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# Diagnostic accuracy of isometric knee extension strength as a sarcopenia criteria in older women

Pilar Pérez-Ros[1†], Joaquín Barrachina-Igual[2,3†], Ana Pablos[3*], Rosa Fonfria-Vivas[1], Omar Cauli[1] and Francisco M. Martínez-Arnau[4]

## Abstract

**Background** Muscle strength is one of the most reliable measures used for the identification of sarcopenia. The European Working Group on Sarcopenia in Older People update (EWGSOP2) proposed the use of grip strength and chair stand tests, while clarifying that isometric torque methods can be used when performing the grip strength test is impossible. This study aims to evaluate the diagnostic accuracy of isometric knee extension strength in screening for sarcopenia.

**Methods** This cross-sectional study included community-dwelling women aged 70 years and over. IKE and sarcopenia criteria (EWGSOP2) were assessed. Skeletal muscle mass was assessed by bioelectrical impedance analysis; muscle mass strength by handgrip; and physical performance by the 5 times sit-to-stand test, the Short Physical Performance Battery, and gait speed. The diagnostic accuracy for each sarcopenia criterion was calculated using sensitivity, specificity, positive and negative predictive value, and the area under the curve (AUC). Cutoff points for sarcopenia from IKE were defined with the ROC curve.

**Results** The sample comprised 94 women with a mean age of 75.9 years (standard deviation 5.6, range 70–92), of whom 25.5% ($n=24$) met criteria for sarcopenia—mainly severe sarcopenia (73.8%, $n=17$). Correlations were observed between IKE and each individually analyzed sarcopenia criterion except skeletal muscle mass, with AUC values exceeding 0.70 in all cases. The IKE cutoff showing the highest accuracy for the diagnosis of sarcopenia was 12.5 kg or less (AUC 0.76, 95% confidence interval [CI] 0.64–0.88; sensitivity: 65.2%, 95% CI 45.7–84.7; specificity 77.4%, 95% CI 60.3–94.5; positive predictive value 62.5%, 95 CI% 42.7–82.3; negative predictive value 88.8%, 95% CI 75.9–100).

**Conclusions** IKE could be a suitable tool for measuring muscular strength in sarcopenia when other strength parameters cannot be assessed or in people with walking difficulties.

**Keywords** Sarcopenia, Older, Women, Strength, Isometric knee extension

†Pilar Pérez-Ros and Joaquín Barrachina-Igual contributed equally to this work.

*Correspondence:
Ana Pablos
ana.pablos@ucv.es
[1]Department of Nursing, Universitat de València, C/ Menendez Pelayo 19, Valencia 46010, Spain
[2]Conselleria de Educación, Cultura, Universidades y Empleo de Valencia, C/Av de Campanar 32, Valencia 46015, Spain
[3]Department of Physical Activity and Sport Sciences, Universidad Católica de Valencia San Vicente Mártir, C/ Ramiro de Maetzu 14, Torrent, Valencia 46900, Spain
[4]Department of Physiotherapy, Universitat de València, C/ Gascó Oliag 5, Valencia 46010, Spain

## Introduction

Sarcopenia is one of the most common age-related musculoskeletal disorders. It is characterized by a reduction in strength and in skeletal muscle mass, which gradually leads to a deterioration in muscle function [1]. The prevalence of sarcopenia ranges from 10% to 27% in people aged 60 years or older, and it is higher in men and in people with more comorbidities and dependency [2]. The association between sarcopenia and different adverse health outcomes, such as increased falls, fractures, respiratory and cardiac diseases, and dependency, along with loss of function and quality of life, have driven efforts to improve detection [3]. Three criteria are used to diagnose sarcopenia: (1) low muscle strength, (2) low muscle mass, and (3) low physical performance. According to the first European Working Group on Sarcopenia in Older People guidelines (EWGSOP1), the muscle strength parameter was, together with low physical performance, one of two possible confirmatory criteria, while low muscle mass was mandatory. However, in the 2018 update [3], muscle strength is now a first-level criterion, while low muscle mass is confirmatory and low physical performance indicates severity. This is because muscle strength decreases three times faster than muscle mass with ageing [4]. In addition, muscle strength is one of the most reliable measures used by EWGSOP for identifying sarcopenia [1]. However, the recommended tests to measure strength have changed over time. While the EWGSOP1 proposed the use of grip strength, knee flexion/extension strength, and peak expiratory flow; [1] the EWGSOP2 proposes only the use of grip strength and the chair stand test, while clarifying that isometric torque methods can be used when the grip strength test is not feasible [3].

Grip strength is a health biomarker in older people; [5] reduced grip strength has been associated with morbidity and mortality, and it is easy to measure in clinical settings [6]. Nevertheless, the use of grip strength as the only indicator of overall muscle strength has been criticized, as the association with strength in other body areas is only low to moderate, and this measure has limited sensitivity when monitoring changes in strength and functional performance after resistance training programs—essential interventions for treating sarcopenia. Moreover, some of the most common types of arthritis (osteoarthritis, rheumatoid arthritis, and gout) [7–10] can have a negative impact on grip strength. The other parameter suggested by the EWGSOP2 for assessing muscle strength is the chair stand test, but a common problem with this test is the "ceiling effect", which occurs when the scores of the test participants are all clustered near the top. In this test, most people complete the test in less than 15 s [11].

In light of these considerations, different authors have suggested complementing the grip strength measurement with a lower limb strength assessment, bearing in mind that the lower limbs are more important than the upper limbs for gait and physical function [1]. The isometric knee extension (IKE) test may be one such method, as it directly measures the strength of the quadriceps, the lower extremity muscle with the greatest age-related decline in strength (up to 76%) [12]. Moreover, it can be measured with isokinetic devices or handheld dynamometers [13]. While the isokinetic dynamometer is the gold standard for assessing strength, its use is limited due to lack of portability and high costs. A handheld dynamometer is a good alternative, and the IKE test has proven to be a reliable strategy suitable for lower-limb screening in institutionalized older adults. Previous studies have shown a moderate correlation between isokinetic devices and handheld dynamometers for right and left knee extension ($r$=.58–0.75; $P$<.05) [14]. Based on this finding, the IKE test could represent a sensitive, practical, and affordable approach for evaluating muscle strength during the initial assessment of sarcopenia, and for continuously monitoring this physical capacity during a training program [15]. Nevertheless, the IKE has not yet been included in algorithms to screen for sarcopenia or assess its severity [3], and cutoff values have not been established.

This study aims to evaluate the diagnostic accuracy of isometric knee extension strength in screening for sarcopenia.

## Methods

This cross-sectional study included older, community-dwelling women in Valencia, Spain. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee for Human Research of the University of Valencia (protocol code 1534298 approved 14 January 2021). Following a briefing about the study and its aims, all participants signed informed consent as a precondition for taking part.

### Participants

Women aged 70 years or older who were able to stand independently for 5 min for bioelectrical impedance analysis (BIA) were included. Exclusion criteria were: advanced dementia (Global Deterioration Scale score of 7 diagnosed by physician); terminal illness (life expectancy of less than 6 months); implanted pacemaker or desfibrillator; edema or hydration disorders that could affect BIA results; corticosteroid treatment within the previous 30 days; [16] hearing or visual impairments that could interfere with the study; degenerative muscle diseases or any osteoarticular condition that could condition the performance of the tests, and the presence of any other condition that could entail a risk to the participant.

Participants were included consecutively; recruitment took place in primary healthcare centres and social centres for older people between April and December 2021. Assessments took place in dedicated rooms of the University of Valencia Physiotherapy School. In total, 104 older women underwent an assessment; 7 declined to participate, and 3 were excluded for being in poor general health due to acute problems, leaving a final study population of 94 women.

### Sample size

The estimated prevalence of sarcopenia in community-dwelling older people in a Mediterranean geographical area, according to the EWGSOP2 criteria, is 3.2% [17]. For a margin of error of 5% and a confidence level of 95%, the required sample size was 53 older women (G-Power, Dusseldorf, Germany).

### Measurements

The assessments were performed by two nurses, one physiotherapist, and two physical activity professionals, each with more than 10 years of research experience in studies with older people. Prior to the assessments, all the people involved in the assessments trialled the measurements in 10 women to detect and correct any procedural errors in the assessment of each criterion. Each test in the assessment was performed by the same evaluator to avoid inter-observer variations. The assessment was carried out in fasting participants between 8:00 a.m. and 10:00 a.m. The order of the tests performed followed the EWGSOP2 assessment criteria (Fig. 1).

We defined sarcopenia according to EWGSOP2 criteria. This included the SARC-F questionnaire and measurements of muscle strength, muscle quantity, and physical performance [3]. The SARC-F questionnaire comprises five items, which elicit information on strength, the need for assistance in walking, rise from a chair, stair climbing, and falls. Each item is scored from 0 to 2, with total scores of 4 points or more out of a total of 10 points indicating a positive screening result [18].

The three sarcopenia criteria were measured as specified below.

#### *Muscle strength*

- Handgrip strength technique. The Jamar Hydraulic Hand Dynamometer 5030J1 (Loughborough, UK) was used to measure dominant handgrip. We recorded the highest value out of three assessments [19]. The cutoff was < 16 kg [20].
- The 5 times sit-to-stand (5TSTS) test, in which the participant stood up and sat down on a chair 5 times

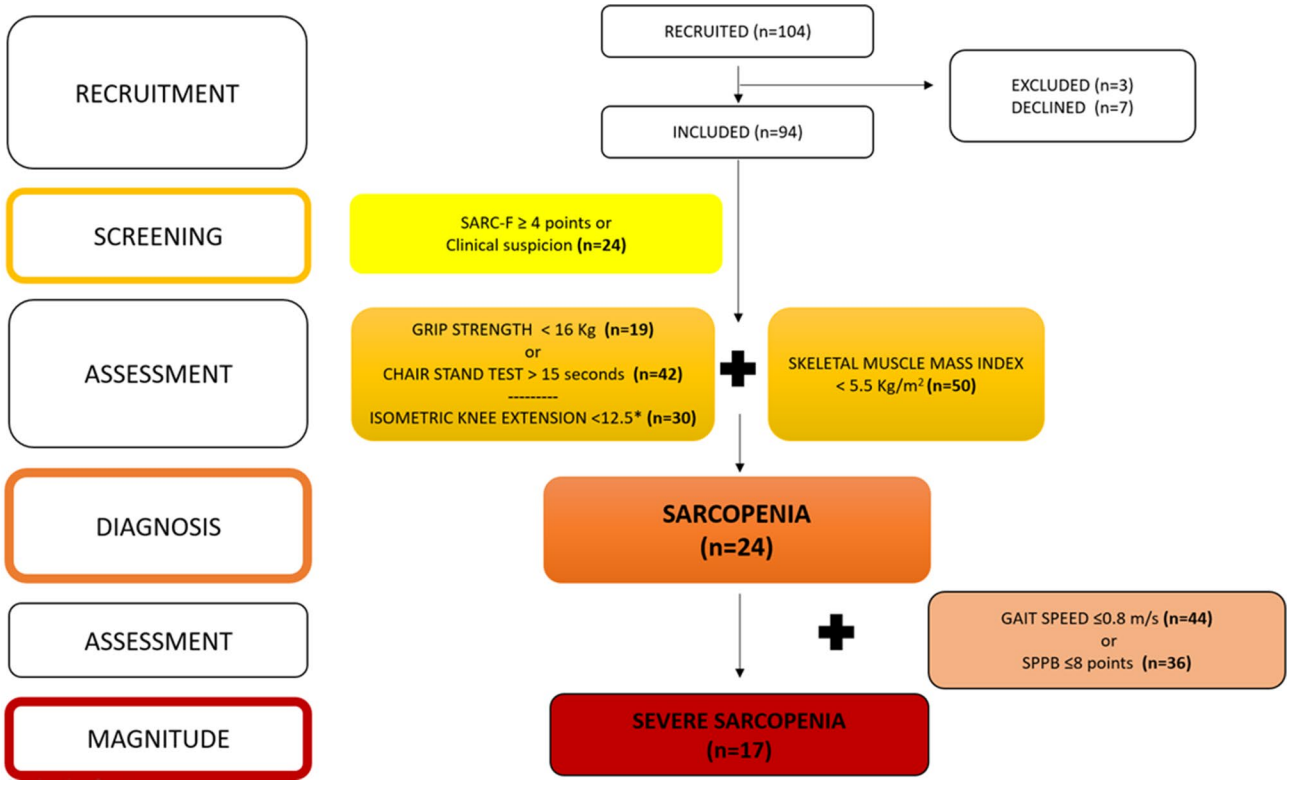


**Fig. 1** Sarcopenia screening and diagnostic criteria using EWGSOP2 algorithm. Note: EWGSOP2: European Working Group on Sarcopenia in Older People; SPPB: Short Physical Performance Battery

as quickly as possible, and the total time spent was recorded. The cutoff was > 15 s [21]. This test was performed as part of the Short Physical Performance Battery (SPPB) assessment (detailed below), as it is part of this scale.

- Maximum isometric knee extension (IKE). A previously calibrated handheld digital dynamometer (model 01165, LaFayette, USA) was used to measure the isometric strength of the dominant leg [22]. A hip flexion angle of 110° and a knee flexion angle of 60° from the anatomical zero (180°) were maintained [23]. A pad was placed on the shin 4–5 cm above the tibial malleolus to prevent excessive pain. The best of 5 attempts was analyzed. The handheld dynamometer showed a good degree of internal consistency, with a Cronbach's alpha of 0.762 and a test-retest reliability (ICC) of 0.96 [14].

#### *Muscle mass*

Weight and body weight muscle mass were collected using a previously calibrated BC-418 MA BIA device (Tanita 2016, America). The literature shows that the TANITA BC418-MA provides a valid measure of body composition when compared to DEXA using segmental analysis [24]. Comparisons of SMM from segmental BIA against reference methods to measure body composition, such as dual-energy X-ray absorptiometry (DEXA), suggest that this is a reliable method to measure SMM, including in older populations [25–28]. The TANITA BC418MA provides the clinician with a reliable method for assessing body composition in both men and women, and although there are significant interactions between gender and the method of assessment, they do not represent a clinical barrier to using this system. In addition, its ease of use and less invasive nature make it suitable for body composition assessment in vulnerable populations such as children, the elderly and the obese [29]. To ensure the predictive accuracy of the electrical bioimpedance equations, we checked that patients adhered to the following instructions prior to the assessment: (1) Do not take diuretics 7 days before, (2) Do not drink alcohol in the 48 h prior to the test, (3) Urinate 30 min before the test, (4) Do not perform vigorous exercise 12 h before the test, (5) Do not eat or drink anything in the 4 h prior to the test, (6) Preferably, electrical bioimpedance should not be performed during menstruation, (7) Remove all metallic elements from the body (watches, rings, bracelets, earrings, piercings, etc.) [30]. Height was measured with a previously calibrated stadiometer, and body mass index (BMI) was calculated. The skeletal muscle mass index (SMMI) was calculated as muscle mass/height (kg/m$^2$), where low muscle mass was defined as less than 5.5 kg/m$^2$.

#### *Physical performance*

- Walking speed was assessed as follows: the participant walked at her usual pace for a distance of 4 m along a corridor, using a technical aid if needed, from a standing start and without eliminating acceleration and deceleration phases. This test was performed as part of the SPPB assessment (detailed below), but it was performed twice, and the shortest time was recorded, with a cutoff value of less than 0.8 m/s [1].
- SPPB, according to the instructions of Guralnik et al. [11] This includes three tests, each scored from 0 to 4: a balance test, a walking test, and a repeated chair stand test (5TSTS). In the balance test, the participants were asked to stand with their feet together, in the semi-tandem and tandem positions, and the time they needed to walk 4 m was measured. The cutoff is 8 points or fewer out of a total possible score of 12.

Following these assessments, participants were classified according to the EWGSOP2 algorithm [3]. Specifically, a SARC-F score of 4 points or more represented a positive screening result, and these participants were classified as having (1) probable sarcopenia in the presence of low muscle strength alone (grip strength < 16 kg or 5TSTS > 15 s); (2) confirmed sarcopenia when low quantity muscle was also detected (SMMI < 5.5 kg/m2); or (3) severe sarcopenia, when low physical performance was added (gait speed < 0.8 m/s; SPPB ≤ 8 points) (Fig. 1).

### Statistical analysis

All data entered into the database were verified by an independent second person. Descriptive statistics were expressed as mean and standard deviation (SD) for normally distributed continuous variables and relative frequencies for categorical variables.

The normality of the distribution of the quantitative variables was evaluated using the D'Agostino-Pearson test (K samples). Parametric tests (Student's *t*-test and Pearson correlation) were used for SMMI, IKE and gait speed. Non-parametric tests (Mann-Whitney U) and Spearman's correlation (Rho) were used for SARC-F, gait speed, 5STST and SPPB.

Correlations between IKE and the different EWGSOP2 sarcopenia criteria were analyzed separately and in clusters (positive screen, muscle mass strength, and physical performance). To ascertain whether a linear relationship existed between the paired data from both instruments, a regression analysis was conducted using the Passing and Bablok regression for nonparametric samples [31]. The equation $y = ax + b$ can be used to characterize the relationship between two variables and predict the values of

the dependent variable *y* based on the values of the independent variable *x*. Parameter *a* gives information on the proportionate differences between the two approaches and reflects the slope, which should ideally be 1.

The receiver operating characteristics (ROC) curve was used to determine the cutoff value and sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratio positive and negative (LR+, LR-) of the IKE, each sarcopenia criterion, and sarcopenia criteria clusters. A *P* value of less than 0.05 was considered statistically significant. The statistical analysis was carried out with the SPSS Version 26.0 for Windows (IBM Corp., Armonk, NY, USA), XLStats 2023 for Microsoft Excel, and Jamovi 2.2.5 statistical packages.

## Results

The study included 94 women with a mean age of 75.9 years (SD 5.6, range 70–92). Of these, 25.5% ($n=24$) were classified as having probable sarcopenia based on the SARC-F score alone (≥4 points). Following the assessment of additional strength and physical performance criteria, 24 participants (25.5%) met criteria for sarcopenia, of whom just 13 (54.2%) had obtained a positive screening result. Of the 24 women with sarcopenia, 73.8% ($n=17$) were classified as having severe sarcopenia.

Mean age was similar in women with (77.8 years SD 6.37) and without (75.2 years SD 5.2) sarcopenia (Table 1). For its part, mean muscle strength, as assessed by IKE, was 15.1 kg (SD 5.2) in the sample as a whole, with a significant difference between women with and without sarcopenia (11.73 kg SD 4.8 vs. 16.33 kg SD 4.8 vs.; mean difference [MD] −4.06, 95% confidence interval [CI] −6.97, −2.37; $P<.001$).

Correlations between IKE and SARC-F, grip strength, 5TSTS and SPPB were over 0.4, while there was no correlation with SMMI (Fig. 2; Table 2).

An analysis of the concurrent validity of the IKE with the grip strength and 5TSTS criteria showed a linear relationship in both cases ($P=.238$ and $P=.504$ respectively), with a slope close to 1 (Fig. 3; Table 3).

The ROC curves were analyzed for each EWGSOP2 criterion (SARC-F, grip strength, 5TSTS, SPPB, gait speed, and SMMI), with the highest curve observed for SMMI (AUC 0.85) (Fig. 4). Between the two low strength criteria, the highest curve was obtained for the 5TSTS (area under the ROC curve [AUC] 0.78), and between the two low physical performance criteria, it was the SPPB (AUC=0.72) (Table 4).

The IKE is a measure of low strength within the cluster of sarcopenic criteria. Its AUC value (Fig. 5a) was higher than that for grip strength and lower than that for the 5TSTS. The cutoff point showing the highest sensitivity and specificity for diagnosing sarcopenia was 12.5 kg or less (Fig. 5b), with an accuracy higher than grip strength (Table 4; Figs. 4 and 5). Of the total sample, 34.1% ($n=29$) met this IKE criterion: 62.5% ($n=15$) in the sarcopenia group, and 20% ($n=14$) in the non-sarcopenia group ($P<.001$).

We then analyzed the AUC of the two recommended sarcopenia strength criteria cluster (grip strength and 5TSTS) and the IKE together (Table 4).

## Discussion

The present study proposes IKE cutoff points to diagnose sarcopenia in community-dwelling older women. Using 12.5 kg or lower as a cutoff, we assessed whether the IKE

**Table 1** Sarcopenia screening results in the measures for EWGSOP2 sarcopenia criteria: muscle strength, muscle mass and physical performance

| | | Total (*N*=94) | No sarcopenia (*n*=70) | Sarcopenia (*n*=24) | *P* value |
|---|---|---|---|---|---|
| Screening result | SARC-F points, mean (SD) | 2.27 (2.13) | 1.85 (1.9) | 3.5 (2.34) | .001[u] |
| | SARC-F ≥ 4 points, n (%) | 24 (25.5) | 11 (45.8) | 13 (19.1) | 0.010 [χ2] |
| Skeletal muscle strength | Grip strength kg, mean (SD) | 19.57 (5.07) | 20.62 (4.67) | 16.5 (5.01) | < .001[u] |
| | Grip strength < 16 kg, n (%) | 19 (20.2) | 9 (12.9) | 10 (41.7) | .002[χ2] |
| | 5TSTS, seconds, mean (SD) | 17.06 (11.48) | 15.03 (9.09) | 23 (15.36) | < .001[u] |
| | 5TSTS > 15 s, n (%) | 42 (44.7) | 20 (28.6) | 22 (91.7) | < .001[χ2] |
| | IKE*, kg, mean (SD) | 15.08 (5.2) | 16.33 (4.80) | 11.73 (4.80) | < .001[t] |
| Skeletal muscle mass | SMMI predicted by (BIA), kg/m$^2$, mean (SD) | 5.84 (1.20) | 6.19 (1.15) | 4.86 (0.71) | < .001[t] |
| | SMMI < 5.5 kg/m$^2$, n (%) | 24 (25.5) | 0 (0) | 24 (25.5) | < .001[χ2] |
| Physical performance | Gait speed seconds, mean (SD) | 0.82 (0.25) | 0.85 (0.24) | 0.75 (0.22) | .068[t] |
| | Gait speed ≤ 0.8 m/s, n (%) | 44 (46.8) | 29 (41.4) | 15 (34.1) | 0.074 |
| | SPPB points, mean (SD) | 9.01 (2.66) | 9.49 (2.47) | 7.50 (2.65) | .001[u] |
| | SPPB ≤ 8 points, n (%) | 36 (38.3) | 22 (31.4) | 14 (58.3) | 0.019 |

χ2: Chi square test; t: t-Test; U: Mann-Whitney U test

IKE: Maximum isometric knee extension; SMMI: skeletal muscle mass index; SPPB: Short physical performance battery; 5TSTS: 5-times sit-to-stand; * Possible sarcopenia criteria

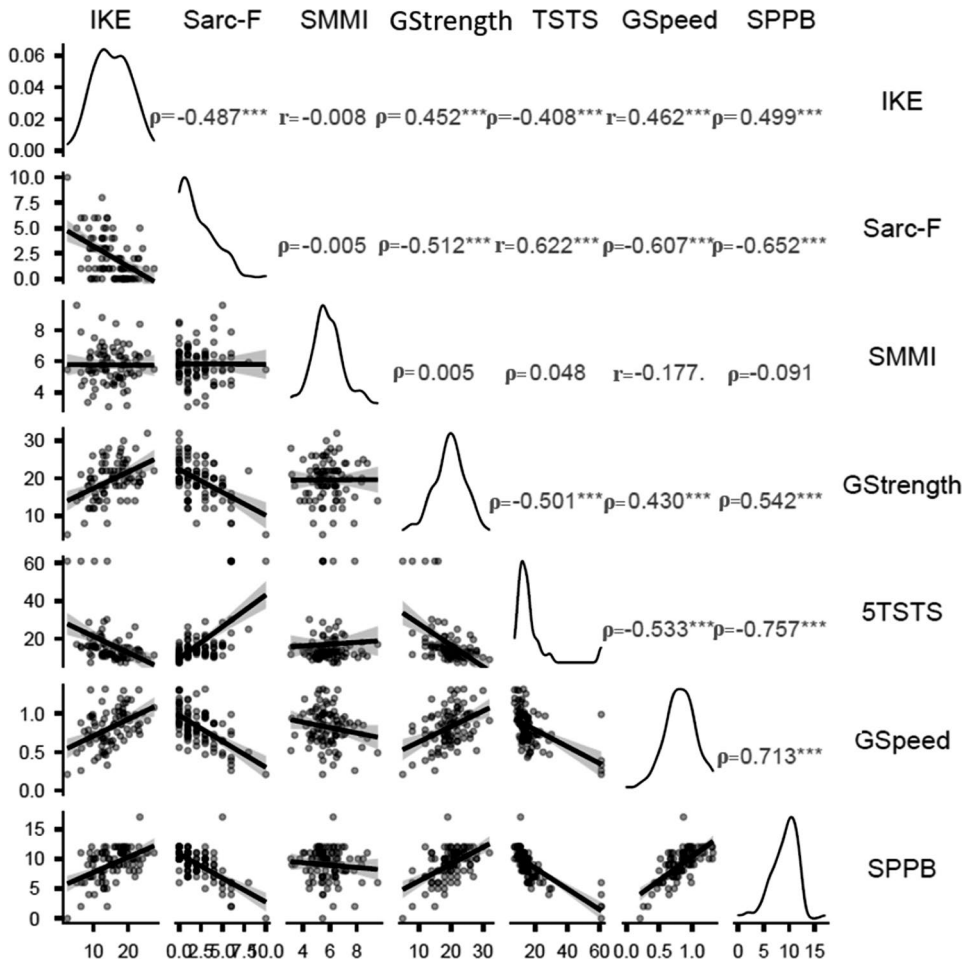


**Fig. 2** Correlations between Isometric Knee Extension and each EWGSOP2 sarcopenia criteria. Note: GSpeed: gait speed; GStrength: grip strength; IKE: Isometric Knee Extension Strength; SMMI: skeletal muscle mass index; SPPB: Short Physical Performance Battery; 5TSTS: 5-times sit-to-stand, r = Pearson correlation; ρ = Spearman correlation; ***: significant at $P < .001$

**Table 2** Correlation matrix for EWGSOP2 sarcopenia criteria

| | | IKE | SARC-F | SMMI | Grip strength | 5TSTS | Gait speed | SPPB |
|---|---|---|---|---|---|---|---|---|
| SARC-F | Spearman (Rho) | −0.487 | — | | | | | |
| | *P* value | < 0.001 | — | | | | | |
| SMMI | R (Pearson) | −0.008 | — | | | | | |
| | *P* value | 0.270 | — | | | | | |
| | Spearman (Rho) | — | −0.005 | — | | | | |
| | *P* value | — | 0.535 | — | | | | |
| Grip Strength | Spearman (Rho) | 0.452 | 0.512 | 0.005 | — | | | |
| | *P* value | < 0.001 | < 0.001 | 0.649 | — | | | |
| 5TSTS | Spearman (Rho) | −0.408 | 0.622 | 0.048 | −0.501 | — | | |
| | *P* value | < 0.001 | < 0.001 | 0.762 | < 0.001 | — | | |
| Gait Speed | R (Pearson) | 0.462 | — | −0.177 | — | — | — | |
| | *P* value | < 0.001 | — | 0.088 | — | — | — | |
| | Spearman (Rho) | | −0.607 | — | 0.430 | −0.533 | — | |
| | *P* value | | < 0.001 | — | < 0.001 | < 0.001 | — | |
| SPPB | Spearman (Rho) | 0.499 | −0.652 | −0.091 | 0.542 | 0.757 | 0.713 | — |
| | *P* value | < 0.001 | < 0.001 | 0.419 | < 0.001 | < 0.001 | < 0.001 | — |

IKE: Isometric Knee Extension Strength SMMI: skeletal muscle mass index; SPPB: Short physical performance battery; 5TSTS: 5-times sit-to-stand

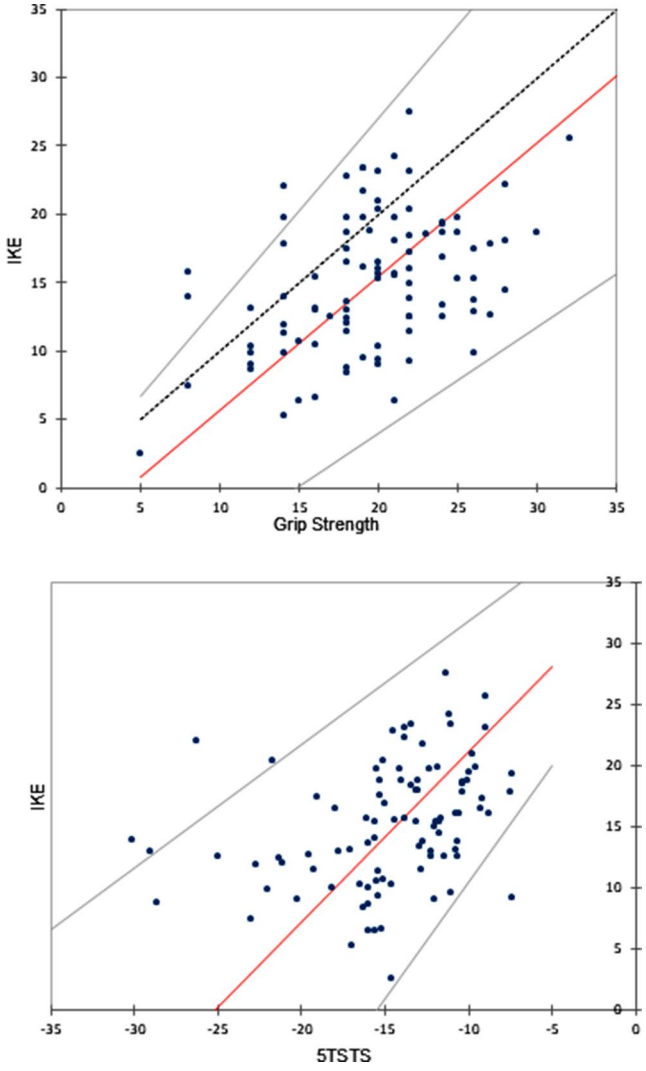


**Fig. 3** ROC curve for strength sarcopenia criteria. Note: 5TSTS: 5-times sit-to-stand; IKE: isometric knee strength

**Table 3** Values of passing Bablock regression between IKE and grip strength and 5 times sit to stand test

| IKE and Grip Strength | Value (95% CI) |
|---|---|
| Interception | -4.04 (-11.52, -010) |
| slope coefficient | 0.99 (0.76, 1.36) |
| **IKE and 5TSTS** | |
| Interception | 35.07 (41.85, 29.53) |
| slope coefficient | 1.39 (1.01, 1.91) |

is an appropriate tool for measuring strength in women with sarcopenia, in both clinical practice and in research.

The EWGSOP2 recommends using grip strength and 5TSTS as the strength tests for diagnosing sarcopenia but clarifies that isometric torque methods can be used when grip strength is not possible [3], and it could even be a suitable screening tool for sarcopenia in people who have difficulty walking [32]. Both grip strength and IKE appear to be very sensitive for detecting functionally relevant muscle weakness in older adults. Grip strength is probably most appropriate for monitoring the efficacy of treatments in sedentary populations. However, exercise interventions should be monitored with appropriate regional measures [33]. In addition, in patients affected by common types of arthritis, grip strength may not be strongly correlated with overall muscle function. For example, osteoarthritis of the hand may hinder the assessment of grip strength, while osteoarthritis of the hip and knee may hinder the assessment of sit-stand or IKE. Given that these conditions have a relatively high prevalence in the older population, it is of interest to have data that enable the selection of the most appropriate measurements according to the characteristics of the women [34].

Although to our knowledge, there are no published studies proposing a cutoff for IKE as a possible criterion for sarcopenia, research on the topic is increasing.

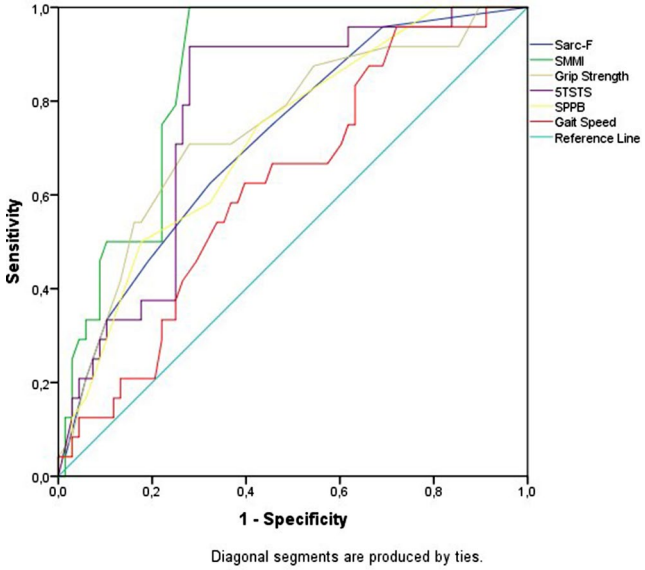


**Fig. 4** ROC curve and cutoff for Isometric Knee Extension according to EWGSOP2 sarcopenia diagnosis

For example, one study in Thailand studied the reduction in IKE over time in older adults and correlated its values with sarcopenia criteria [32], while other authors have used different assessments of knee strength [33, 35]. These studies also obtained AUCs of over 0.70, confirming that the quantification of lower limb strength could be a possible criterion for sarcopenia.

The sensitivity of grip strength based on the data obtained in our study was 23% less sensitive than IKE. These results are consistent with other studies supporting the suitability of IKE for assessing lower limb strength [36]. At their onset, functional limitations may be caused by a considerable decrease in the strength of the lower limbs, which is greater than the drop in handgrip strength. Indeed, the estimated reduction in quadriceps strength linked to ageing is 48%, compared to 23% for grip strength [37]. This reflects the differential age-related loss in strength according to muscle group. When using handgrip strength to assess potential strength loss, we may be underestimating the early loss of strength that actually occurs in the quadriceps [37].

The importance of assessing performance using IKE has been reported and could be particularly useful in those at high risk of functional decline [36]. The IKE has been shown to have the highest predictive value against grip strength in assisted living facilities; [35] however, people in these settings are often approaching or in the early stages of functional limitations. The use of IKE should be considered at the initial stages of sarcopenia, where early detection is essential [38], and it is indicated if the person is unable to perform a dynamic squat test(to obtain a general indication of dynamic posture) [15], which is necessary for tests like the 5TSTS. Given the direct involvement of the knee extensor muscles for actions such as walking or getting up from a chair, its correlation with functional performance in tests such as the 6 m and Time Up and Go (TUG) should not be surprising [15].

We observed significant correlations between IKE and performance tests (SPPB and gait speed). Buendía-Romero et al. [15] reported a similar relationship with the TUG and 6-m gait speed tests. Taken together, the data confirm the close relationship between IKE and functional performance.

The diagnostic accuracy of the IKE relative to other sarcopenia criteria, whether individually or in clusters, was high in our sample, yielding better values than grip strength as a criterion for low strength in both sarcopenia and severe sarcopenia. The criterion of low muscle strength is associated with higher mortality and worse health outcomes [39], so detecting older people at risk is critical for implementing early prevention measures. Assessing IKE with an isokinetic dynamometer is more expensive than using a handheld device (e.g. JAMAR, Smedley). However, its high accuracy [15] makes it a useful option in cases where the assessment of other low-strength criteria is difficult. It shows better accuracy than grip strength, both as an isolated criterion or in combination with other measures; it can be used in people with walking difficulties; and it is relatively quick to perform, taking only about 5 min/participant.

## Limitations

Our study is not without its limitations. The first is that the analysis was conducted only in women in a community setting. The sarcopenia criteria used were those in the EWGSOP2, so the results using other sarcopenia criteria could be different. Drugs that can affect muscle

**Table 4** Accuracy of IKE and each EWGSOP2 sarcopenia criterion, alone and in clusters

| Variable | AUC (95%CI) | Sensitivity (95%CI) | Specificity (95%CI) | PPV (95%CI) | NPV (95%CI) | LR+ (95%CI) | LR- (95%CI) |
|---|---|---|---|---|---|---|---|
| IKE ≤ 12.5 kg | 0.76 (0.64–0.88) | 65.2 (45.7–84.7) | 77.4 (60.3–94.5) | 62.5 (42.7–82.3) | 88.8 (75.9–100) | 3.62 (1.7–5.5) | 0.56 (0.44–0.67) |
| **Positive screen and single sarcopenia criterion** | | | | | | | |
| SARC-F ≥ 4 points | 0.72 (0.60–0.83) | 45.8 (25.9–65.7) | 80.9 (65.2–96.6) | 45.8 (25.9–65.8) | 80.9 (65.2–96.6) | 8.18 (2.7-19.14) | 0.58 (0.46–0.69) |
| SMMI < 5.5 kg/m$^2$ | 0.85 (0.78–0.93) | 100 (95–100) | 71.4 (53.3–89.5) | 54.5 (36.6–74.5) | 100 (100–100) | 3.5 (1.6–5.4) | - |
| 5TSTS > 15 seconds | 0.78 (0.68–0.89) | 91.7 (80.7–100) | 71.4 (53.3–89.5) | 52.4 (32.4–72.4) | 96.2 (88.5–100) | 3 (1.2–4.83) | 0.12 (0.01–0.03) |
| GRIP S < 16 kg | 0.74 (0.62–0.86) | 41.7 (22.0-61.4) | 87.1 (73.7–100) | 52.6 (32.7–72.6) | 81.3 (65.7–96.9) | 2.82 (1.02–4.62) | 0.58 (0.46–0.69) |
| SPPB ≤ 8 points | 0.72 (0.61–0.83) | 52.4 (30.5–74.3) | 96.2 (91.7–100) | 91.7 (80–100) | 71.4 (60.8–81.9) | 13.6 (1.1–27.6) | 0.49 (0.37–0.60) |
| GAIT S ≤ 0.8 m/s | 0.62 (0.50–0.75) | 62.5 (43.1–81.9) | 58.6 (38.9–78.3) | 34.1 (15.1–53.1) | 82.0 (66.6–97.4) | 2.04 (-0.3-8.52) | 0.58 (0.46–0.69) |
| **Sarcopenia criteria (SSMI + one criterion from skeletal muscle strength)** | | | | | | | |
| SMMI + GRIP S | 0.92 (0.86–0.97) | 41.7 (22.0-61.4) | 100 (94–100) | 100 (94–100) | 83.3 (68.1–98.5) | - | 0.58 (0.47–0.69) |
| SMMI + 5TSTS | 0.99 (0.97-1.00) | 91.7 (80.66–100) | 100 (95–100) | 100 (95–100) | 97.2 (90.5–100) | - | 0.08 (0.01–0.14) |
| SMMI + *IKE** | 0.94 (0.89–0.99) | 65.2 (46.1–84.3) | 98.6 (93.8–100) | 93.8 (83.9–100) | 89.5 (77.2–100) | 40.4 (20.7-60.03) | 0.35 (0.24–0.46) |
| **Severe sarcopenia criteria (SSMI + one criteria from skeletal muscle strength + one physical performance criteria)** | | | | | | | |
| SMMI + GRIP S + SPPB | 0.98 (0.96-1.00) | 75 (53.3–90.2) | 98.6 (93–100) | 94.7 (85.7–100) | 92 (85.6–98.4) | 52.4 (32.4–72.4) | 0.25 (0.14–0.35) |
| SMMI + GRIP S + GAIT S | 0.96 (0.92-1.00) | 70.8 (48.9–87.4) | 94.3 (86-98.4) | 81 (65.3–96.7) | 90.4 (83.5–97.3) | 12.4 (1-26.9) | 0.31 (0.2–0.42) |
| SMMI + 5TSTS + SPPB | 0.98 (0.95-1.00) | 91.7 (73-99.1) | 95 (89–100) | 100 (94–100) | 97.2 (93–100) | - | 0.08 (0.02–0.14) |
| SMMI + 5TSTS + GAIT S | 0.99 (0.97-1.00) | 91.7 (73-99.1) | 95 (89–100) | 100 (94–100) | 97.2 (93–100) | - | 0.08 (0.02–0.14) |
| SMMI + *IKE** +SPPB | 0.98 (0.95-1.00) | 78.3 (61.8–94.8) | 96.8 (92.6–100) | 90 (78–100) | 92.3 (86.1–98.6) | 24.3 (7-41.5) | 0.22 (0.1–0.56) |
| SMMI + *IKE** + GAIT S | 0.99 (0.97-1.00) | 82.6 (67.4–97.7) | 91.9 (85.5–98.3) | 79.2 (62.9–95.4) | 93.4 (87.6–99.2) | 10.2 (0.01-22) | 0.19 (0.01–0.51) |

AUC: area under the curve; GAIT S: Gait speed; GRIP S: Grip strength; IKE: maximum isometric knee extension; LR+: likelihood ratio positive; LR-: likelihood ratio negative; PPV: positive predictive value; NPV: negative predictive value; SMMI: skeletal muscle mass index; SPPB: Short Physical Performance Battery; 5TSTS: 5-times sit-to-stand; * Possible sarcopenia criteria

AUC: area under the curve; GAIT S: Gait speed; GRIP S: Grip strength; IKE: maximum isometric knee extension; LR+: likelihood ratio positive; LR-: likelihood ratio negative; PPV: positive predictive value; NPV: negative predictive value; SMMI: skeletal muscle mass index; SPPB: Short Physical Performance Battery; 5TSTS: 5-times sit-to-stand; * Possible sarcopenia criteria

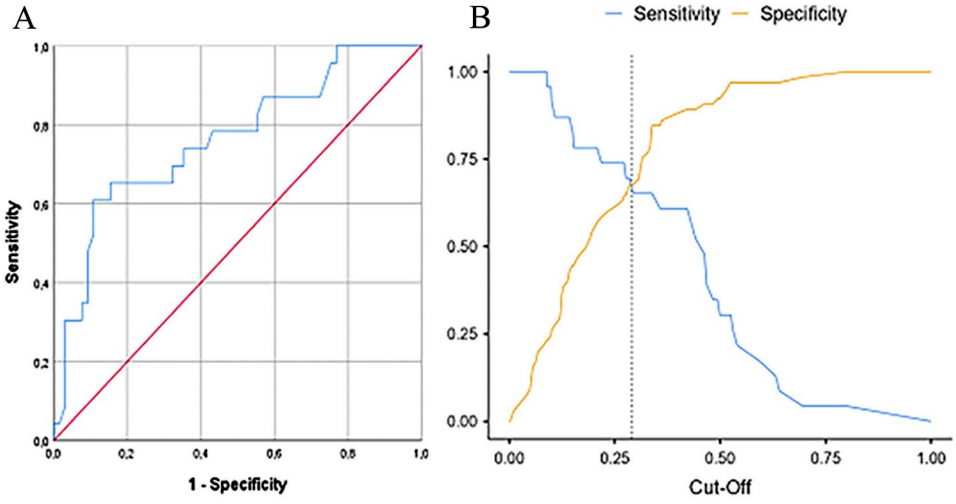


**Fig. 5** Passing Bablock regression between IKE and (**A**) Grip Strength (**B**) 5 times sit to stand test

function, such as statins or psychotropic medication, were also not analyzed.

Even though the results obtained are a step forward, there is a need for further studies to identify the best diagnostic tools in both sexes as well as in different settings, and to assess the impact of associated comorbidity and the use of drugs, especially those that could have undesirable adverse effects, such as an increase in muscle weakness.

## Conclusions

The IKE could be a suitable measure of strength in both clinical practice and research settings in patients with sarcopenia, particularly where other strength parameters cannot be assessed or in people with walking difficulties. The cutoff of ≤ 12.5 kg has acceptable diagnostic accuracy for older women in the community setting. Further studies in different sexes and settings are needed.

**Abbreviations**

| | |
|---|---|
| AUC | area under the curve |
| EWGSOP1 | European Working Group on Sarcopenia in Older People guidelines 1 |
| EWGSOP2 | European Working Group on Sarcopenia in Older People guidelines 2 |
| IKE | Isometric knee extension |
| PPV | Positive predictive value |
| ROC | Receiver operating characteristics |
| SPPB | Short Physical Performance Battery |
| SMMI | Skeletal muscle mass index |
| 5TSTS | The 5 times sit-to-stand |

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**Author contributions**

OC and FMMA have contributed to the conception and design of the work; PPR, JBI, AP, RFV and FMM have contributed to data acquisition; PPR, JBI, AP, RFV and FMM contributed to the analysis and interpretation of data; PPR, JBI, AP, RFV and FMM drafted the manuscript; OC and FMMA have critically reviewed the manuscript for important intellectual content; PPR, JBI, AP, RFV, OC and FMM have approved the submitted version (and any substantially modified version that involves the author's contribution to the study);

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**Data availability**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee for Human Research of the University of Valencia (protocol code 1534298 approved 14 January 2021). Following a briefing about the study and its aims, all participants signed informed consent as a precondition for taking part.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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## Publisher's note