functional impairments.

Methods. Data are from 1,462 women aged 75 years and older recruited in the Toulouse EPIDémiologie de l'OStéoporose cohort. Body composition (assessed by dual energy x-ray absorptiometry), handgrip, and knee extension strength were assessed. Physical function was measured using the chair stand test as well as the usual and fast gait speed tests. Participants were also asked if they experienced any difficulty at performing functional tasks.

Results. Results showed that knee extension strength relative to body weight was the strongest correlate of physical function measures ($.30 < r < .40$). Women in the lowest quartile of knee extension strength relative to body weight were 5.9-, 24.7-, 12.1-, and 20.9-fold, respectively, more likely to present impairments at self-reported activities, chair stand test, and usual and fast gait speed compared with women in the highest quartile, respectively.

Conclusions. Knee extension strength relative to body weight appears to be well associated with self-reported difficulties and functional impairments. A threshold between 2.78 and 2.86 (knee extension strength [kPa]/body weight [kg]), determined using receiver operating characteristics curves analysis, may be a potential cut point to discriminate women presenting higher functional impairments.

Key Words: Muscle strength—Mobility limitation—Disability evaluation—Aging—Women.

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WITH the aging of the "baby boomers" population, prevalence of multiple types of disability, including activities of daily living (ADL), instrumental activities of daily living (IADL), and mobility limitations is expected to increase (1). In turn, a heavy burden may be imposed on families and society because of the increased health care and assistance needs associated with this phenomenon. To intervene before the onset of physical impairments, more efficient tools are needed to identify individuals most likely to present functional impairments.

It is now widely recognized that muscle functioning, in its broadest sense, plays a key role in maintaining functional independence. For the past 30 years, special emphasis was put on sarcopenia (the age-associated loss of muscle mass [2]) assuming that the loss of muscle mass may be directly and fully responsible for the loss of muscle strength and function. The first evidence, based on cross-sectional studies, suggested that the association between sarcopenia and physical function was moderate to strong in magnitude. However, findings from recent longitudinal studies showed that the effects of sarcopenia on functional impairment and physical disability were overestimated (3). This is concomitant with results reporting a dissociation between muscle mass and strength. For instance, longitudinal analysis from the Health ABC Study showed that regardless of the variation of muscle mass, both men and women (3,075 participants aged 70–79 years at baseline) lost muscle strength during the 5 years of the study (4).

Afterward, more evidence demonstrated that muscle strength would be a better indicator of functional capacity, risks of hospitalization, and mortality than muscle mass (5,6). In light of this, low muscle quality (defined as the ratio of strength to muscle mass) and low muscle strength have been suggested as potential indexes for identifying individuals at risk of functional impairments (7,8).

Because the main purpose of measuring muscle mass is to evaluate the risk for an individual to present impairments and that this index is no longer the most relevant indicator, there is a need to establish new ones. According to the literature, indexes based on muscle strength measurements are expected to be more relevant than those based on muscle mass. Furthermore, recent evidence suggests that the muscle strength per body weight ratio index would be particularly appropriate (9). The secondary analyses presented in this article aim to determine which indexes would be clinically relevant to detect individuals at risk of functional impairments by comparing the association between different indexes of muscle mass or strength with self-reported difficulties and functional capacity test scores.

Methods

Study Population

Data for this study were obtained from the EPIDemiologie de l'OSteoporose (EPIDOS) study. EPIDOS is a prospective cohort study carried out in five French cities (Amiens, Lyon, Montpellier, Paris, and Toulouse) whose primary purpose was to assess hip fracture risk factors in a healthy community-dwelling population of elderly women. The sampling and data collection procedures were previously described in detail (10). Briefly, all women aged 75 years and older and living in one of the five cities were invited to participate by mail through the use of population-based listings, such as voter registration or health-insurance membership rolls or conferences in associations such as "third-age university" and advertisements. To be included, women had to (a) live in the community, (b) have no previous history of hip fracture or hip replacement, and (c) be able to understand and answer the questionnaire. This study was limited to the 1,462 Toulouse participants. All participants gave written informed consent. The program was approved by the Toulouse Hospital ethics committee. The baseline examination was performed in a clinical research center by a trained geriatric nurse.

Demographic and Health Assessment

A physical examination and health status questionnaire were used to record comorbid conditions (hypertension, diabetes, cancer, stroke, Parkinson's disease, depression, or other disease), and the use of medication and dietary supplements. Cognitive impairment was assessed with Pfeiffer's test (11) and a test score of less than 8 was considered low. The highest level of education (illiterate, elementary, primary school, high school, or postgraduate school) was noted. Participants also self-reported in a structured questionnaire whether they regularly practiced leisure physical activities, such as walking, gymnastics, cycling, swimming, or gardening. The type, frequency, and duration of each leisure physical activity were recorded. Women were considered physically active if they practiced at least one recreational physical activity for greater than or equal to 1 h/wk for the past month or more. Monthly income was divided into four groups: less than 450€, 450–900€, 900–1,300€, and more than 1,300€.

Anthropometric Measurement and Body Composition Assessment

Anthropometric measurements (weight and height) were performed using standardized techniques (12). Dual energy x-ray absorptiometry (QDR 4500W Hologic, Waltham, MA) was used to measure muscle mass and fat mass. Dual energy x-ray absorptiometry measurements were performed by a trained technician, and the dual energy x-ray absorptiometry machine was regularly calibrated.

Sarcopenia was based on appendicular skeletal muscle mass (ASM) measures. ASM corresponds to the sum of the two upper and lower limb muscle masses in kilogram. ASM was then normalized for height (ASM/height^2). Participants were considered sarcopenic if they were in the lowest quartile of ASM index (ASMI). For this index and the following muscle indexes, quartiles were used to maximize the variance between groups.

Muscle Strength Measurement

Handgrip strength.—Handgrip strength was measured on the dominant hand with a hydraulic hand dynamometer (Martin Vigorimeter, Medizin Tecnik, Tuttlingen, Germany). The size of the grip was adjusted so that the participant felt comfortable. The participant stood upright with the arm vertical and the dynamometer close to the body. The maximal peak pressure expressed in kilopascal was recorded for a set of three contractions. Handgrip strength measurements were analyzed as a continuous variable and by quartiles.

Knee extension strength.—Knee extension strength was assessed using a strain gauge system attached to a chair upon which participants were seated with both hips and knees flexed at 90° angle. The tested leg was fixed to the lever arm on an analog strain gauge to measure strength. The highest of three maximum voluntary contractions expressed in kilopascal was recorded for the dominant leg. Leg strength measurements were analyzed as a continuous variable and by quartiles.

Relative Muscle Strength Indexes Calculation

Two relative muscle strength indexes were calculated by dividing handgrip strength (upper body relative muscle strength [UB-RMS]) and knee extension strength (lower body relative muscle strength [LB-RMS]) by body weight. Participants were then divided in quartiles based on their UB-RMS and LB-RMS indexes. Participants in the lowest quartile of UB-RMS or LB-RMS index were considered to have a low UB-RMS or LB-RMS, respectively.

Muscle Quality Calculation

Upper body muscle quality (UB-MQ) was calculated by dividing handgrip strength by upper limbs muscle mass. Lower body muscle quality (LB-MQ) was calculated by dividing leg strength by lower limbs muscle mass. Participants were then divided in quartiles based on their UB-MQ and LB-MQ indexes. Participants in the lowest quartile of UB-MQ or LB-MQ index were considered to have a low UB-MQ or LB-MQ, respectively.

This definition of muscle quality is commonly used in large-scale studies (5,13,14) because of its convenience. However, it is not without its limitation because it also involves nonmuscular aspects of force generation such as neural activation (15). Thus, it slightly differs from the definition commonly used in human studies of smaller scale or in animal studies where more accurate measurements can be performed (eg, electrically stimulated muscle strength measurement).

Physical Function Assessment

Moving impairments.—Participants were asked by a trained research nurse if they had difficulty (no, some, or serious difficulty) performing different physical tasks: walking, climbing stairs, rising from a chair or bed, picking up an object from the floor, and lifting heavy objects or reaching objects. For each physical task, women who reported "some" or "serious" difficulty were considered to have difficulty performing that task. Women with three or more self-reported difficulties among the physical tasks were considered having "moving impairments." As previously suggested (16), having difficulty performing several functional tasks may better characterize individuals with high limitations in everyday life than would be characterized based on difficulty performing a single physical function.

Repeated chair stands test.—This test was performed using a straight-backed chair, placed with its back against a wall. Participants were first asked to stand from a sitting position without using their arms. If they were able to perform the task, they were then asked to stand up and sit down 5 times, as quickly as possible with arms folded across their chests. The time to complete five stands was recorded. For further analysis, women were divided in quartiles based on their performance. Women belonging to the quartile with the poorer score (high time required to perform the test) were considered having impairment. Quartiles were used to maximize the variance between groups.

Gait speed.—Participants were asked to walk at their usual pace over a 6-m course. Participants were instructed to stand with both feet touching the starting line and to start walking after a specific verbal command. Participants were allowed to use walking aids (cane, walker, or other walking aid) if necessary, but no assistance was provided by another person. Timing began when the command was given, and the time in seconds needed to complete the entire distance was recorded. The faster of two walks was used for the present analysis. Women were then divided in quartiles based on their performance. Women belonging to the quartile with the poorer score (high time required to cover the distance) were considered having impairment.

This test was then repeated under the same conditions, by asking participants to cover the same distance walking as fast as possible. The faster of two walks was recorded. Women were then divided in quartiles based on their performance. Women belonging to the quartile with the poorer score (high time required to cover the distance) were considered having impairment. For usual and fast gait speed, quartiles were used to maximize the variance between groups.

Statistical Analysis

Stepwise multiple regression analyses were used to determine the predictors of impairments with the physical function measures among the body composition or muscle strength measurements. Before entering variables in the model, a correlation table including the different indexes of muscle mass and strength was generated to bring out groups of highly correlated variables. Three groups emerged (muscle mass indexes, as well as lower limb and upper limb strength indexes) in which R values were greater than 0.70. Among muscle mass and upper limb muscle strength indices, ASMI and UB-RMS were the indexes most highly correlated with the other indexes of their own group, whereas weakly related to indexes of other groups ($r < .40$). However, among the "lower limb muscle strength indexes" group, LB-RMS, LB strength, and LB-MQ appeared interchangeable. Then, LB-RMS, LB-strength, and LB-MQ were successively, one by one, entered in the model, with UB-RMS and ASMI. Stepwise multiple regression analyses were adjusted for age. Logistic regression models were used to identify the odds of having impairments with the physical function measures associated with poor muscle mass or muscle strength measurements. Logistic regression models were adjusted for age and cortisol intake. Additionally, receiver operating characteristics curves were constructed to assess the ability of the LB-RMS index to discriminate between women with impairments from women without impairments and determine the optimal cutoff values. Analyses were performed using SPSS 17.0 (Chicago, IL). $p < .05$ was considered statistically significant. Unless specified, all data are presented as mean ± *SD*.

Results

Participants' main characteristics are presented in Table 1. Using the total sample, average age was 80.4 years (*SD* = 3.9). The average weight was 58.7 kg (*SD* = 9.9), for a body mass index of 25.2 (*SD* = 4.0), and an average fat mass percentage of 36.3 (*SD* = 8.3). Average handgrip and leg strength were 53.9 kPa (*SD* = 13.4) and 174.0 kPa (*SD* = 49.3), respectively. Within the 1,462 participants, 37.1 were physically active. About 47.7% of participants had hypertension, 18.2% had stroke, 14.9% had cognitive impairment, and 12.9 % had depression.

Table 1. EPIDOS-Toulouse Cohort Psychosocial and Physical Characteristics (January 1992–January 1994)

Variables	Mean (*SD*)
Age (y)	80.4 (3.9)
Education level (%)	
Illiterate	1.4
Elementary	17.6
Primary	41.1
High school	29.0
Postgraduate degree	10.8
Income (%)	
<450 euros/mo	36.0
450–900 euros/mo	21.7
900–1,300 euros/mo	36.5
>1,300 euros/mo	5.8
Lifestyle habits (%)	
Physically active*	37.1
Current smoking	3.7
Anthropometric measures	
Body weight (kg)	58.7 (9.9)
Body mass index (kg/m^2)	25.2 (4.0)
Fat mass (%)	36.3 (8.3)
Appendicular lean body mass (kg)	14.86 (2.04)
Appendicular lean body mass index (kg/m^2)	6.37 (0.77)
Muscle strength measures	
Handgrip strength (kPa)	53.9 (13.4)
Knee extension strength (kPa)	174.0 (49.3)
Arm muscle quality (kPa/kg)	14.5 (4.3)
Leg muscle quality (kPa/kg)	16.0 (4.5)
Upper body relative muscle strength (kPa/kg)	0.9 (0.3)
Lower body relative muscle strength (kPa/kg)	3.0 (0.9)
Comorbidities (%)	
Hypertension	47.7
Stroke	18.2
Diabetes	5.3
Cancer	5.2
Depression	12.9
Parkinson's disease	3.5
Cognitive impairment†	14.9

Notes: *Defined as participation in a recreational physical activity (hiking, gymnastics, cycling, swimming, or gardening) regularly (≥1 h/wk) for ≥1 mo.

†Defined as a Pfeiffer score <8.

As a means of examining a greater depth of the relationship between functional impairments and muscle strength and mass indexes, we performed stepwise regression analyses including ASMI, UB-RMS, and LB-RMS or LB-strength or LB-MQ to predict self-reported and performance-based impairments. We observed an absence of intercorrelation between residuals (Durbin-Watson: 0.324–1.758) and no problem of multicollinearity between variables (variance inflation factor: 1.278–1.294; tolerance: 0.773–0.782). Thus, the model respected the postulates of a stepwise linear regression. Regardless of the functional measure considered and "the lower-body muscle strength index" (LB-RMS or LB-strength or LB-MQ) entered in the model (with ASMI and UB-RMS), this lower body muscle strength index (LB-RMS or LB-Strength or LB-MQ) was systematically the best associated with the score at the functional task. Furthermore, for each task, the strongest model was obtained when LB-RMS was entered in the analyses. LB-RMS explained 9%, 12%, 14%, and 15% of the variance of self-reported mobility function, repeated chair test score, normal and fast gait speed, respectively.

Odds of having impairments with self-reported activities, repeated chair test, and usual and fast gait speed according to different muscle strength indexes are presented in Figures 1–4. Briefly, women in the lowest quartile of LB-RMS were, respectively, 5.9- (4.1–8.9), 24.7- (14.0–43.7), 12.1- (7.2–20.2), and 20.9-fold (11.8–37.0) more likely to have impairments in self-reported activities, repeated chair test, and usual and fast gait speed compared with women in the highest quartile (Table 3). Odd ratios for impairments for women belonging to the second and third tertiles compared with the highest tertile are also presented in Table 2. Additional analyzes concerning fat mass percentage were also performed. These showed that women in the highest quartile of fat mass percentage were, respectively, 2.6- (1.8–3.6), 1.9- (1.2–3.0), 3.7- (2.3–5.9), and 4.2-fold (2.6–6.8) more likely to have impairments in self-reported activities, repeated chair test and, and usual and fast gait speed compared with women in the lowest quartile.

Thresholds for LB-RMS were identified using receiver operating characteristics curves analysis. Generally, the LB-RMS threshold was around 2.8 (2.86, 2.80, 2.78, and 2.78 for moving impairments, repeated chair test, and usual and fast gait speed, respectively). Associated specificity and sensitivity of the LB-RMS thresholds for moving impairments, repeated chair test, and usual and fast gait speed were 63/64, 67/67, 64/66, and 63/68, respectively. Therefore, values less than this threshold could potentially identify individuals who are at risk of functional impairment.

Discussion

Health care and assistance needs due to impairments are expected to increase in the coming years. Determining a

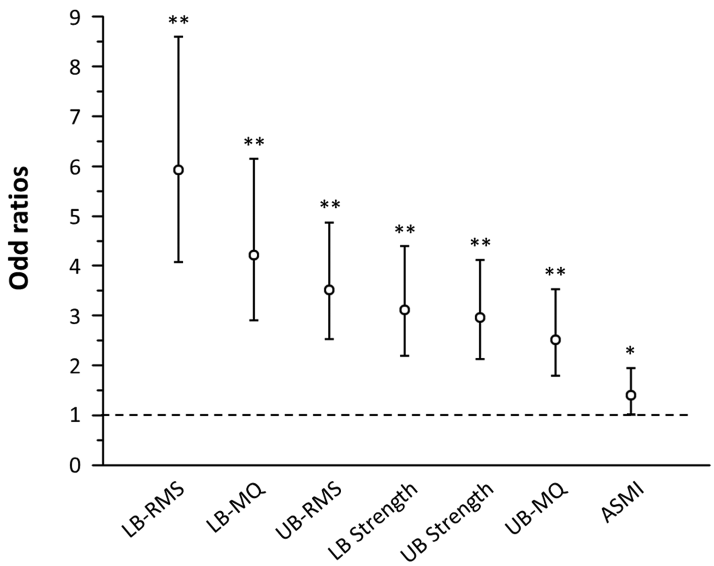

Figure 1. Odd ratios (ORs) of having impairments at the self-reported mobility function for individuals in the lowest quartile of scores for each index compared with individuals in the highest quartile. For each index, participants in the higher quartile were used as the reference category. The circles represent ORs and the bars represent the 95% confidence interval (CI). Logistic regression analyses were controlled for age and cortisol intake. RMS = relative muscle strength; MQ = muscle quality; LB = lower body; UB = upper body; ASMI = appendicular skeletal muscle mass index. *$p < .05$; **$p < .001$.

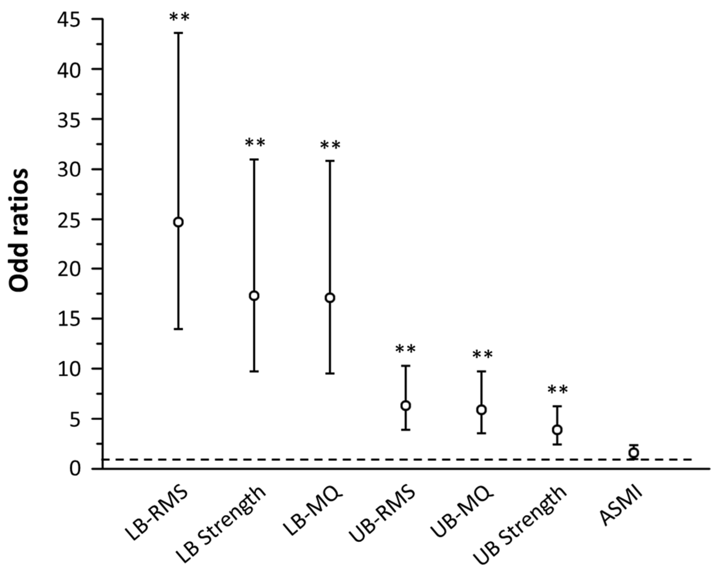

Figure 2. Odd ratios (ORs) of having impairments at the repeated chair test for individuals in the lowest quartile of scores for each index compared with individuals in the highest quartile. For each index, participants in the higher quartile were used as the reference category. The circles represent ORs and the bars represent the 95% confidence interval (CI). Logistic regression analyses were controlled for age and cortisol intake. RMS = relative muscle strength; MQ = muscle quality; LB = lower body; UB = upper body; ASMI = appendicular skeletal muscle mass index. *$p < .05$; **$p < .001$.

clinical index to identify individuals at risk of impairments may help health practitioners to provide appropriate treatment for prevention of these negative events in order to limit the society and families of this burden.

The aim of the present secondary analyses was to compare the association between different indexes of muscle mass or strength with self-reported difficulties and functional capacity test scores to determine which would be relevant to detect postmenopausal women at risk of impairments in a well-characterized cohort. In addition, we attempted to determine an operational cut point for the most relevant index.

The major finding of these analyzes was the strong and systematic association between the LB-RMS index and self-reported and measured functional performances compared with several other potential or currently used indexes.

Muscle mass index has long been used as a useful index to evaluate the risks of developing functional impairments in older women. In line with this, our results showed that having a low ASMI was associated with increased

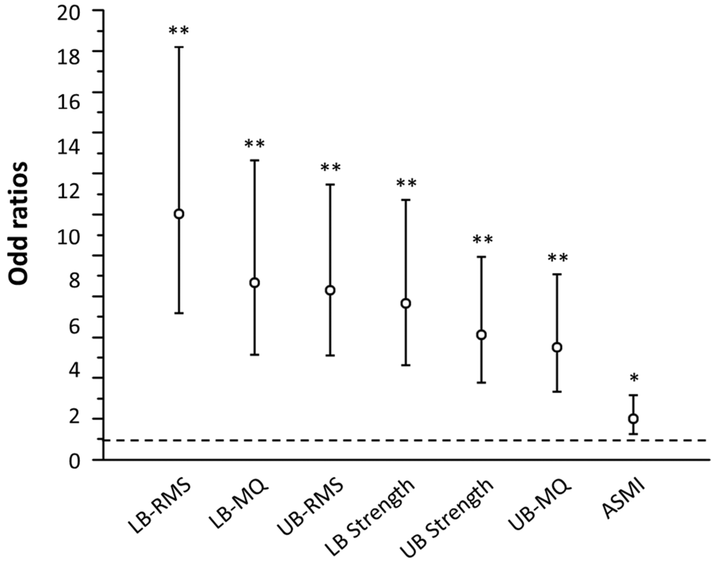

Figure 3. Odd ratios (ORs) of having impairments at the usual gait speed test for individuals in the lowest quartile of scores for each index compared with individuals in the highest quartile. For each index, participants in the higher quartile were used as the reference category. The circles represent ORs and the bars represent the 95% confidence interval (CI). Logistic regression analyses were controlled for age and cortisol intake. RMS = relative muscle strength; MQ = muscle quality; LB = lower body; UB = upper body; ASMI = appendicular skeletal muscle mass index. *$p < .05$; **$p < .001$.

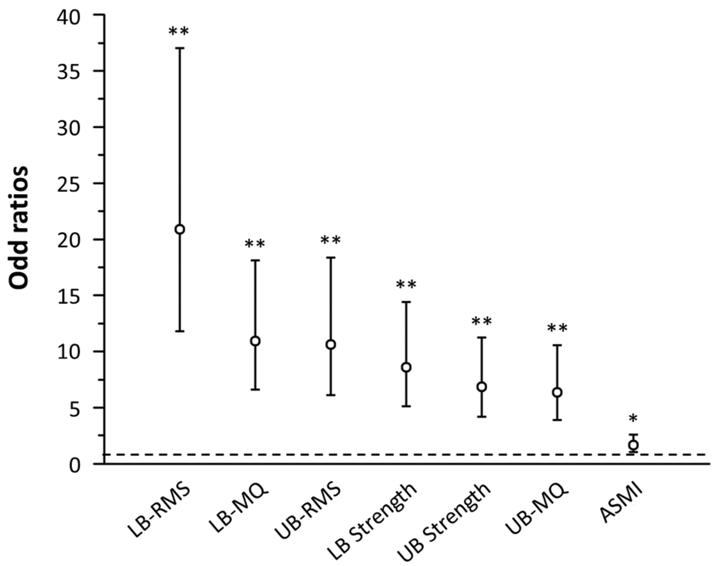

Figure 4. Odd ratios (ORs) of having impairments at the fast gait speed test for individuals in the lowest quartile of scores for each index compared with individuals in the highest quartile. For each index, participants in the higher quartile were used as the reference category. The circles represent ORs and the bars represent the 95% confidence interval (CI). Logistic regression analyses were controlled for age and cortisol intake. RMS = relative muscle strength; MQ = muscle quality; LB = lower body; UB = upper body; ASMI = appendicular skeletal muscle mass index. *$p < .05$; **$p < .001$.

risks (1.4- to 2-fold) of having self-reported disabilities and low functional capacity test scores, which is close, although slightly lower, to previously observed results (17–19). For instance, in the New Mexico Elder Health Survey, sarcopenic women aged 73.7 ± 6.1 years were from 1.1 to 4.1 times more likely to have physical disabilities (19). Similarly, in the Third National Health and Nutrition Examination Survey, sarcopenic women aged 60 years and older were from 1.8 to 4 times more likely to have physical disabilities (17).

However, analyzes clearly demonstrate that the association between functional impairments and ASMI is much weaker than with muscle strength indexes (upper and lower RMS or MQ). Regardless of the muscle strength index used, the risk of presenting disabilities is at least three times higher in individuals with low indexes values compared with individuals with high indexes values. Among these indexes, the LB-RMS index seems to be the most relevant. It is also particularly appropriate because it combines two measures (body weight and quadriceps

Table 2. Risk of Functional Impairment According to Lower Body Relative Muscle Strength (LB-RMS) Quartiles

	Quartile 4 (>3.62 kPa/kg)	Quartile 3 (2.98–3.62 kPa/kg)	Quartile 2 (2.43–2.98 kPa/kg)	Quartile 1 (<2.43 kPa/kg)
Self-reported mobility function				
Model 1	1	1.92 (1.30–2.83)*	3.08 (2.12–4.48)†	6.12 (4.23–8.86)†
Model 2	1	1.86 (1.26–2.75)*	2.97 (2.04–4.33)†	5.93 (4.09–8.60)†
Repeated chair test				
Model 1	1	3.39 (1.98–5.80)†	7.69 (4.52–13.10)†	23.95 (13.68–41.92)†
Model 2	1	3.24 (1.88–5.59)†	7.66 (4.47–13.14)†	24.69 (13.96–43.67)†
Usual gait speed				
Model 1	1	1.92 (1.17–3.15)*	5.22 (3.17–8.60)†	11.66 (7.06–19.25)†
Model 2	1	1.85 (1.11–3.08)*	5.09 (3.05–8.50)†	12.05 (7.18–20.22)†
Fast gait speed				
Model 1	1	3.26 (1.92–5.53)†	7.31 (4.31–12.39)†	18.41 (10.62–31.92)†
Model 2	1	3.24 (1.87–5.62)†	7.55 (4.37–13.04)†	20.92 (11.81–37.03)†

Notes: Data are presented as odds ratio (95% confidence interval).
Quartile 4: Highest value of LB-RMS. Model 1: unadjusted and Model 2: adjusted for age and cortisol consumption.
*$p < .05$ and †$p < .001$.

muscle strength) that may be relatively accessible in a clinical setting.

In line with our observation, the predominant role of lower extremities in performing ADL has previously been emphasized (20,21). However, because the tasks evaluated in this study mainly engage the lower limbs, our results may have been influenced by the choice of the tasks itself. Handgrip strength has been repeatedly shown to be a strong predictor of disability and mortality (22,23), and it is not excluded that if upper body functional tasks had been employed, results favoring handgrip strength (rather than quadriceps muscle strength) may have been found. Therefore, relative handgrip strength should not be overlooked.

The tasks evaluated may also justify the role of body weight. Walking, rising from a chair, or climbing stairs requires moving and carrying its own weight and our results suggest that muscle function (eg, quality) or body composition alone (eg, muscle mass or fat mass percentage) may not matter as long as enough strength is generated to move the entire body. Indeed, although individuals in the highest quartile of fat mass percentage had a 2- to 4-fold increased risk of having impairments, this risk is very low compared with an individual with a low LB-RMS. Thus, in terms of functional capacity, if losing weight (and more particularly fat mass) would be beneficial, losing weight while maintaining or increasing muscle strength would be even more beneficial because clearly, the combination of these two factors appears decisive.

It is, however, interesting to note that, although LB-RMS was systematically the best correlate of functional performances, the percent of explained variance is relatively low (9%–15%), implying that other parameters are involved. Some of them were very well identified. For example, Cuoco and colleagues (24) showed that contraction velocity was a strong determinant of usual gait speed, a task highly predictive of subsequent disability. Similarly, Clark and colleagues (25) observed that impaired activation of agonist quadriceps and concomitant deficits in muscle torque and power may contribute to compromised mobility function. Certainly, these and other parameters might strengthen our model; however, the reader should keep in mind that the purpose of our analysis is to identify an index that would be both convenient and effective.

Previous studies used a similar index based on quadriceps muscle strength to assess the risk of functional incapacities (26,27). In a cohort of 99 men and women aged 52–92 years, Ploutz-Snyder and colleagues (26) observed a strong relationship between this index and chair rise, gait speed, and stair ascent and descent and function. They also identified thresholds (3–3.5 Nm/kg) below which functional performance began to be impaired. In the Health ABC Study, Manini and colleagues (27) reported that such index well identify older adults who are at high, moderate, and low risk of future mobility limitation. Furthermore, they determined that high risk of severe mobility limitation corresponded to less than 1.13 Nm in men and 1.01 Nm in women. Although highly relevant, the main shortcoming of these studies is the lack of comparison with other indexes, so that it is impossible to assert, based on these studies, that this index is more appropriate than others. On the other hand, Choquette and colleagues (9) recently showed that this index was better associated with functional performance than other muscle strength or body composition indexes. For instance, individuals in the lowest tertile of quadriceps strength to body weight ratio were seven times more likely to present a low mobility compared with individuals on the highest tertile, whereas individuals in the lowest tertile of muscle mass index were two more likely to have mobility limitation compared with individuals in the highest tertile. However, only a few strength-based indexes were considered (eg, muscle quality was not considered). Furthermore, although their results have highlighted the LB-RMS index, no thresholds were determined, and the cohort studied included both men and women.

The present analyses add to the current literature on aging and functional capacity by both comparing several indexes, which represent varied aspects of muscle function and determining cut points that could be used to target individuals most likely to benefit from interventions in a relatively homogeneous, well characterized, and older cohort than previously studied (9). As previously mentioned, the LB-RMS index may be the most relevant because it was the strongest correlate of physical function measures. Receiver operating characteristics curves analysis also showed that a threshold between 2.78 and 2.86 kPa/kgBW would be appropriate. Such threshold must however be considered with caution as the sensitivity and specificity associated with this cut point are relatively low (64–68 and 63–67, respectively). Previous study attempted to determine cut points. By comparison, the sensitivity and specificity were of 58 and 58, respectively, for the cut point proposed by Cress and Meyer (28) and 76–81 and 78–94 for the cut points proposed by Ploutz-snyder and colleagues (26).

MQ has been proposed as a potential clinical index of functional impairments (7). Our results showed that indeed, MQ is well associated with self-reported and functional difficulties. However, its role in functional performance and its ability to discriminate individuals at risk of disability appears to be lower than that of LB-RMS. MQ may be perceived as a good indicator of muscle function but neglects body composition, whereas the latter may play a key role in functional performance.

The term dynapenia has been proposed to qualify the age-related loss of muscle strength (8). These authors now advocate the proposal of an objective definition of this concept (29) and take for example the proposed definition of sarcopenia made by the European Working Group on Sarcopenia in Older People, which is based on clinical and operational tools. As observed in our results, the relationship between muscle strength and functional performance varies depending on how muscle strength is defined (absolute or relative muscle strength). From a clinical perspective, it appears that the muscle strength to body weight ratio (and particularly quadriceps strength, although its clinical assessment may be discussed) is the most adapted index. It may thus be considered as an operational index of "functional dynapenia."

A major limitation to our results is the cross-sectional design of the analyses. Not only this design does not allow us to determine the ability of the proposed index to predict future disabilities, but it is also likely to overestimate the risks of having impairments compared with longitudinal studies (30). Furthermore, our cohort is only composed of women aged 75 years and older; thus, our results are limited to this population. Unfortunately, functional assessment was limited to tasks mainly involving lower extremities. As stated in the discussion, if upper body functional tasks had been employed, different results may have been observed. The classification by quartiles may also be perceived as a limitation given the arbitrary nature of the cut points between the quartiles. This implies that being in the lowest quartile of a measured physical performance does not necessarily mean there is impairment. Finally, the devices used in this study (dual energy x-ray absorptiometry and dynamometer) are not always accessible in a clinical field. On the other hand, the used of these accurate devices in this large sample reinforce our findings. Another strength of this study is the use of objective measurements of functional capacity in addition to self-reported difficulties. Finally, rather than strictly comparing the odds of having impairments according to a group whose criteria are arbitrary and therefore questionable (eg, quartiles), the idea of this analysis is to show that some indexes are more related to functional capacity scores than others and that being considered as "weak" in regard to one of these indexes may lead to increased risks for such impairments.

In conclusion, LB-RMS was the index that appears to be the best associated with self-reported difficulties and functional impairments. Interventions designed to reduce body weight or increase muscle strength are thus likely to favorably influence the risk of developing functional incapacities. A threshold between 2.78 and 2.86 kPa/kgBW may adequately help identifying women at risk of physical impairments. Furthermore, such index is convenient to use in large-scale studies and to some extent in clinical practice. However, the sensitivity and sensibility of these thresholds being relatively low, they should be considered with caution. Future longitudinal studies are now needed to confirm the actual capacity of this index to predict the occurrence of impairments.

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Conflict of Interest

None of the authors had any financial interest or support for this paper.

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