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CONSENSUS STATEMENT

Guidance for assessment of the muscle mass phenotypic criterion for the Global Leadership Initiative on Malnutrition diagnosis of malnutrition

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Abstract

The Global Leadership Initiative on Malnutrition (GLIM) provides consensus criteria for the diagnosis of malnutrition that can be widely applied. The GLIM approach is based on the assessment of three phenotypic (weight loss, low body mass index, and low skeletal muscle mass) and two etiologic (low food intake and presence of disease with systemic inflammation) criteria, with diagnosis confirmed by any combination of one phenotypic and one etiologic criterion fulfilled. Assessment of muscle mass is less commonly performed than other phenotypic malnutrition criteria, and its interpretation may be less straightforward, particularly in settings that lack access to skilled clinical nutrition practitioners and/or to body composition methodologies. In order to promote the widespread assessment of skeletal muscle mass as an integral part of the GLIM diagnosis of malnutrition, the GLIM consortium appointed a working group to provide consensus-based guidance on assessment of skeletal muscle mass. When such methods and skills are available, quantitative assessment of muscle mass should be measured or estimated using dual-energy x-ray absorptiometry, computerized tomography, or bioelectrical impedance analysis. For settings where these resources are not available, then the use of anthropometric measures and physical examination are also endorsed. Validated ethnic- and sex-specific cutoff values for each measurement and tool are recommended when available. Measurement of skeletal muscle function is not advised as surrogate measurement of muscle mass. However, once malnutrition is diagnosed, skeletal muscle function should be investigated as a relevant component of sarcopenia and for complete nutrition assessment of persons with malnutrition.

KEYWORDS
adult life cycle, nutrition assessment nutrition, weight loss

INTRODUCTION

The Global Leadership Initiative on Malnutrition (GLIM) is a recent initiative by major global clinical nutrition societies, aimed at providing criteria and guidance for a consensus-based approach to diagnosis of malnutrition in adults applicable in diverse global clinical settings.[1,2] Among its main features, the GLIM construct aims at combining clinical accuracy and consistency with simple implementation that may be applied by nonspecialized healthcare personnel in everyday practice.[1,2] Therefore, the GLIM malnutrition diagnosis is based on widely recognized criteria that were selected based on their inclusion in all major existing diagnostic tools.[1,2] Three phenotypic (weight loss, low body mass, and low skeletal muscle mass) and two etiologic (low food intake and presence of disease or systemic

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inflammation) criteria were proposed, with malnutrition confirmed by any combination of one phenotypic and one etiologic criterion. After publication in 2019, the GLIM criteria for malnutrition diagnosis have been embraced by many in the clinical nutrition community, and their utilization in clinical practice is growing.[1–4] Recent research publications suggest that the GLIM approach is comparable to other long-established nutrition assessment tools in diagnosis of malnutrition and associated risk of adverse outcomes.[5–21] The GLIM approach also offers simplicity that supports practical use by a wide variety of practitioners and healthcare professionals.

Among the criteria included in the GLIM malnutrition diagnosis, assessment of skeletal muscle mass is, however, less commonly performed in clinical nutrition practice, and even less so in those settings that lack access to skilled clinical nutrition practitioners and to specialized body composition methods.[5–21] In addition, whereas the original GLIM guidance remained provisionally open to the inclusion of skeletal muscle function as a surrogate or proxy measure for skeletal muscle mass,[1,2] the role of muscle function both as an indicator of malnutrition and as a potential surrogate for skeletal muscle mass remains under debate. In order to further promote the use of skeletal muscle mass as an integral part of the GLIM approach for the diagnosis of malnutrition, the GLIM consortium of representatives of the four global clinical nutrition societies appointed a working group to provide consensus-based guidance on assessment of skeletal muscle mass and the role of skeletal muscle function in the malnutrition diagnostic and assessment process. The GLIM Body Composition Working Group hereby provides five consensus-based statements on methods for measuring/assessing skeletal muscle mass and its related body compartments for the diagnosis of malnutrition, related cutoffs, and the role of skeletal muscle function.

METHODS

The GLIM core leadership of representatives of four major global clinical nutrition societies (the American Society for Parenteral and Enteral Nutrition [ASPEN], the European Society for Clinical Nutrition and Metabolism [ESPEN], the Latin American Federation for Nutritional Therapy, Clinical Nutrition and Metabolism [FELANPE], and the Parenteral and Enteral Nutrition Society of Asia [PENSA]) appointed a Steering Committee of two representatives for each Society (R. B., T. C., C. C., G. J., M. I. T. D. C., M. C. G., T. H., and H. S.) for this task. Two cochairs (R. B. and C. C.) were selected by the Steering Committee and each society was further invited to appoint four to six experts to create the working group.

On behalf of the Steering Committee, the cochairs proposed an initial, preliminary survey with the main goals to (1) evaluate existing tools for direct or indirect skeletal muscle measurement, (2) evaluate potential proposals and approaches for cutoff utilization, and (3) identify the level of agreement on the use of skeletal muscle function parameters as a surrogate of skeletal muscle mass in the diagnosis of malnutrition. The survey results were evaluated and discussed during virtual meetings of the working group during the ESPEN virtual Congress in September 2020. Based on results and subsequent discussions, a set of five summary statements was circulated by the cochairs on behalf of the Steering Committee in the beginning of 2021. The whole working group was asked to express agreement on a 5-point scale (strongly agree; agree; neither agree nor disagree; disagree; strongly disagree; 75% of combined agree or strongly agree votes was the required threshold for consensus on each statement).[22] In addition, succinct comments for initial discussion of each statement were provided by the Steering Committee and the whole group was invited to write additional comments or suggestion for discussion, independent of agreement on the related statement.

STATEMENTS FROM THE GLIM BODY COMPOSITION WORKING GROUP

Measuring muscle mass for the diagnosis of malnutrition (Figure 1)

Statement 1. In general, use of validated tools is acceptable based on availability, reference values, and operator expertise for direct and indirect measurement of skeletal muscle mass or its related body compartments, such as fat-free mass (FFM), appendicular lean soft tissue, and skeletal muscle area. Use and dissemination of techniques like bioelectrical impedance analysis (BIA), dual-energy x-ray absorptiometry (DXA), and computerized tomography (CT) is recommended when the methods and access to expert analysis are available.

Level of agreement 96%

General comments on technology-based methods

We support a general inclusive approach to use established tools for direct or indirect measurement of skeletal muscle mass and body composition. We advocate that priority be given to utilization and further dissemination of technologies such as BIA, DXA, and CT for body composition assessment. In addition, the group emphasizes the importance of quantitative assessments such as those obtained with BIA, DXA, and CT as well as anthropometry for comparison and validation purposes. BIA, DXA, and CT have been used in clinical research for some time and have generated a large body of evidence supporting their ability to identify changes in body composition and/or skeletal muscle mass and its related body compartments.[1,23] BIA, DXA, and CT use for clinical malnutrition diagnosis is therefore supported, when the method is available along with appropriate expertise by experienced personnel. Operator expertise is particularly important to avoid errors and misleading conclusions from misinterpretation of data. It is anticipated that advances in the field will soon bring further improvements in portable bedside body composition technologies that may enhance widespread access and use. Limitations and advantages for each tool are acknowledged as follows.

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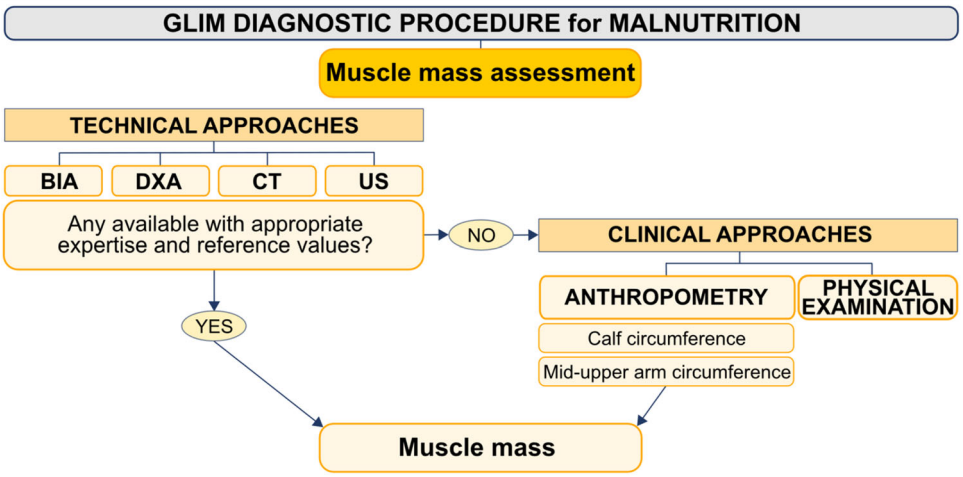

FIGURE 1 GLIM approach to diagnosis of malnutrition with focus on muscle mass assessment. The use of technology-based measurements is primarily recommended when devices, expertise for device utilization and result interpretation, and appropriate validated cutoffs are available. We recognize that no criterion-standard or superior technique is currently acknowledged, and use of different techniques should be based on availability criteria and with consideration for strengths and limitations described in the text. If use of technology-based measurements is not possible because of any of the above reasons, use of anthropometry or trained physical examination for signs of low skeletal muscle mass is recommended. In this case, trained personnel and validated cutoffs for the desired application should also be available. BIA, bioelectrical impedance analysis; CT, computerized tomography; DXA, dual-energy x-ray absorptiometry; GLIM, Global Leadership Initiative on Malnutrition; US, ultrasound.

Comments on the use of BIA

BIA provides practical advantages including relatively low cost and device portability, with potential for repeated measurements. Many studies have generally reported good results for BIA in terms of predictive value for relevant clinical outcomes, as its use has increased over the past several years.[24–27]

However, several limitations need to be considered for the use of BIA in routine clinical practice. BIA-derived assessment of body composition relies on electrical impedance to provide estimates of total body water, leading to equation-derived estimates of body fat- and FFM, the latter of which includes various nonmuscle components.[23] These equations have been usually established within specific populations (persons with undernutrition or obesity, older populations) and against specific methodologies (water dilution, DXA, magnetic resonance imaging [MRI]), so that use of direct results from different devices and in different populations should be cautiously analyzed. BIA results are also influenced by hydration status with overhydration and edema resulting in overestimation, and dehydration resulting in underestimation of FFM. It is also important to note that BIA devices vary and include single- and multiple-frequency electrical analyses as well as segmental BIA.[24] Multiple-frequency BIA allows better estimates of extracellular fluid separately from intracellular and therefore fluid distribution and different fluid compartments.[28] Different methods will likely require additional comparisons for validation and generation of cutoffs.[25] Importantly, equations for estimates of body compartments are device and population-specific, and parameters derived from the direct assessment of reactance and resistance, for example, phase angle, have been proposed as surrogate markers for muscle mass with studies supporting its predictive value for clinical outcomes.[29,30]

Comments on the use of DXA

DXA provides accurate measurements of body composition, based on x-ray attenuation through different body components.[23] DXA is routinely used in clinical practice for measurement of bone density and it is a cornerstone in osteoporosis diagnostics and management.[31] Additional information on fat and lean soft tissue mass can be determined with validated accuracy from whole-body DXA scans.[23,32–34] Relatively few assumptions are required for DXA-based body composition analyses, although it should be pointed out that skeletal muscle is not directly measured as such, but is estimated from appendicular lean soft tissue.[23] DXA can also provide regional body composition assessment with separate measurements for limbs (appendicular) and trunk.[23] Appendicular lean soft tissue (also commonly termed appendicular muscle mass) estimates may be particularly useful in clinical estimates of body composition and skeletal muscle mass, with some limitations in persons with overweight, obesity, or in older age groups.[35]

However, DXA is generally less available than BIA, and dedicated devices are significantly more expensive and often not available or applicable for routine use in clinical settings across the globe.[36] Furthermore, lean soft tissue assessed by DXA is not well validated in clinical populations.[35] Except for bone density, DXA is not commonly used for measurement of body composition in many countries and healthcare systems. X-ray exposure is considered to be modest[23] but should be considered in certain clinical conditions and for repeated measurements.

Comments on the use of CT

CT has been increasingly employed in clinical research for measurement of selected skeletal muscle areas, which may be used as

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surrogate markers of whole-body skeletal muscle. CT imaging of regional body skeletal muscle has been validated against clinical outcomes in various disease settings.[37,38] Typically, skeletal muscle index at L3 (cross-sectional area divided by height squared) is recommended from abdominal CT scans,[39] although other muscles and muscle groups have been proposed, for example, from chest and mid-thigh scans.[40–42]

Use of CT scans specifically for routine diagnosis of malnutrition may be limited because of practical reasons including availability of images from medical records, additional radiation exposure that results from CT scans potentially obtained only for skeletal muscle assessment, significant costs, operational complexity and heterogeneity in the protocols and technical settings used. Nonetheless, there is a strong rationale and the opportunity to incorporate body composition and muscle mass assessment in large groups of patients undergoing CT examinations related to standard care for various disease conditions. For example, many patients with cancer undergo CT imaging for cancer staging and they are also at high risk to develop malnutrition. Radiologists or other trained personnel can be engaged in pursuing muscle mass assessments by CT imaging completed for other diagnostic reasons. The increasing number of automated analysis software applications may facilitate this task. Routine implementation of muscle assessment from available images will require increased awareness on the clinical relevance of malnutrition diagnosis in many patients undergoing CT scans. This in turn may further enhance availability of automated software for muscle analysis, as well as training and commitment of personnel.

Statement 2. When technology-based devices and the expertise to interpret them are not readily available, then the use of anthropometric measures like calf circumference and mid-arm muscle circumference are supported, as well as physical examination, due to universal availability, and according to preference and training.

Level of agreement 92%

Comments on the use of arm and leg anthropometry

When BIA, DXA, or CT are not available or feasible, we support the use of anthropometric measures for assessment of skeletal muscle mass. For estimation of upper arm muscle area, anthropometry measures include calf circumference or mid-arm muscle circumference,[43–46] the latter being calculated as mid-arm circumference minus π times triceps skinfold thickness. Both techniques require appropriate methodological training,[47] although less training may be needed for calf circumference. They are suitable and applicable to many clinical settings, including bedside hospital rounds, skilled nursing and rehabilitation facilities, outpatient clinics, and community settings. Ethnic-specific cutoffs must also be considered, and cutoffs may be unavailable for oldest age groups (>80 years). Anthropometry is focused on the selected muscle groups which have been found to be reduced in individuals with malnutrition. Note that anthropometry is generally less sensitive than appropriately implemented imaging or bioelectrical impedance methods.

Comments on the use of physical examination

Physical examination to detect qualitative signs of reduced muscle mass at the temple, neck, clavicle, shoulder, scapula, thigh, and calf sites is a component of major assessment tools such as Subjective Global Assessment (SGA) and the Academy/ASPEN approach.[48,49] Physical examination has been validated for assessment of nutrition status when implemented by trained personnel.[50] The subjective nature of physical examination can be limited by operator expertise and training as well as standardization of results.[50] Physical examination is therefore supported according to preference and training, particularly in the context of using standardized examination approaches for nutrition assessment in order to limit potential interobserver variability.

Statement 3. Ultrasound (US) is supported in the presence of experienced operators, particularly for repeated measurements.

Level of agreement 79%

Comments on the use of US

US technique is widely available also for bedside measurements, and may be practical for repeated longitudinal measurements of muscle thickness and cross-sectional area. Standardization methods have been proposed in consensus statements.[51] Studies have reported strong comparisons against techniques like MRI and DXA[52–55] for thickness and cross-sectional area measures at various sites including thigh, calf, upper arm, and musculus rectus abdominis. However, relevant limitations remain, particularly in terms of interoperator reproducibility, and standardized techniques and protocols in terms of degree of compressibility of the skin at measurement site, and cut-points in specific patient populations.[56] We support the use of US, particularly in settings where its practical applicability provides potential for patient follow-up through repeated measurements,[57,58] but it requires standardization through experienced operators, and repeated measurements performed by the same individual.[56–58] Further validation studies for US are encouraged.

COMMENTARIES ON SECTION A—MEASURING MUSCLE MASS FOR THE DIAGNOSIS OF MALNUTRITION

General limitations imposed by obesity and edema

Current body composition measures to assess skeletal muscle mass suffer limitations in settings of excess fat or fluid accumulation such as commonly observed in persons with significant obesity or edema, respectively.[59]

With regard to technology-based methods, persons with very high body mass often cannot be accommodated on standard CT or DXA examination tables. Obesity may also reduce the DXA accuracy for body composition estimation.[23] Edema may confound CT interpretation since water and skeletal muscle can be difficult to

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distinguish. Equations derived for body composition determinations by BIA suffer limitations in accuracy for persons at high extremes of body fatness or edema. It may also be difficult to place such persons in supine position with adequate separation of the extremities for BIA. In addition, obesity and edema make land marking and visualization of muscle groups difficult for US assessment.

Regarding anthropometry and physical examination, muscle circumferences can be difficult to accurately obtain in individuals with obesity or edema, and appreciation of reduced skeletal muscle mass is also challenging by physical examination in such individuals. Older persons with obesity frequently have low skeletal muscle mass (sarcopenic obesity) as do persons with comorbidities.[60,61] The issue of obesity for calf circumference has been addressed in the NHANES general US population cohort,[62] demonstrating that use of body mass index (BMI)–based adjustment factors resulted in the ability to detect age-associated, and sex-specific lower values of calf circumference.[62] Further studies are needed to validate adjustment for BMI to detect low calf circumference, low skeletal muscle mass, and associated malnutrition in persons with obesity. In the presence of edema, if it is observed at lower and not at upper extremities, mid-arm muscle circumference could be considered as alternative preferred measurement.

Research methods

MRI and novel techniques like the Deuterium and D3-creatine dilution tests are recommended for research purposes in experienced research facilities.

Level of agreement 79%

Research is advocated to develop innovative methods, devices, and artificial intelligence, aimed at advancing the field of body composition measurement, and for further validation testing of such methods against existing approaches used in clinical practice. Although MRI[23] and deuterium and D3-creatine dilution tests[63,64] are currently available, we consider it unlikely that they will soon be available for routine clinical practice. Some of these methods are being currently tested and validated.[63–65] In general, their relevance to the implementation of the GLIM criterion of low skeletal muscle mass for diagnosis of malnutrition in clinical practice remains limited until more widespread implementation and comparison with clinically established methods becomes possible.

Use of cutoffs for identification of reduced muscle mass for the diagnosis of malnutrition

Statement 4. Cutoff values are needed for use for each measurement and method, including ethnic- and sex-specific cutoffs, and validated cutoffs are recommended for use when available. At present, there is not enough evidence to clearly define cutoffs between moderately and severely reduced muscle mass using the available data for currently recommended techniques.

Level of agreement 88%

Comments on the choice of cutoff values to use

We recommend a general inclusive approach to use consensus-based cutoffs at this time (Table 1). It is acknowledged that some devices and techniques do not currently rely on universally accepted cutoff values for normality and disease.[35,75] Age-, sex-, ethnicity-specific cutoffs may not be universally available and accepted for all methods. Research is encouraged to extend cutoff validation testing where needed. Identification of cutoffs may be based on standard approaches such as 1–2 SD below mean values of young (*T*-scores) or age-matched (*z* scores) individuals, respectively, or below 5th–10th percentile in reference to a general healthy population.[71,72] Receiver operating characteristic curves (using a validated tool as the criterion standard to classify low or normal) could be used to identify the best cutoff for a new approach when there are no data from a reference population. Although use of general comparison to reference population is encouraged, disease-specific cutoffs also may be used for clinical practice, particularly in chronic disease states when cutoffs could be validated against clinical outcomes (survival rate, hospitalization rate, complications, clinical events).

TABLE 1 Examples of recommended thresholds for reduced muscle mass or its surrogate markers

Thresholds	Males	Females
ALMI, kg/m^2[2a,66,67] (DXA)	<7	<5.5
ASMI or ALMI, kg/m^2[2b,67–69]		
BIA[b,69]	<7	<5.7
DXA[b,70]	<7	<5.4
FFMI, kg/m^2[72,271] (BIA)	<17	<15
ALM/weight, %[73] (DXA)	<25.7	<19.4
ALM/BMI, m^2[274] (DXA)	<0.827	<0.518
Calf circumference, cm[c,d,62]	<33	<32

Note: Adjustments by height or weight (for use in persons with obesity). The recommendations are feasible for adults.

Abbreviations: ALM, appendicular lean mass; ALMI, appendicular lean mass index (ie, lean soft tissue index); ASMI, appendicular skeletal muscle mass index; BIA, bioelectrical impedance analysis; BMI, body mass index; DXA, dual-energy x-ray absorptiometry; FFMI, fat-free mass index.

[a]Recommendation from The European Working Group on Sarcopenia in Older People 2 (for White people).[66]

[b]Recommendation from The Asian Working Group for Sarcopenia (for Asian populations).[69]

[c]Recommendation based on the agreement between the authors of this consensus report.

[d]In adults with obesity, decrease the measured value by 3 cm (BMI, 25–30) or 7 cm (BMI, 30–40).[62]

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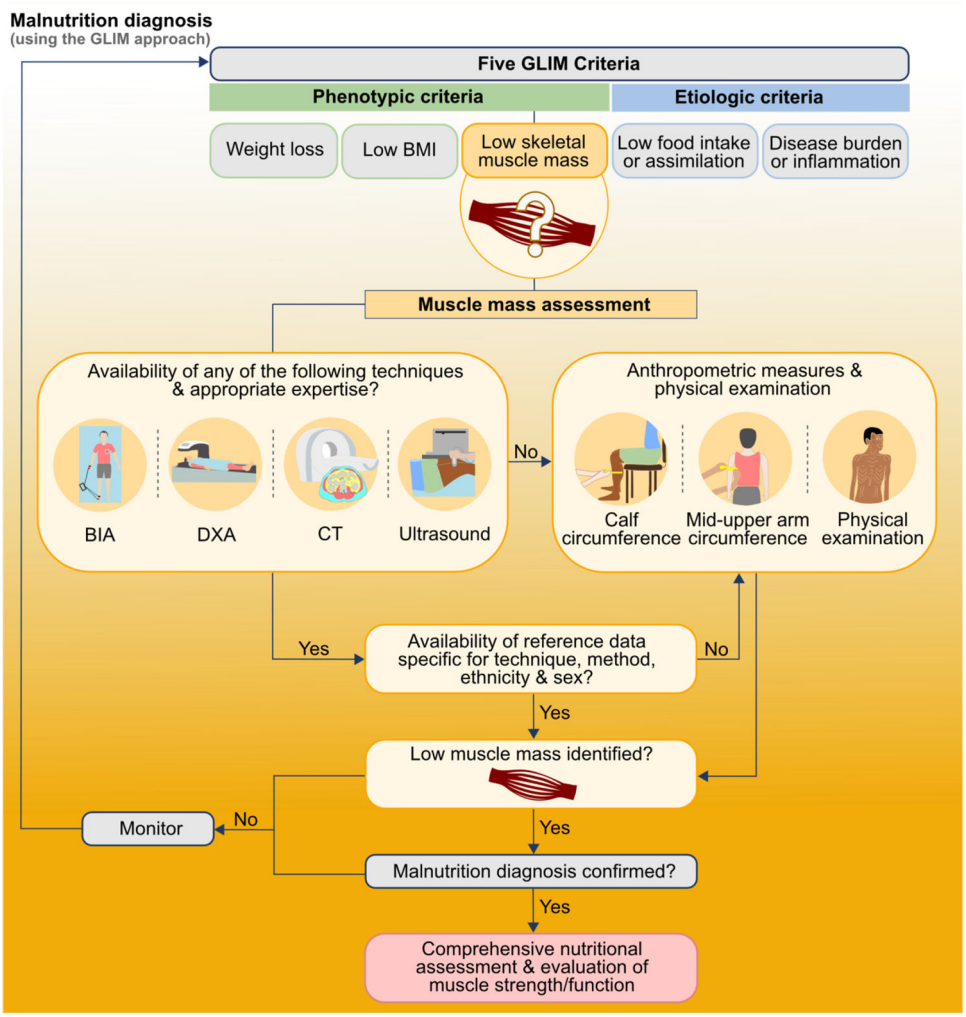

FIGURE 2 Graphical summary. Flowchart for implementation of the five GLIM criteria for malnutrition diagnosis, with summarized algorithm for muscle mass assessment and need for nutrition assessment and evaluation of muscle strength in case of malnutrition diagnosis. BIA, bioelectrical impedance analysis; BMI, body mass index; CT, computerized tomography; DXA, dual-energy x-ray absorptiometry; GLIM, Global Leadership Initiative on Malnutrition.

Besides definition of normal values, reliable cutoffs that can be accepted for the definition of moderate vs severe reductions of skeletal muscle mass are generally lacking. This limitation is a serious short-coming particularly in the context of GLIM implementation, since GLIM aims at differentiating between moderate and severe malnutrition stages. Clinical research and testing to identify severity cutoffs for low muscle mass are therefore urgently advocated. In persons with obesity, low muscle mass may be especially common with older age and in the presence of comorbidities.[60] In these settings standardization of approaches to interpretation of muscle mass is needed.[61]

As we recognize the importance of summarizing validated cutoffs as an important step to further facilitate implementation of the muscle mass assessment and interpretation, we advocate for a literature review to indicate available cutoffs which should include ethnicity-, sex-specific values as well as age- and disease-specific ones whenever available.

The role of muscle function for the diagnosis of malnutrition

Statement 5. Although important, measurements of muscle function are not recommended as surrogates or proxies for muscle mass. Once malnutrition is diagnosed, skeletal muscle function should be investigated as a relevant component of nutrition assessment of individuals with malnutrition. Detection of low muscle function and potentially mass, ie, sarcopenia should however increase suspicion for associated malnutrition. Full implementation of the GLIM approach should therefore be applied to patients with suspected or probable sarcopenia.

Level of agreement: 92%

Comments on the role of muscle function assessment

Skeletal muscle mass and function are commonly associated, but their changes following various pathophysiological stimuli may not

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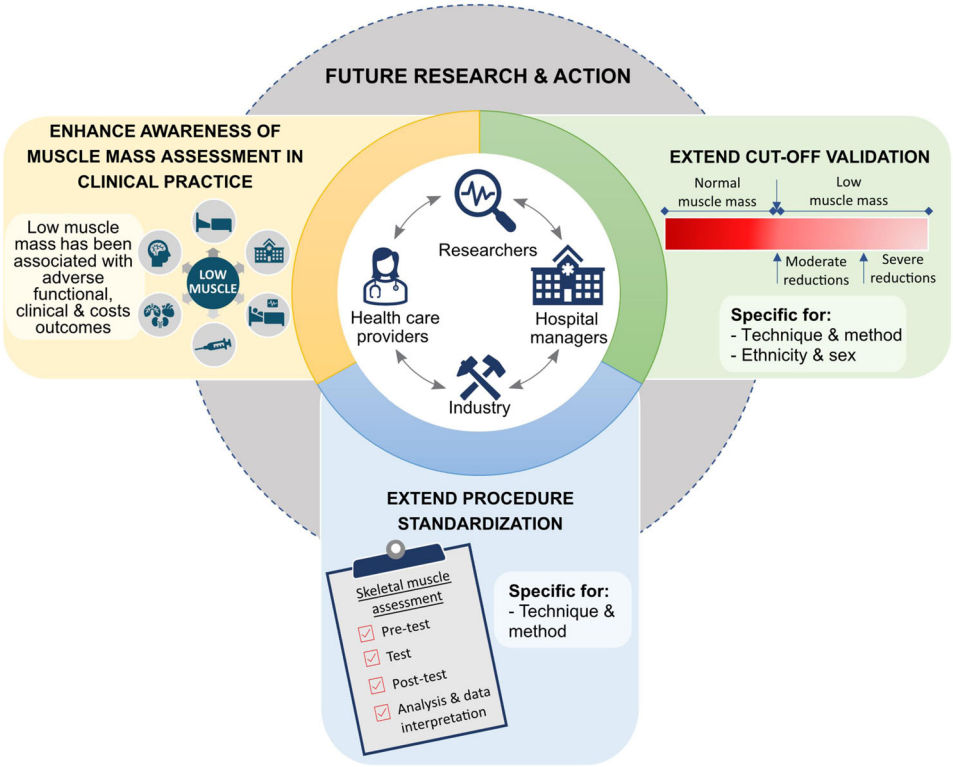

FIGURE 3 Future research plans. Main lines of action for further extension of skeletal muscle mass assessment in routine clinical practice for GLIM implementation are identified and described. Actions include (1) enhancing awareness of the relevance of skeletal muscle mass for clinical outcomes; (2) extending research for cutoff identification and validation in different settings and for different techniques, including identification of severity cutoffs for low muscle mass; and (3) extending standardization of different procedures.

align, especially in disease conditions.[76–81] Reduction in function may often precede loss of muscle mass.[68] However, muscle function may be adversely impacted by nonnutrition factors and, therefore, should not replace muscle mass assessment in the malnutrition diagnostic process.

We recognize and emphasize the important clinical contiguity between malnutrition and sarcopenia, low muscle function being a defining feature of the latter.[66,71,82] Malnutrition may be a key contributing factor in sarcopenia and both conditions frequently coexist. Therefore, when low muscle function is detected or becomes apparent in a person of any age or under any clinical circumstances, especially in persons with overweight or obesity, we recommend that skeletal muscle mass should be investigated, and GLIM criteria implemented.

Although not necessarily reflecting changes in muscle mass, evaluation of skeletal muscle function should continue to be included in the assessment of patients at risk or with malnutrition because muscle function may still be variably affected by reduced muscle mass.[76–81] Furthermore, muscle function is important in the general evaluation of patient functional status. In addition, muscle function parameters may be useful in assessment of effectiveness of nutrition treatment. Muscle strength measurement may include handgrip test, or knee-extension when available, as complementary harmonized methods. Additional tests that may be conveniently performed in clinical practice include repeated sit-to-stand or 4-meter walking test. In sum, we consider evaluation of muscle function to be an integral part of nutrition and functional assessment of patients, even though not required for the diagnosis of malnutrition.

General commentary and conclusions (Figure 2)

The current paper aims at providing practical guidance on implementation of the GLIM phenotypic criterion of low skeletal muscle mass for malnutrition diagnosis. The paper is therefore not intended to provide a review of available evidence on body composition and muscle mass assessment methods, nor an evidence-based guideline to evaluate methods and recommend criterion-standard techniques in various clinical conditions. The GLIM initiative aims at increasing opportunities to diagnose malnutrition in all clinical settings, including healthcare personnel without specialized nutrition training. The working group therefore provides expert opinion-based guidance to select acceptable methods and cutoffs, and thereby encourage the widespread use of skeletal muscle mass assessment in malnutrition diagnosis. Altered body composition with low skeletal muscle mass is a key clinical feature of malnutrition, and it should be a widely available criterion for diagnosis as well as treatment and follow-up of patients with malnutrition. To this aim, we hereby advocate that validated tools for assessing muscle mass and its surrogates, such

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as lean soft tissue, are considered to be acceptable based on availability, reference values. and operator expertise. In order to promote the global implementation of the GLIM approach to malnutrition diagnosis, the use of anthropometric measures and physical examination are supported Because of their potential widespread availability in clinical settings that may lack access to other methods for assessment of muscle mass. Validated cutoff values for each measurement and tool are recommended for use when available, including ethnic- and sex-specific cutoffs. Available cutoffs should be ideally summarized for practical guidance for implementation. Although important, measurements of skeletal muscle function are not advised as surrogates or proxies for muscle mass. However, once malnutrition is diagnosed, skeletal muscle function should be investigated as a relevant component of nutrition assessment of individuals with malnutrition.

Perspectives (Figure 3)

Priorities for future research and action are strongly advocated to include (1) development and refinement of appropriately identified cutoff values, when missing, for each technique and method, and identification of cutoffs for stratification of moderate vs severe reduction in muscle mass; (2) development and refinement of standardized procedures for skeletal muscle mass assessment and malnutrition diagnosis for each technique and method, particularly when they are currently more commonly primarily employed for different purposes (eg, DXA, CT, US); (3) promotion of awareness of the importance of skeletal muscle mass assessment in clinical practice, both for malnutrition diagnosis and for the independent relevance of low muscle mass as a negative prognostic factor in several conditions including but not limited to sarcopenia, frailty, disability, and chronic disease.

AUTHOR CONTRIBUTIONS

All authors equally contributed to the conception and design of the project; Charlene Compher and Rocco Barazzoni contributed to the acquisition and analysis and interpretation of the data; all authors drafted the manuscript, critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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REFERENCES

1. Cederholm T, Jensen GL, Correia MITD, et al. GLIM criteria for the diagnosis of malnutrition—a consensus report from the global clinical nutrition community. *Clin Nutr*. 2019;38(1):1-9.
2. Jensen GL. GLIM criteria for the diagnosis of malnutrition: a consensus report from the global clinical nutrition community. *JPEN J Parenter Enteral Nutr*. 2019;43(1):32-40.
3. de van der Schueren MAE, Keller H, Glim C, et al. Global Leadership Initiative on Malnutrition (GLIM): guidance on validation of the operational criteria for the diagnosis of protein-energy malnutrition in adults. *Clin Nutr*. 2020;39(9):2872-2880.
4. Keller H. Global Leadership Initiative on Malnutrition (GLIM): guidance on validation of the operational criteria for the diagnosis of protein-energy malnutrition in adults. *JPEN J Parenter Enteral Nutr*. 2020;44(6):992-1003.
5. Allard JP, Keller H, Gramlich L, Jeejeebhoy KN, Laporte M, Duerksen DR. GLIM criteria has fair sensitivity and specificity for diagnosing malnutrition when using SGA as comparator. *Clin Nutr*. 2020;39(9):2771-2777.
6. Balci C, Bolayir B, Eşme M, et al. Comparison of the efficacy of the global leadership initiative on malnutrition criteria, subjective global assessment, and nutrition risk screening 2002 in diagnosing malnutrition and predicting 5-year mortality in patients hospitalized for acute illnesses. *JPEN J Parenter Enteral Nutr*. 2021;45(6):1172-1180.
7. Boslooper-Meulenbelt K, van Vliet IMY, Gomes-Neto AW, et al. Malnutrition according to GLIM criteria in stable renal transplant recipients: reduced muscle mass as predominant phenotypic criterion. *Clin Nutr*. 2021;40(5):3522-3530.
8. Brito JE, Burgel CF, Lima J, et al. GLIM criteria for malnutrition diagnosis of hospitalized patients presents satisfactory criterion validity: a prospective cohort study. *Clin Nutr*. 2021;40(6):4366-4372.
9. Cederholm T, Barazzoni R. A year with the GLIM diagnosis of malnutrition—does it work for older persons? *Curr Opin Clin Nutr Metab Care*. 2021;24(1):4-9.
10. Hirose S, Matsue Y, Kamiya K, et al. Prevalence and prognostic implications of malnutrition as defined by GLIM criteria in elderly patients with heart failure. *Clin Nutr*. 2021;40(6):4334-4340.
11. Ozer NT, Akin S, Gunes Sahin G, Sahin S Prevalence of malnutrition diagnosed by the Global Leadership Initiative on Malnutrition and Mini Nutritional Assessment in older adult outpatients and comparison between the Global Leadership Initiative on Malnutrition and Mini Nutritional Assessment energy-protein intake: a cross-sectional study. *JPEN J Parenter Enteral Nutr*. 2022;46(2):367-377.
12. Rosato E, Gigante A, Gasperini ML, Proietti L, Muscaritoli M. Assessing malnutrition in systemic sclerosis with Global Leadership Initiative on Malnutrition and European Society of Clinical Nutrition and Metabolism Criteria. *JPEN J Parenter Enteral Nutr*. 2021;45(3):618-624.
13. Sanz-Paris A. GLIM criteria at hospital admission predict 8-year all-cause mortality in elderly patients with type 2 diabetes mellitus: results from VIDA study. *JPEN J Parenter Enteral Nutr*. 2020;44(8):1492-1500.
14. Shimizu A, Maeda K, Wakabayashi H, et al. Predictive validity of body mass index cutoff values used in the global leadership initiative on malnutrition criteria for discriminating severe and moderate malnutrition based on in-patients with pneumonia in Asians. *JPEN J Parenter Enteral Nutr*. 2021;45(5):941-950.

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15. Theilla M, Rattanachaiwong S, Kagan I, Rigler M, Bendavid I, Singer P. Validation of GLIM malnutrition criteria for diagnosis of malnutrition in ICU patients: an observational study. *Clin Nutr*. 2021;40(5):3578-3584.
16. Xu LB, Shi MM, Huang ZX, et al. Impact of malnutrition diagnosed using Global Leadership Initiative on Malnutrition criteria on clinical outcomes of patients with gastric cancer. *JPEN J Parenter Enteral Nutr*. 2022; 46(2):385-394.
17. Yin L. Evaluation of the global leadership initiative on malnutrition criteria using different muscle mass indices for diagnosing malnutrition and predicting survival in lung cancer patients. *JPEN J Parenter Enteral Nutr*. 2021;45(3):607-617.
18. Yin L, Lin X, Liu J, et al. Classification tree-based machine learning to visualize and validate a decision tool for identifying malnutrition in cancer patients. *JPEN J Parenter Enteral Nutr*. 2021;45(8): 1736-1748.
19. Zhang Q, Zhang KP, Zhang X, et al. Scored-GLIM as an effective tool to assess nutrition status and predict survival in patients with cancer. *Clin Nutr*. 2021;40(6):4225-4233.
20. Zhang X, Tang M, Zhang Q, et al. The GLIM criteria as an effective tool for nutrition assessment and survival prediction in older adult cancer patients. *Clin Nutr*. 2021;40(3):1224-1232.
21. Zweers HEE, Bordier V, In 't Hulst J, Janssen MCH, Wanten GJA, Leij-Halfwerk S. Association of body composition, physical functioning, and protein intake in adult patients with mitochondrial diseases. *JPEN J Parenter Enteral Nutr*. 2021;45(1):165-174.
22. Bischoff SC, Singer P, Koller M, Barazzoni R, Cederholm T, van Gossum A. Standard operating procedures for ESPEN guidelines and consensus papers. *Clin Nutr*. 2015;34(6):1043-1051.
23. Heymsfield S, Lohman T, Going SB, Wang ZM, eds. *Human Body Composition*. 2nd ed. Human Kinetics; 2005.
24. Gonzalez MC, Barbosa-Silva TG, Heymsfield SB. Bioelectrical impedance analysis in the assessment of sarcopenia. *Curr Opin Clin Nutr Metab Care*. 2018;21(5):366-374.
25. Kaysen GA, Zhu F, Sarkar S, et al. Estimation of total-body and limb muscle mass in hemodialysis patients by using multifrequency bioimpedance spectroscopy. *Am J Clin Nutr*. 2005;82(5):988-995.
26. van Venrooij LM, Verberne HJ, de Vos R, Borgmeijer-Hoelen MM, van Leeuwen PA, de Mol BA. Preoperative and postoperative agreement in fat free mass (FFM) between bioelectrical impedance spectroscopy (BIS) and dual-energy X-ray absorptiometry (DXA) in patients undergoing cardiac surgery. *Clin Nutr*. 2010;29(6):789-794.
27. Kyle UG, Genton L, Hans D, Pichard C. Validation of a bioelectrical impedance analysis equation to predict appendicular skeletal muscle mass (ASMM). *Clin Nutr*. 2003;22(6):537-543.
28. Sipers W, Dorge J, Schols J, Verdijk LB, van Loon LJC. Multifrequency bioelectrical impedance analysis may represent a reproducible and practical tool to assess skeletal muscle mass in euvolemic acutely ill hospitalized geriatric patients. *Eur Geriatr Med*. 2020;11(1):155-162.
29. Gonzalez MC, Barbosa-Silva TG, Bielemann RM, Gallagher D, Heymsfield SB. Phase angle and its determinants in healthy subjects: influence of body composition. *Am J Clin Nutr*. 2016;103(3):712-716.
30. Lukaski HC, Kyle UG, Kondrup J. Assessment of adult malnutrition and prognosis with bioelectrical impedance analysis: phase angle and impedance ratio. *Curr Opin Clin Nutr Metab Care*. 2017;20(5):330-339.
31. Kanis JA, McCloskey EV, Johansson H, Oden A, Melton LJ, 3rd, Khaltaev N. A reference standard for the description of osteoporosis. *Bone*. 2008;42(3):467-475.
32. Bridge P, Pocock NA, Nguyen T, et al. Validation of longitudinal DXA changes in body composition from pre- to mid-adolescence using MRI as reference. *J Clin Densitom*. 2011;14(3):340-347.
33. Freda PU, Shen W, Reyes-Vidal CM, et al. Skeletal muscle mass in acromegaly assessed by magnetic resonance imaging and dual-photon X-ray absorptiometry. *J Clin Endocrinol Metab*. 2009;94(8): 2880-2886.
34. Kim J, Heshka S, Gallagher D, et al. Intermuscular adipose tissue-free skeletal muscle mass: estimation by dual-energy X-ray absorptiometry in adults. *J Appl Physiol*. 2004;97(2):655-660.
35. Walowski CO, Braun W, Maisch MJ, et al. Reference values for skeletal muscle mass—current concepts and methodological considerations. *Nutrients*. 2020;12(3):755.
36. Sheean P, Gonzalez MC, Prado CM, McKeever L, Hall AM, Braunschweig CA. American Society for Parenteral and Enteral Nutrition clinical guidelines: the validity of body composition assessment in clinical populations. *JPEN J Parenter Enteral Nutr*. 2020;44(1):12-43.
37. Prado CM, Lieffers JR, McCargar LJ, et al. Prevalence and clinical implications of sarcopenic obesity in patients with solid tumours of the respiratory and gastrointestinal tracts: a population-based study. *Lancet Oncol*. 2008;9(7):629-635.
38. Prado CM, Purcell SA, Alish C, et al. Implications of low muscle mass across the continuum of care: a narrative review. *Ann Med*. 2018; 50(8):675-693.
39. Mourtzakis M, Prado CM, Lieffers JR, Reiman T, McCargar LJ, Baracos VE. A practical and precise approach to quantification of body composition in cancer patients using computed tomography images acquired during routine care. *Appl Physiol Nutr Metab*. 2008; 33(5):997-1006.
40. Derstine BA, Holcombe SA, Ross BE, Wang NC, Su GL, Wang SC. Skeletal muscle cutoff values for sarcopenia diagnosis using T10 to L5 measurements in a healthy US population. *Sci Rep*. 2018;8(1): 11369.
41. Jaitovich A, Khan M, Itty R, et al. ICU admission muscle and fat mass, survival, and disability at discharge: a prospective cohort study. *Chest*. 2019;155(2):322-330.
42. Tsukasaki K, Matsui Y, Arai H, et al. Association of muscle strength and gait speed with cross-sectional muscle area determined by mid-thigh computed tomography—a comparison with skeletal muscle mass measured by dual-energy X-ray absorptiometry. *J Frailty Aging*. 2020;9(2):82-89.
43. Kawakami R, Murakami H, Sanada K, et al. Calf circumference as a surrogate marker of muscle mass for diagnosing sarcopenia in Japanese men and women. *Geriatr Gerontol Int*. 2015;15(8):969-976.
44. Real GG, Fruhauf IR, Sedrez JHK, Dall'Aqua EJF, Gonzalez MC. Calf circumference: a marker of muscle mass as a predictor of hospital readmission. *JPEN J Parenter Enteral Nutr*. 2018;42(8):1272-1279.
45. Saito R, Ohkawa S, Ichinose S, Nishikino M, Ikegaya N, Kumagai H. Validity of mid-arm muscular area measured by anthropometry in nonobese patients with increased muscle atrophy and variation of subcutaneous fat thickness. *Eur J Clin Nutr*. 2010;64(8):899-904.
46. Santos LP. New prediction equations to estimate appendicular skeletal muscle mass using calf circumference: results from NHANES 1999-2006. *JPEN J Parenter Enteral Nutr*. 2019;43(8):998-1007.
47. Centers for Disease Control and Prevention National Health and Nutrition Examination Survey (NHANES): Anthropometry Procedures Manual. January 2007. Accessed March 22, 2022. https://wwwn.cdc.gov/nchs/data/nhanes/2007-2008/manuals/manual_an.pdf
48. Steiber AL, Kalantar-Zadeh K, Secker D, McCarthy M, Sehgal A, McCann L. Subjective Global Assessment in chronic kidney disease: a review. *J Renal Nutr*. 2004;14(4):191-200.
49. White JV, Guenter P, Jensen G, et al. Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: characteristics recommended for the identification and documentation of adult malnutrition (undernutrition). *J Acad Nutr Diet*. 2012;112(5):730-738.
50. Simpson F, Doig GS. Bedside nutrition evaluation and physical assessment techniques in critical illness. *Curr Opin Crit Care*. 2016; 22(4):303-307.
51. Perkisas S. Application of ultrasound for muscle assessment in sarcopenia: 2020 SARCUS update. *Eur Geriatr Med*. 2021;12(1):45-59.

19412444, 2022, 6, Downloaded from https://aspenjournals.onlinelibrary.wiley.com/doi/10.1002/jpen.2366 by Readcube (Labtiva Inc.), Wiley Online Library on [17/01/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

52. Abe T, Loenneke JP, Young KC, et al. Validity of ultrasound prediction equations for total and regional muscularity in middle-aged and older men and women. *Ultrasound Med Biol*. 2015;41(2):557-564.
53. Abe T, Thiebaud RS, Loenneke JP, Young KC. Prediction and validation of DXA-derived appendicular lean soft tissue mass by ultrasound in older adults. *Age*. 2015;37(6):114.
54. Nijholt W, Scafoglieri A, Jager-Wittenaar H, Hobbelen JSM, van der Schans CP. The reliability and validity of ultrasound to quantify muscles in older adults: a systematic review. *J Cachexia Sarcopenia Muscle*. 2017;8(5):702-712.
55. Paris MT, Lafleur B, Dubin JA, Mourtzakis M. Development of a bedside viable ultrasound protocol to quantify appendicular lean tissue mass. *J Cachexia Sarcopenia Muscle*. 2017;8(5):713-726.
56. Sabatino A, Regolisti G, Bozzoli L, et al. Reliability of bedside ultrasound for measurement of quadriceps muscle thickness in critically ill patients with acute kidney injury. *Clin Nutr*. 2017;36(6):1710-1715.
57. Looijaard W, Molinger J, Weijs PJM. Measuring and monitoring lean body mass in critical illness. *Curr Opin Crit Care*. 2018;24(4):241-247.
58. Mourtzakis M, Parry S, Connolly B, Puthucheary Z. Skeletal muscle ultrasound in critical care: a tool in need of translation. *Ann Am Thorac Soc*. 2017;14(10):1495-1503.
59. Price KL, Earthman CP. Update on body composition tools in clinical settings: computed tomography, ultrasound, and bioimpedance applications for assessment and monitoring. *Eur J Clin Nutr*. 2019;73(2):187-93.
60. Barazzoni R, Bischoff SC, Boirie Y, et al. Sarcopenic obesity: time to meet the challenge. *Clin Nutr*. 2018;37(6 Pt A):1787-1793.
61. Donini LM, Busetto L, Bauer JM, et al. Critical appraisal of definitions and diagnostic criteria for sarcopenic obesity based on a systematic review. *Clin Nutr*. 2020;39(8):2368-2388.
62. Gonzalez MC, Mehrnezhad A, Razaviarab N, Barbosa-Silva TG, Heymsfield SB. Calf circumference: cutoff values from the NHANES 1999-2006. *Am J Clin Nutr*. 2021;113(6):1679-1687.
63. Cawthon PM, Orwoll ES, Peters KE, et al. Strong relation between muscle mass determined by D3-creatine dilution, physical performance, and incidence of falls and mobility limitations in a prospective cohort of older men. *J Gerontol A Biol Sci Med Sci*. 2019;74(6):844-852.
64. Clark RV, Walker AC, O'Connor-Semmes RL, et al. Total body skeletal muscle mass: estimation by creatine (methyl-d3) dilution in humans. *J Appl Physiol (1985)*. 2014;116(12):1605-1613.
65. Zhu K, Wactawski-Wende J, Ochs-Balcom HM, et al. The association of muscle mass measured by D3-creatine dilution method with dual energy X-ray absorptiometry and physical function in postmenopausal women. *J Gerontol A Biol Sci Med Sci*. 2021;76(9):1591-1599.
66. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age Ageing*. 2019;48(1):16-31.
67. Gould H, Brennan SL, Kotowicz MA, Nicholson GC, Pasco JA. Total and appendicular lean mass reference ranges for Australian men and women: the Geelong osteoporosis study. *Calcif Tissue Int*. 2014;94(4):363-372.
68. Lauretani F, Russo CR, Bandinelli S, et al. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *J Appl Physiol*. 2003;95(5):1851-1860.
69. Tanimoto Y, Watanabe M, Sun W, et al. Association between muscle mass and disability in performing instrumental activities of daily living (IADL) in community-dwelling elderly in Japan. *Arch Gerontol Geriat*. 2012;54(2):e230-e233.
70. Chen LK, Lee WJ, Peng LN, Liu LK, Arai H, Akishita M. Recent advances in sarcopenia research in Asia: 2016 update from the Asian Working Group for Sarcopenia. *J Am Med Dir Assoc*. 2016;17(8):767.
71. Cederholm T, Bosaeus I, Barazzoni R, et al. Diagnostic criteria for malnutrition—an ESPEN Consensus Statement. *Clin Nutr*. 2015;34(3):335-340.
72. Schutz Y, Kyle UU, Pichard C. Fat-free mass index and fat mass index percentiles in Caucasians aged 18-98 y. *Int J Obes Relat Metab Disord*. 2002;26(7):953-960.
73. Levine ME, Crimmins EM. The impact of insulin resistance and inflammation on the association between sarcopenic obesity and physical functioning. *Obesity*. 2012;20(10):2101-2106.
74. Pasco JA, Holloway-Kew KL, Tembo MC, et al. Normative data for lean mass using FNIH criteria in an Australian setting. *Calcif Tissue Int*. 2019;104(4):475-479.
75. Bahat G, Tufan A, Kilic C, et al. Cut-off points for weight and body mass index adjusted bioimpedance analysis measurements of muscle mass. *Aging Clin Exp Res*. 2019;31(7):935-942.
76. Correa-Perez A, Abraha I, Cherubini A, et al. Efficacy of non-pharmacological interventions to treat malnutrition in older persons: a systematic review and meta-analysis. The SENATOR project ONTOP series and MaNuEL knowledge hub project. *Ageing Res Rev*. 2019;49:27-48.
77. Hiol AN, von Hurst PR, Conlon CA, Mugridge O, Beck KL. Body composition associations with muscle strength in older adults living in Auckland, New Zealand. *PLoS One*. 2021;16(5):e0250439.
78. Hsu KJ, Liao CD, Tsai MW, Chen CN. Effects of exercise and nutritional intervention on body composition, metabolic health, and physical performance in adults with sarcopenic obesity: a meta-analysis. *Nutrients*. 2019;11(9):2163.
79. Lai CC, Tu YK, Wang TG, Huang YT, Chien KL. Effects of resistance training, endurance training and whole-body vibration on lean body mass, muscle strength and physical performance in older people: a systematic review and network meta-analysis. *Age Ageing*. 2018;47(3):367-373.
80. Haaf DSM, Eijsvogels TMH, Bongers CCWG, et al. Protein supplementation improves lean body mass in physically active older adults: a randomized placebo-controlled trial. *J Cachexia Sarcopenia Muscle*. 2019;10(2):298-310.
81. Ten Haaf DSM, Nuijten MAH, Maessen MFH, Horstman AMH, Eijsvogels TMH, Hopman MTE. Effects of protein supplementation on lean body mass, muscle strength, and physical performance in nonfrail community-dwelling older adults: a systematic review and meta-analysis. *Am J Clin Nutr*. 2018;108(5):1043-1059.
82. Chen LK, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. *J Am Med Dir Assoc*. 2020;21(3):300-307.

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