Review

MEDICAL IMAGING

Muscle matters: a review of diagnostic methods in sarcopenia

Miruna M. Soare[1], Ionela M. Pascanu[2]

1) Doctoral School of Medicine and Pharmacy, George Emil Palade University of Medicine, Pharmacy, Science, and Technology, Târgu Mureș, Romania

2) Department of Endocrinology, George Emil Palade University of Medicine, Pharmacy, Science, and Technology, Târgu Mureș, Romania

Abstract

Background. Sarcopenia is characterized by the progressive loss of muscle mass and strength, associated with increased risk of fractures, frailty, morbidity, and mortality. Despite being a preventable and potentially reversible condition, its diagnosis remains challenging due to variability in diagnostic criteria and methods. The Global Leadership Initiative in Sarcopenia recommends including both muscle mass and strength in the diagnostic definition of sarcopenia. This review aims to explore different diagnostic approaches for sarcopenia, focusing on their accuracy, feasibility, clinical utility, and existing limitations.

Methods. A narrative review was conducted using PubMed to identify studies on sarcopenia diagnosis and assessment. Articles were selected based on relevance to muscle strength, muscle mass, and physical performance, with predefined inclusion and exclusion criteria. Consensus guidelines from major international working groups were also included.

Key findings. Assessment of muscle mass in sarcopenia is constrained by a fundamental imbalance between measurement accuracy and clinical feasibility. In clinical settings, dual-energy X-ray absorptiometry and bioelectrical impedance analysis remain at the forefront of muscle mass evaluation despite the limitation of being indirect methods. Muscle ultrasound is emerging as a promising method for the future and can be used adjunctly to evaluate muscle architecture. Cross-sectional direct imaging techniques such as CT and MRI can be used opportunistically as they provide high accuracy but lower feasibility. D3-creatine dilution is emerging as an accurate assessment tool for the future but requires further research into clinical implementation. Overall, assessment of muscle strength and muscle mass remains central to the diagnosis of sarcopenia, while physical performance measures are important for outcome prediction.

Conclusion. No single diagnostic method is sufficient on its own, and substantial heterogeneity remains in sarcopenia assessment. A pragmatic approach combining measures of muscle strength, muscle mass, and physical performance is therefore required.

Keywords: sarcopenia, diagnosis, handgrip strength, dual-energy X-ray absorptiometry, bioelectrical impedance, CT, MRI, muscle ultrasound, D3-creatine dilution, physical performance

DOI: 10.15386/mpr-2964

Manuscript received: 12.01.2026
Received in revised form: 18.07.2026
Accepted: 20.07.2026

Address for correspondence:
Maria Soare
bartelick.miruna@gmail.com

Introduction

Sarcopenia, a term coined in 1989, is characterized by a generalized and progressive loss of muscle mass and function. Initially, it was defined solely as the loss of muscle mass. However, evidence suggests that loss of strength is the primary determinant of patient outcomes. As a result, sarcopenia is now recognized as a muscle disease or "muscle failure" [1,2]. Muscle mass declines gradually with age, with a 1–2% loss per year after the age of 50 [3]. The pathogenesis of sarcopenia is multifactorial, involving hormonal changes, a reduction in neuromuscular

junction units, oxidative stress, and damage to skeletal muscle fibers by reactive oxygen species (ROS)—a key component of age-related inflammation, or "inflammaging" [4,5].

Sarcopenia has a significant impact on an individual's health, increasing the risk of fractures, frailty, hospitalization, cognitive impairment, and all-cause mortality [6]. Despite being a preventable and potentially reversible condition, heterogeneity in diagnostic methods and cut-off values makes diagnosis a challenge.

Over the years, various groups have defined and classified sarcopenia. The most recent classifications include those from the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) and the Asian Working Group on Sarcopenia 2 (AWGS2) in 2019, as well as the Sarcopenia Definition and Outcomes Consortium (SDOC) in 2020 [2,7,8]. The EWGSOP2 revised definition emphasizes muscle strength as the primary indicator of muscle health. According to this classification, "probable sarcopenia" is identified when muscle strength is low, sarcopenia is confirmed if low muscle quantity is also present, and the condition is considered severe if physical performance is impaired [2]. The SDOC agree that sarcopenia should be diagnosed based on muscle strength and physical performance, as these factors have the most significant impact on morbidity and mortality. However, they reported mixed opinions on whether DXA-derived muscle mass should be included in the definition [8].

Recognizing the need for a global consensus, the Global Leadership Initiative in Sarcopenia (GLIS) committee was formed. The committee agreed that sarcopenia should be conceptually defined by both muscle mass and strength, while physical performance should be considered an outcome of sarcopenia rather than a defining criterion. Additionally, the GLIS emphasizes that sarcopenia assessments should remain consistent across both research and clinical practice [9].

The aim of this review is to evaluate and compare the current methods for assessing muscle mass and function. By analyzing the strengths and limitations of different evaluation techniques, this review seeks to provide a comprehensive understanding of their clinical applicability and relevance in diagnosing sarcopenia.

Methods

A narrative review was conducted to provide a comprehensive overview of diagnostic methods used in the assessment of sarcopenia, with a particular focus on their accuracy, clinical utility, standardization, and feasibility. Methods encompassing the assessment of muscle strength, muscle mass, and physical performance were included.

A literature search was performed using PubMed as the primary database. Articles published up to April 2025 were eligible for inclusion. Search terms included combinations of the keywords "sarcopenia", "muscle mass", "diagnosis", "CT", "MRI", "DXA", "bioimpedance", "ultrasound", "D3-creatine dilution", "muscle strength", and "physical performance". In addition, consensus statements and guidelines from international working groups, including the Global Leadership Initiative in Sarcopenia, the European Working Group on Sarcopenia in Older People, the Sarcopenia Definition and Outcomes Consortium, and the Asian Working Group for Sarcopenia, were reviewed.

Studies were selected based on their relevance to the diagnosis and assessment of sarcopenia. Case reports, editorials, non-English publications, and studies not directly related to sarcopenia diagnosis were excluded. Eligible sources included original research articles, systematic reviews, meta-analyses, and consensus papers. Findings were synthesized according to diagnostic modality, with particular attention given to feasibility, standardization, clinical utility, and associations with functional outcomes.

Following peer review, the literature search was updated in June 2026 using the terms "sarcopenia", "diagnosis", "meta-analysis", "screening", "physical performance", "SPPB", "TUG", and "400-meter walk test". Additional manual searches of relevant references and consensus documents were also performed. This update resulted in the inclusion of 15 additional studies, two of which were consensus guidelines.

As this was a narrative review, the search was intended to identify and synthesize relevant evidence rather than systematically capture all available studies. Consequently, the number of records identified, screened, and excluded at each stage was not formally documented. The final review included 75 studies, including 6 consensus guidelines.

Techniques for screening in sarcopenia

Identifying potential cases of sarcopenia is important in clinical practice to avoid debilitating outcomes and reduce disease burden. Clinical suspicion is typically raised based on self-reported limitations in strength or physical performance. Current major consensus guidelines, including EWGSOP2, recommend the SARC-F questionnaire as a simple and rapid screening tool for routine clinical use. The SARC-F consists of five questions assessing self-perceived strength, ability to rise from a chair, climb stairs, walk assistance, and history of falls over the past year, with a score ≥4 indicating increased risk of sarcopenia. A key advantage of SARC-F is its high specificity, making it useful for identifying more advanced cases; however, its low sensitivity limits its utility for early detection [2] This trade-off is consistently reflected in the literature. For example, Lu et al. reported pooled sensitivities ranging from 27% to

77% and specificities from 63% to 91%, depending on the diagnostic criteria used, highlighting variability in performance across populations and reference standards [10]. To improve sensitivity, combined tools have been proposed. The AWGS additionally recommended calf circumference alone or the SARC-CalF, which integrates calf circumference with the SARC-F questionnaire. This modification introduces an objective anthropometric component to address the subjectivity of SARC-F [7]. In a study by Mo et al. using AWGS 2019 criteria in community-dwelling older adults, SARC-CalF demonstrated substantially higher sensitivity compared with SARC-F alone (81.4% vs 17.9%), suggesting that adding simple physical measurements may significantly improve case detection in primary care settings [11].

The EWGSOP2 also recognizes the Ishii test as an alternative or adjunct screening tool [2]. Developed by Ishii et al. in 2014, it combines age, handgrip strength, and calf circumference into a sex-specific scoring system to estimate sarcopenia risk [12]. In a study by Erdogan et al., the Ishii test demonstrated high sensitivity (84% for probable sarcopenia and 100% for confirmed and severe sarcopenia) alongside good specificity (83.9%–86.1%), indicating strong overall diagnostic performance. Compared with SARC-F, this suggests improved balance between sensitivity and specificity; however, its reliance on handgrip dynamometry and formal scoring may reduce practicality in some primary care or resource-limited settings [13].

Overall, sarcopenia screening tools vary considerably in their balance between simplicity, feasibility, and diagnostic accuracy. While SARC-F remains widely recommended due to its ease of use and high specificity, it consistently underperforms in sensitivity. In contrast, tools incorporating objective measures such as SARC-CalF and the Ishii test improve detection rates, but it reduces the rapidity of screening compared with SARC-F. The ICFSR therefore recommends either SARC-F or gait speed for screening and emphasizes annual assessment in adults over 65 years, as well as reassessment following major health events [14]. Collectively, these differing recommendations reflect an ongoing need in optimization of screening modalities.

Techniques for assessing muscle strength

Handgrip strength (HGS) is the most widely used proxy of global muscle strength and is independently associated with activities of daily living, mobility, disability, and mortality [2,15]. The most recent protocols for measuring HGS are the 2015 American Society of Hand Therapists'(ASHT) and the 2011 Southampton protocols displayed in table I.

Differences in protocols and patient positioning can yield different strength values, complicating inter-study comparability, while poor adherence to standardized measurement protocols in clinical studies further increases heterogeneity [18]. This heterogeneity may partly explain discrepancies in the identification of low muscle strength. Lim et al. demonstrated that average HGS identified a greater proportion of individuals with low strength based on EWGSOP2 criteria compared with maximal HGS, with proportions of 40% and 21%, respectively. However, only maximal HGS independently predicted physical performance decline over two years, which highlights a trade-off between diagnostic sensitivity and prognostic utility [19].

Additionally, emerging evidence highlights the clinical relevance of HGS asymmetry (>10% difference between hands). Patients with asymmetry had significantly higher odds of sarcopenia, fracture and frailty risk [20,21,22]. Currently, HGS asymmetry is not included in the EWGSOP2 protocol, but may serve as a potentially valuable adjunct marker in sarcopenia assessment.

HGS is influenced by several factors, including gender, age, ethnicity, and socioeconomic status. These variables contribute to the heterogeneity of cut-off values across different populations. Yong-chan et al. highlighted inconsistencies and a lack of normative data across countries, limiting global comparability [23]. The use of population-specific reference values together with protocol harmonization would enhance the comparability and utility of HGS as a diagnostic tool.

Table I. Protocols for measuring handgrip strength.

Protocol	Positioning Guidelines	Grip Strength Assessment
ASHT (American Society of Hand Therapists) [16]	• seated, no arm rest, hips and knees at 90° • Arms abducted, elbows at 90° • Forearms neutral • Wrists in 15–30° extension • up to 15° ulnar deviation	• mean of three trials • 15-second intervals between each trial
Southampton [17]	• Arm positioned on an armchair with wrist resting over the edge • Thumb facing up	• Highest value from three attempts per arm recorded

Muscle strength can also be evaluated using knee extension strength, typically assessed via isometric or isokinetic dynamometry, directly measuring the strength of the quadriceps muscles, which are among the first to experience strength and mass loss in sarcopenia. Although not formally incorporated into the EWGSOP2 diagnostic algorithm, knee extension testing is recommended when HGS assessment is not feasible. It additionally serves as a reliable tool for longitudinal monitoring of strength changes [2]. Further supporting its clinical relevance, Martien et al. reported that combining HGS with knee extension strength significantly improved the sensitivity of detecting functional decline, reaching up to 90% [24]. Nevertheless, the absence of standardized testing procedures and established diagnostic thresholds limits its clinical application.

The Five Times Sit-to-Stand Test (5STS) and the Timed Sit-to-Stand Test (30CST) are recognized by EWGSOP2 for assessing lower limb strength, particularly the quadriceps. The 5STS measures the time taken to stand up five times from a seated position without using the arms, whereas the 30CST records the number of sit-to-stand repetitions completed in 30 seconds. Both tests provide valuable insights into lower limb strength and functional ability [2]. However, as they also require endurance, they may be challenging for frail patients. In a geriatric rehabilitation cohort, Verstraeten et al. reported that 76.8% of patients could not perform the CST, while only 7.4% were unable to complete HGS measurement. Notably, handgrip strength—but not CST performance—was associated with institutionalization and mortality. These findings support HGS as the preferred first-line assessment tool in geriatric patients, with other functional tests serving as complementary measures [25].

Techniques for evaluating muscle mass and body composition

The role of CT in assessing muscle mass

CT is considered one of the gold standards for evaluating muscle mass because it can precisely distinguish muscle from other tissues and assess intramuscular adipose tissue through attenuation. However, its use in clinical practice for assessing sarcopenia is limited by factors such as cost, radiation exposure, and the need for highly trained personnel. Additionally, variability in study protocols—including contrast use and kilovoltage differences that affect attenuation values—further limits standardization and comparability [26].

Opportunistic CT, performed either prospectively or retrospectively in patients undergoing scans for other conditions, usually measures the cross-sectional area at the L3 vertebra, which correlates well with total skeletal muscle mass [27]. Derstine et al. reported sex-specific cut-off values for CT-derived skeletal muscle index and area from T10 to L5 [28]. Although alternatives to the L3 vertebra can be useful when scans do not capture this area, it is unclear how well they reflect total skeletal muscle mass.

CT has also been applied to assess the quadriceps femoris in research settings. Oba et al. reported significant correlations between quadriceps cross-sectional area, handgrip strength, knee extension strength, and CT attenuation values [29]. Similarly, Mizuno et al. found moderate-to-high correlations between quadriceps area—both uncorrected and height-adjusted—and knee extension strength in men and women, with CT attenuation further strengthening functional associations [30].

Although CT accurately assesses muscle size and architecture and correlates with functional outcomes, its drawbacks make it largely a research or opportunistic tool, limiting its practical use in clinical settings.

MRI for quantitative and qualitative muscle mass assessment

Magnetic resonance imaging (MRI) is one of the most accurate methods for determining muscle mass and analyzing muscular architecture, as it can precisely identify adipose infiltration, muscular atrophy, and edema. More recently, Dixon MRI, or 3D multi-echo sequences, has gained popularity for assessing intramuscular adipose tissue. Grimm et al. reported excellent short-term and long-term repeatability in measuring the proton density fat fraction (PDFF) of the quadriceps using Dixon MRI. However, hydration status influenced long-term repeatability, particularly in elderly individuals [31].

A large UK Biobank study of 44,520 individuals found that muscle volume was positively correlated with handgrip strength, while quadriceps intramuscular adipose tissue and PDFF of the paraspinal muscles were inversely correlated with muscle strength [32]. Salaffi et al. demonstrated high inter-observer agreement (0.91, CI 0.881-0.998) for quadriceps cross-sectional area measurements, with significant correlations to handgrip strength and physical performance [33]. Similarly, Sanz-Requena et al. reported moderate inverse correlations between quadriceps PDFF and both handgrip strength and Short Physical Performance Battery (SPPB) scores, indicating that higher fat infiltration was associated with poorer physical performance [34].

Despite its accuracy, MRI remains costly and resource-intensive, making it more feasible for research than routine clinical use. Opportunistic strategies may partially address these constraints; Morell et al. demonstrated that a single-slice MRI of the psoas muscle at the L4-L5 level provided a reasonable estimate of total skeletal muscle mass, although it was less precise than thigh muscle evaluation [35]. Nevertheless, the time requirements and high cost associated with MRI continue to limit its applicability as a routine tool for sarcopenia assessment.

DXA as a standard method for muscle mass evaluation

Dual-energy X-ray absorptiometry (DXA), the reference method for diagnosing osteoporosis, is also widely used to assess body composition through a three-compartment model comprising lean mass, fat mass, and bone mineral content. However, DXA does not directly quantify skeletal muscle, and reported sarcopenia prevalence varies depending on the DXA-derived index applied, such as skeletal muscle mass adjusted for height, weight, or BMI [36]. The EWGSOP2 recommends using skeletal muscle mass and skeletal muscle mass indexed to height squared [2]. Schweighofer et al. further proposed weight-adjusted indices to improve diagnostic accuracy in sarcopenic obesity, emphasizing the need to account for sex, age, ethnicity, and body composition. They also highlighted that different indices identified different individuals as having low muscle mass [37].

Despite its practicality and widespread availability, the SDOC identified DXA-derived lean mass as a poor predictor of physical performance, hip fractures, and mortality [4]. Monereo-Muñoz et al. reported associations between DXA-derived body composition and physical outcomes in older hospitalized adults, although prognostic performance was highly dependent on the cut-off values applied [38]. Together, these findings underscore the limitations of DXA in reliably predicting clinically meaningful outcomes.

Several studies have shown strong correlations between DXA-derived indices and MRI measurements of muscle [39,40]. However, Tavoian et al. reported that while overall agreement between DXA and MRI was high, DXA was less sensitive in detecting changes in appendicular muscle size after exercise interventions, potentially limiting its use for longitudinal monitoring [40].

While DXA remains a valuable tool for assessing body composition and correlates strongly with MRI-derived measurements, its inability to directly measure skeletal muscle and variability across indices can lead to inconsistent sarcopenia classification, highlighting the need for careful selection and interpretation of DXA-derived indices.

Bioimpedance analysis in estimating muscle mass

Bioimpedance analysis (BIA) is a widely used tool for evaluating body composition due to its low cost, portability, and ease of use, with good inter-observer agreement. However, BIA is less reliable in patients with overhydration syndromes or extreme BMIs. It estimates body composition by measuring resistance and reactance to a low electrical current, distinguishing between conductive and non-conductive tissues [41,42].

Several predictive equations have been developed to estimate appendicular skeletal muscle mass from BIA-derived indices and are summarized in table 2. The Method column indicates the reference modality used to measure muscle mass for validation of each equation. R^2 represents the coefficient of determination, that is, the proportion of variance in the reference measure of muscle mass explained by the model. The standard error of estimate (SEE) reflects the average deviation between the predicted and measured values of muscle mass and is expressed in the same units as the outcome variable (kg), with lower SEE values indicating greater precision and lower prediction error.

Studies have reported strong correlations between BIA-estimated ASM using predictive equations and DXA-derived muscle mass. At an individual level, BIA tended to overestimate muscle mass. However, overestimations were not considered clinically significant [49,50].

Furthermore, raw bioelectrical parameters such as phase angle (PhA), which reflects the ratio of resistance to reactance, can be used without predictive equations. PhA correlates with muscle strength and physical performance across multiple studies [51,52]. A systematic review by Vincenzo et al. reported consistently lower PhA values in sarcopenic patients [53], and a two-year prospective study by Piglowska et al. found lower baseline PhA in sarcopenic individuals [54]. However, PhA varies between populations, so cut-off values should be tailored to factors such as age, health status, and ethnicity and require standardization.

In summary, BIA is a practical and accessible tool for estimating muscle mass; however, predictive equations should be carefully selected based on the population and device used. Additionally, phase angle may serve as a valuable biomarker without the need for predictive equations, though further research and standardization of its application are needed.

Table II. Performance of bioimpedance-derived equations for estimating appendicular skeletal muscle mass across different reference methods and populations.

Study	Method	R^2	SEE	Population
Janssen et al. [43]	MRI	0.86	2.7 kg	Caucasians, Hispanics, African Americans
Kyle et al. [44]	DXA	0.953	1.12 kg	Caucasians, aged 22–94 years
Sergi et al. [45]	DXA	0.92	1.14 kg	European population > 60 years old
Scafoglieri et al. [46]	DXA	0.896 (Hologic), 0.832 (Lunar)	1.322 kg (Hologic), 1.391 kg (Lunar)	Adults > 65, BMI 30–40
Kanellakis et al. [47]	DXA	0.944	2.65 kg	Greek population
Yamada et al. [48]	DXA	0.87 (men), 0.86 (women)	1.53 kg (men), 1.15 kg (women)	Japanese population

The role of ultrasound in the diagnosis of sarcopenia

Muscle ultrasound is an emerging technique for evaluating muscle mass. To address the need for standardization, Perkisas et al. established the SARCUS working group to harmonize protocols for ultrasound-based muscle assessment. Ultrasound enables the measurement of several structural and architectural parameters, including muscle thickness, cross-sectional area, fascicle length, pennation angle, and echo-intensity [55,56]. These measures provide insight into age-related changes in muscle architecture, with echo-intensity in particular showing inverse associations with handgrip strength [57] and knee extension strength [58,59].

The ultrasound sarcopenia index, defined as the ratio of fascicle length to muscle thickness, has been proposed as a biomarker that accounts for architectural changes while remaining independent of height and body weight [60,61]. Beyond conventional measures, newer ultrasound-based approaches such as elastography and contrast-enhanced ultrasound may further enhance assessment by providing information on muscle stiffness and microvasculature [56].

Muscle ultrasound offers several practical advantages, including low cost, wide availability, bedside applicability, and good inter- and intra-observer reliability. Ultrasound-derived parameters correlate well with measurements obtained from CT, MRI, DXA, and BIA. Evidence is strongest for larger muscle groups, particularly the gastrocnemius, rectus femoris and quadriceps femoris, whereas assessment of smaller muscles requires further validation [62-65]. A meta-analysis by Fu et al also reported better diagnostic performance when echo-intensity was combined with quantitative ultrasound measurements [65].

Despite these advantages, clinical implementation remains limited by the lack of universally accepted protocols and cut-off values for low muscle mass. Variability related to sex, body size, and hydration status must also be considered. Notably, fluid status assessed by BIA has been shown to significantly influence echo-intensity, especially in elderly hospitalized patients [66].

Overall, muscle ultrasound represents a valuable tool for muscle mass evaluation, but further research and standardization are required to support its routine clinical use.

D_3 Creatine dilution method as a novel, direct method in the diagnosis of sarcopenia

Although creatine dilution techniques have been used since the 1960s, the D_3-creatine dilution method is a recent innovation that allows direct measurement of skeletal muscle mass. By exploiting the fact that 98% of creatine resides in skeletal muscle, a single oral dose of deuterated creatine is administered, and urine collected after 3–6 days is analyzed via mass spectrometry and chromatography to quantify D_3-creatinine, creatine, and unlabeled creatinine. A validated algorithm then estimates total muscle mass. This approach is minimally burdensome for patients and is unaffected by hydration status or renal function [67,68].

Validation studies have shown strong correlations between D_3-creatine derived muscle mass and DXA-measured appendicular lean mass. Balachandran et al. reported that D_3-creatine dilution was more sensitive to training-induced changes, detecting a 2.29 kg increase in muscle mass versus 1.09 kg via DXA [69]. Furthermore, Cawthon et al. demonstrated that D_3-creatine derived muscle mass, adjusted for body mass, was strongly associated with physical performance in older men; individuals in the lowest quartile were six times more likely to experience mobility limitations, while those in the highest quartile had superior gait speed, grip strength, 5STS, and SPPB scores [70].

Despite these promising findings, the clinical utility of D_3-creatine dilution remains under investigation. Limitations include the need for specialized laboratory equipment and technical expertise. Moreover, further studies in diverse populations are needed.

Integrative comparison of muscle mass assessment techniques

Across modalities, assessment of skeletal muscle mass reflects a continuum between anatomical precision, feasibility, and standardization. Cross-sectional imaging techniques such as CT and MRI provide the highest anatomical accuracy and are generally considered reference standards; however, their limited accessibility and high cost restrict routine clinical use.

In contrast, DXA and BIA are more widely applicable in clinical and epidemiological settings but estimate muscle mass indirectly through derived indices and predictive models. This introduces methodological variability across populations and study designs, which may contribute to differences in reported muscle mass estimates and sarcopenia classification.

Emerging modalities, including muscle ultrasound and D_3-creatine dilution, aim to improve either feasibility or biological specificity but remain limited by incomplete standardization and insufficient validation across populations.

Differences in feasibility and operational standardization across modalities are summarized in table III.

While feasibility and operational considerations influence the selection of assessment techniques in clinical practice, the clinical utility of each modality ultimately depends on its diagnostic performance in identifying low muscle mass. A summary of reported sensitivity, specificity, and area under the curve (AUC) across modalities is provided in table IV.

Table III. Operational characteristics and feasibility of muscle mass assessment techniques.

Method	Operational Standardization	Cost	Time
CT	Moderate–High	High	Moderate–High
MRI	High	Very High	High
DXA	Very High	Moderate	Low
Bioimpedance	Moderate	Low	Very Low
Muscle Ultrasound	Low–Emerging	Low	Low–Moderate
D_3-Creatine Dilution	Emerging	Moderate	Moderate

Table IV. Diagnostic performance of muscle mass assessment techniques.

Study	Population	Modality	Reference Standard	Sensitivity (%)	Specificity (%)	AUC (95% CI)	Pitfalls / Limitations	Key Findings / Notes
Mizuno et al. 2023 (30)	Community-dwellers above age 40	CT mid-thigh quadriceps CSA	AWGS 2019 (DXA + grip strength + performance)	Men: 86%, women 73%	Men: 84-92%, women: 76-78%	Men: 0.917-0.936, women: 0.799-0.824	Cross-sectional, Japanese population only	CSA adjusted by density had highest AUC
Salaffi et al. 2023 (33)	Women with rheumatoid arthritis (n=32)	MRI thigh CSA at 25 cm above knee (summed quadriceps + biceps femoris)	EWGSOP2 (DXA + grip strength + performance)	81.8%	90.5%	0.894 (0.765-1.00)	Small sample size, only women evaluated	Correlates well with physical performance; needs validation in larger, mixed-sex population
Fu et al. 2023 (Meta-analysis) (65)	Varied (mostly older adults; mean age 52.6-82.2 years, n=2,143, 14 vstudies);	Muscle ultrasound (MT, CSA, EI of multiple muscles, mainly lower limb)	Heterogenous (EWGSOP2, EWGSOP1, AWGS 2014/2019, or low muscle mass alone)	64-84% (pooled)	64-72% (pooled)	0.64-0.90 [best gastrocnemius MT: 0.83 (0.79-0.86) and RF MT: 0.78 (0.74-0.82)]	High heterogeneity in protocols, cut-offs, populations, and reference standards	Moderate accuracy for lower-limb quantity parameters. Combination of MT/CSA + EI showed superior performance
Nielsen et al. 2023 (49)	Hospitalized patients ≥65 years old (n=42)	Multi-frequency BIA (ASM)	DXA (EWGSOP2 cut-offs for low muscle mass)	86%	94%	Not reported	Small sample size, single-center; overestimates absolute ASM	High specificity, useful for ruling out low-muscle mass in hospitalized setting
Li et al. 2024 (Meta-analysis) (71)	Varied (older adults and clinical settings, n= 4,926, 28 studies	BIA, US, MRI	DXA	BIA: 0.79 (pooled)	BIA: 0.95 (pooled)	BIA: 0.88 (0.85-0.90)	High heterogeneity, limited studies for US (n=8) and MRI (n=4), no CT	US had moderate correlation with DXA (r=0.69). MRI showed excellent correlation with DXA (r=0.96), no sensitivity, specificity, AUC reported

Diagnostic performance across muscle mass assessment modalities demonstrates variability in sensitivity, specificity, and AUC, reflecting differences in study design, populations, and reference standards. Importantly, studies differ in whether the diagnostic target is defined as low muscle mass alone or as sarcopenia, the latter incorporating muscle strength and physical performance within composite criteria.

CT and MRI demonstrate high diagnostic performance and are frequently used as reference modalities rather than purely index tests in comparative studies. DXA also shows good agreement with cross-sectional imaging and is often applied as both an index and reference method depending on study design. In contrast, BIA generally demonstrates higher specificity than sensitivity in reported studies, although performance varies across populations and clinical settings.

Muscle ultrasound shows the greatest variability in diagnostic accuracy, reflecting dependence on measurement site, protocol, and cut-off definitions. Meta-analytic data suggest that lower-limb muscle assessments and combined parameters (muscle thickness and echo intensity) tend to yield better diagnostic performance than single-parameter approaches.

Overall, comparability across modalities is limited by heterogeneity in study design, outcome definitions, and reference standards, particularly the distinction between low muscle mass and sarcopenia as diagnostic endpoints. Current consensus frameworks, including EWGSOP2 and AWGS definitions, primarily recommend DXA as the reference method for clinical assessment of muscle mass, with BIA considered a practical alternative in settings where DXA is not available.

Evaluation of physical performance in sarcopenia

Although low physical performance is no longer classified as a direct marker of sarcopenia severity, it remains an important clinical outcome and may be useful for risk stratification and prognostic assessment. It can be evaluated using several validated tests, including gait speed, the Timed Up and Go (TUG) test, the 400-meter walk test, and the Short Physical Performance Battery (SPPB) [2,9].

Current guidelines differ by their emphasis on these measures. The EWGSOP2, SDOC, and the International Working Group on Sarcopenia (IWGS) criteria primarily recommend gait speed (cut-off 0.8 m/s for EWGSOP2, SDOC; 1.0 m/s IWGS) as a core assessment due to its speed, simplicity, and established prognostic value for adverse outcomes [2, 8, 72]. The AWGS recommend the SPPB, 6-meter walk test, and five-times sit-to-stand test [7]. This variation reflects an ongoing lack of consensus regarding the optimal balance between feasibility and multidimensional functional assessment.

The SPPB test is composed of a combination of gait speed, chair stand test, and a test that evaluates balance [2]. While the SPPB provides multidimensional information, it may be more challenging and time-consuming for frail patients compared with single-item tests such as gait speed. Phu et al. demonstrated that current cut-off values of ≤8 points proposed by the EWGSOP2 showed high sensitivity for identifying sarcopenia and noted that it is a useful test for monitoring physical performance, as a change of as little as 1 point is clinically significant [73]. In terms of risk prediction, a prospective longitudinal study found that gait speed and the SPPB were the most useful in predicting fall risk over four years [74].

The TUG test is another quick and practical measure recognized by the EWGSOP2, which involves patients rising from a chair, walking 3 meters, turning around, and returning to sit on the chair. However, a meta-analysis by Barry et al. reported that it is not a significant predictor of fall risk [75].

The 400-meter walk test is also endorsed by the EWGSOP2 as a valid test for evaluating endurance. It requires patients to complete 20 laps of a 20-metre hallway [2]. In high-functioning older adults, participants with 400-m walk times above the group median exhibited a higher number of reported falls and medical conditions compared with those with faster times. This highlights the test's utility for detecting subtle mobility limitations and elevated risk in ostensibly well-functioning individuals [76]. Additionally, inability to complete the test or prolonged completion time has been associated with increased mortality risk [77]. However, in terms of feasibility, it is constrained by the need for adequate space to perform the test.

On the contrary, Exter et al. systematically reviewed the psychometric properties of the SPPB, TUG, 4-meter gait speed, and 400-meter walk test in community-dwelling older adults with sarcopenia. While these tests generally showed adequate reliability, the overall quality of evidence for their validity and measurement error remains insufficient [78]. This highlights the need for further high-quality, sarcopenia specific validation studies.

All physical performance tests included in the EWGSOP2 algorithm have been linked to mortality risk. In terms of feasibility across clinical settings, gait speed is the most practical due to minimal time, space, and equipment requirements, making it suitable for busy inpatient and outpatient environments. The SPPB and TUG are relatively easy to perform in terms of time and equipment but may be more difficult for frail patients. The 400-meter walk test is more constrained by the need for sufficient hallway space, limiting its routine use in acute hospital settings but may serve as a useful marker for early risk stratification in higher functioning elderly adults.

Integrating diagnostic criteria: challenges and pragmatic clinical approach

A major barrier to comparability across sarcopenia studies is the substantial heterogeneity in diagnostic cut-off values across consensus definitions, as well as variability in the parameters used to define sarcopenia. This directly affects reported prevalence estimates and limits the interpretability of temporal and cross-population comparisons, raising important concerns for epidemiological screening and surveillance.

A systematic review by Petermann-Rocha et al. reported a global sarcopenia prevalence ranging from 8–36% in adults under 60 years and from 10–27% in adults aged 60 years and older, depending on the diagnostic criteria applied [79]. These findings underscore the extent to which prevalence estimates are influenced by the selected consensus definition and associated cut-off values. The differences between major consensus group criteria are summarized in table V.

Table V. Comparative diagnostic cut-off thresholds for sarcopenia across major consensus definitions.

Consensus group	Muscle strength	Muscle mass (DXA / BIA)	Physical performance
EWGSOP2 [2]	HGS: <27 kg men, <16 kg women; chair stand test >15 seconds 5 rises	ASM/height^2: <7.0 kg/m^2 men, <5.5 kg/m^2 women; ASM: <20 kg men, <15 kg women	Gait speed ≤0.8m/s; 400m walk test ≥ 6 min or incomplete; SPPB ≤ 8 points; TUG ≥ 20 seconds
AWGS (2019) [7]	HGS: < 28kg men, <18kg women	ASM DXA: <7.0 kg/m^2 men, <5.4 kg/m^2 women; ASM BIA: <7.0 kg/m^2 men, <5.7 kg/m^2 women	6-meter walk test <1.0 m/s; 5-times chair stand test ≥ 12s; SPPB ≤ 9 points
FNIH Sarcopenia Project [80]	HGS: < 26kg men, < 16 kg women; HGS/BMI < 1.0 men, < 0.56 women	ALM/BMI (recommended): < 0.789 men, < 0.512 women; ALM: < 19.75 Kg men, < 15.02 kg women	Outcome measure, not core diagnostic criterion
SDOC [8]	HGS < 35.5 kg men, < 20 kg women	Excluded (DXA lean mass is unreliable)	Gait speed ≤0.8m/s
IWGS [72]	Excluded	ALM/height^2 DXA/BIA: ≤7.23 kg/m^2 men, ≤5.67 kg/m^2 women	Gait speed <1.0m/s

Abbreviations: EWGSOP2, European Working Group on Sarcopenia in Older People 2; AWGS, Asian Working Group for Sarcopenia; FNIH, Foundation for the National Institutes of Health; SDOC, Sarcopenia Definition and Outcomes Consortium; IWGS, International Working Group on Sarcopenia; HGS, handgrip strength; ASM, appendicular skeletal muscle mass; ALM, appendicular lean mass; BMI, body mass index; SPPB, Short Physical Performance Battery; TUG, Timed Up and Go test.

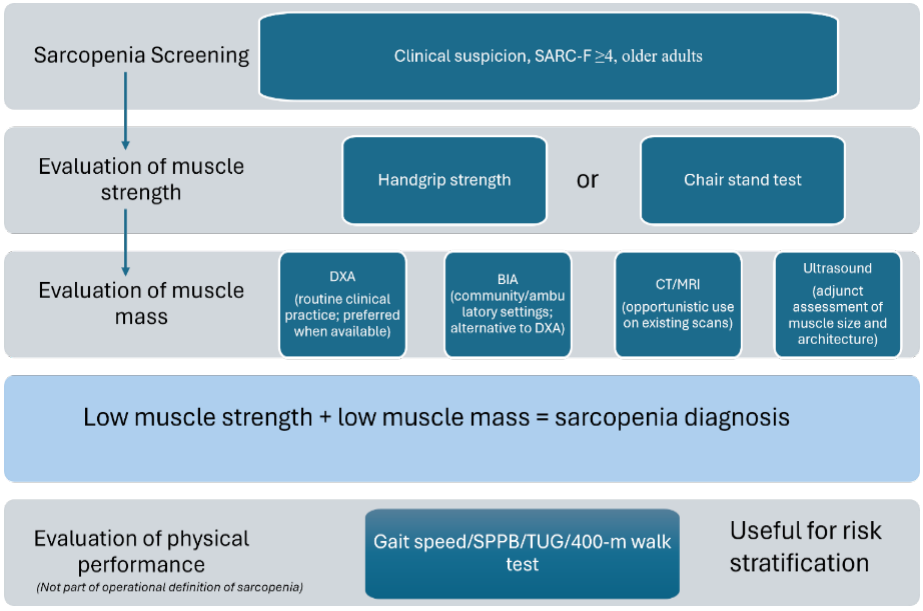

Figure 1. Proposed pragmatic diagnostic algorithm for the evaluation of sarcopenia.

While ethnic and population-specific differences may justify some variation in threshold selection, the absence of a unified operational definition remains a major limitation for both research comparability and clinical implementation. As illustrated in table V, consensus groups differ not only in the cut-off values used to define abnormal findings but also in the relative importance assigned to muscle strength, muscle mass, and physical performance within the diagnostic framework. Consequently, the same individual may be classified differently depending on the criteria applied, contributing to substantial variation in reported prevalence estimates and study outcomes.

The GLIS was established in response to these inconsistencies and aims to provide a harmonized diagnostic framework. By emphasizing the combined presence of reduced muscle strength and muscle mass

while considering physical performance primarily as an outcome of the disease, GLIS seeks to improve consistency across both research and clinical settings [9]. Nevertheless, further work is required to establish universally accepted thresholds and standardized assessment methods.

From a clinical perspective, diagnostic heterogeneity may influence case identification, risk stratification, eligibility for interventions, and epidemiological surveillance. It also complicates comparisons of prevalence estimates across populations and over time. Given the association of sarcopenia with functional decline, disability, and adverse health outcomes, a standardized and clinically applicable diagnostic approach remains an important unmet need.

The variability in diagnostic definitions, assessment modalities, and cut-off values highlights the challenges of translating sarcopenia research into routine clinical practice. Despite these differences, most contemporary frameworks follow a similar conceptual sequence, beginning with the identification of impaired muscle strength, followed by confirmation of low muscle mass and assessment of physical performance. Based on the available evidence and current consensus recommendations, a pragmatic diagnostic approach is proposed to facilitate the evaluation of sarcopenia across diverse clinical settings (Figure 1).

Limitations

The literature search for this narrative review was conducted exclusively using the PubMed database. As a result, relevant studies not indexed in PubMed were missed, which potentially limits the comprehensiveness of the evidence presented.

Conclusion

Accurate assessment of muscle strength and mass is essential for the timely diagnosis of sarcopenia, a condition of growing clinical and research significance. No single diagnostic method is sufficient on its own. We recommend pragmatic diagnostic pathways, in which handgrip strength and gait speed serve as first-line screening tools, while methods for evaluating muscle mass—such as BIA and DXA—are used for confirmation. Ultrasound currently serves mainly as an adjunct to standard techniques but holds considerable potential to become a practical, independent tool with further standardization and cut-offs. D_3-creatine dilution, on the other hand, offers a direct measurement of total skeletal muscle mass and is a promising integrative tool for future sarcopenia research and practice. Establishing standardized, reliable, and practical diagnostic methods is critical not only to improve early detection but also to guide interventions that can preserve function, quality of life, and long-term outcomes for affected individuals.

Authors' Contribution

Conceptualization: M.M.S, I.M.P; Literature search and data curation: M.M.S; Writing – original draft: M.M.S; Writing – substantial revision and editing: I.M.P; Supervision: I.M.P. Both authors approved the final manuscript.

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