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Assessment of muscle mass in the elderly in clinical practice

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Quantification of muscle mass is important in clinical practice and several tools are used for its measurement. This is a review and critical appraisal of the muscle mass assessment tools for use with elderly patients in clinical practice. Of the 10 different tools described to measure skeletal muscle mass (SMM), computerized tomography (CT), and magnetic resonance imaging (MRI) are considered the gold standards. Dual-energy X-ray absorptiometry (DXA) is probably the best known method for measuring muscle mass in the elderly but because of the high cost of the equipment and its operation, its use may be limited. Bioelectrical impedance analysis (BIA) could provide a simpler, less expensive alternative, and it is portable. The use of anthropometrics (such as calf circumference and skin-fold thickness measurement) is feasible in the home setting. There is a lack of studies of the reliability of tools for measuring muscle mass in elderly patients. Additional research is needed to investigate how best to optimize measurement and minimize error.

Αξιολόγηση μυϊκής μάζας σε ηλικιωμένους στην κλινική πρακτική

Περίληψη στο τέλος του άρθρου

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1. INTRODUCTION

Skeletal muscle (SM) is an organ that adapts its mass to various different pathophysiological conditions via pathways that regulate protein and cellular turnover.[1] Skeletal muscle mass (SMM) accounts for about 30–40% of the total body weight. Significant reduction in muscle mass and strength, and alterations in body composition are observed with advancing age.[2–4] The basic structural element of skeletal muscle is muscle fiber, the quality (size and quantity) of which becomes progressively reduced with aging.[5] This reduction leads to difficulties in executing tasks requiring motor skills, and everyday activities, and to loss of balance and falls, which increase the risk of disability.[6] The loss of muscle mass is considered to be a major determinant of the reduction in strength that is observed with aging.[7] Sarcopenia is a syndrome characterized by progressive and generalized loss of SMM and strength with a risk of adverse outcomes, including physical disability, poor quality of life and death.[8] Loss of more than 40% of SMM is frequently seen in elderly people with sarcopenia and this loss is associated with diminished strength and an increase in morbidity.[9]

Appendicular muscle mass (AMM) of the limbs accounts for an estimated 75–80% of the total body SMM (trunk and limb muscle mass).[6,10] Several study groups have defined the sum of the muscle mass of the four limbs as appendicular skeletal mass (ASM) and proposed calculation of a SMM index (SMI) based on the formula ASM/height^2 measured in kg/m^2.[6,11,12] A SMI of two standard deviations below the mean of young male and female reference groups has been defined as the gender-specific cut-off point for sarcopenia.[8] The cut-off points chosen for the diagnosis of sarcopenia depend on the measurement technique and the availability of reference studies. The European Working Group on Sarcopenia (EWGSOP) recommends the use of the normative (healthy young adult), rather than other predictive reference populations, the with cut-off point at two standard deviations below the mean reference value.[8,13]

The first reports of accurate SMM measurement in humans appeared at about the same time as introduction of the sarcopenia concept, in the late 1980s.[14] The prevention and treatment of sarcopenia requires identification of the predictors of SMM compromise,[15] but there is no consensus recommendation regarding the diagnostic tools to be used.[16] Several techniques have been used throughout the years, but the availability of a reliable, valid, non-injurious, and affordable tool for the measurement of SMM for the diagnosis of sarcopenia is still a major issue.[13]

2. WHY MEASURE MUSCLE MASS IN CLINICAL PRACTICE?

There is a growing awareness of the importance of muscle mass (either in total, SMM and or ASM) in many physiological and disease processes.[17] One of the recognized changes in body composition with senescence is the loss of SMM,[18] and it is associated with a decline in muscle function.[19]

Quantification of muscle mass is important in the elderly population because of sarcopenia,[10] which is considered an important disease entity in the elderly,[12] assessed by muscle mass, strength, and physical performance.[13]

SMM assessment is important in studies of physiology and nutrition and in clinical medicine,[20] and particularly in the study of aging, muscle wasting and obesity.[21] The loss of muscle mass with aging is clinically important because it leads to diminished strength and exercise capacity.[22] Skeletal muscle strength is highly dependent on the muscle mass composition and architecture.[23] SMM measurement is necessary for relating muscle mass to exercise performance and evaluating the effect of physical training on muscle mass.[24] There is a close association between muscle mass and inability to perform activities of daily living, and measurement of muscle mass in the elderly population may help in the design of relevant prevention strategies.[25]

Muscle mass also plays a key role in recovery from critical illness or severe trauma. Extensive loss of muscle mass, strength, and function during acute hospitalization, causing sustained physical impairment, have been identified as contributors to prolongation of the recovery phase.[26] Alterations in muscle mass and strength play an important role in the course of many common diseases. Both cardiac failure and cancer are often associated with rapid and extensive loss of muscle mass, strength, and metabolic function (i.e., cachexia), and the loss of muscle mass is an important determinant of survival in these conditions. Osteoporosis is also associated with changes in muscle mass.[27] Decrease in both muscle mass and bone mineral density occurs with aging, and is often associated with falls, trauma, functional disability, impairment of quality of life, and an increase in hospitalization and high mortality.[28,29]

The importance of maintaining SMM for improving cardiovascular health has also been documented.[30] Greater muscle mass was found to be significantly associated with smaller retinal artery size in older people, and poor muscle mass with a greater degree of arterial stiffness and higher cardiovascular risk.[31]

Based on the above evidence, the importance of valid SMM measurement in the elderly in clinical practice is apparent. This paper reviews the available SMM measurement tools and discusses their suitability for use in clinical practice and in research. To assess the methodological quality of the articles, the consensus based standards for the selection of health status measurement instruments (COSMIN) check list was used.[32–34] This critical review is intended to help in the selection of a valid and reliable tool for measuring SMM.

3. MUSCLE MASS ASSESSMENT TOOLS

An overview of the available muscle mass assessment tools is presented in table 1, which lists the suggestions of EWGSOP for use of these techniques in research and in routine clinical practice.[8] The present review includes 21 studies for discussion, and another critical analysis article which was based on 16 studies.[35] Critical appraisal of the studies revealed that they had a fair score in validity.

In all, 10 different tools to measure SMM muscle mass are described.[36] Several methods of quantifying total body and regional SMM were developed over the past few decades.[37]

3.1. Body imaging techniques

SMM or lean body mass (LBM) can be determined using several imaging techniques, including computerized tomography (CT), magnetic resonance imaging (MRI), dual

Table 1. Muscle mass assessment tools for use in research and routine clinical practice.

Variable assessed	Research studies	Clinical practice
	Computed tomography (CT)	BIA
Skeletal	Magnetic resonance imaging (MRI)	DXA
Muscle mass	Dual energy X-ray absorptiometry (DXA)	Anthropometry
	Bioelectrical impedance analysis (BIA)	Ultrasonography

energy X-ray absorptiometry (DXA) and ultrasonography (US).[38,39] CT exposes the subject to a collimated beam of X-rays that are attenuated as they pass through the body to a varying degree according to differences in the physical density of the tissues. The CT method offers high image contrast and clear separation of fat from other soft tissues.[40] CT accurately measures direct physical properties of the muscle (e.g., cross-sectional area and volume). It also allows evaluation of muscle density, and subcutaneous and intramuscular adipose tissue deposition.[18] The advantage of CT and MRI over earlier methods is the direct visualization of images depicting the cross-sectional area of skeletal muscle.[37] The accuracy of CT and MRI with respect to adipose tissue and SMM measurement is well documented.[16] Cadaver validation studies have confirmed the accuracy of CT and MRI in measuring SMM (r=0.99),[6] and CT and MRI are now considered the "gold standard" in this field.[21,39,41] The high cost, limited access to equipment and concerns about radiation exposure limit the use of these whole-body imaging methods for routine clinical practice.[8] Neither MRI nor CT is capable of accommodating obese persons (body mass index [BMI] >40 kg/m^2). The field-of-view for most MRI scanners is limited to 48×48 cm. A further limitation of MRI is that claustrophobic persons cannot be scanned.[42]

DXA is an attractive alternative method, for both research purposes and clinical use, to distinguish between fat, bone mineral and lean tissues. It was developed to measure bone mineral mass, calculated from the differential absorption of X-rays of two different energies.[43] A typical whole body scan takes approximately 10 to 20 minutes and exposes the subject to <5 mrem of radiation.[8,44,45] The estimation of fat and lean tissue from DXA software is based on inherent assumptions regarding levels of hydration, potassium content and tissue density, and these assumptions vary by manufacturer.[44] The limitations of DXA vary according to body shape and outcome.[43] The disadvantages of DXA include a small but still detectable amount of radiation; the scanning bed or stretcher has an upper weight limit and the whole-body field-of-view cannot accommodate very large people.[42]

3.2. Bioelectrical impedance analysis

Bioelectrical impedance analysis (BIA) is a practical method for assessing the body composition and it allows the evaluation of major body compartments, including fat mass, fat-free mass and water.[36] BIA is a noninvasive, quick and inexpensive method of measuring body composition, and has the advantage of being portable.[17,46] The BIA method is based on the electrical properties of tissues, and there are several types, the main of these being: single-frequency BIA (SF-BIA), multifrequency BIA (MF-BIA), the foot-foot system (the subject is positioned vertically and required to stand barefoot on the platform that contains the electrodes), and the vertical model (requires the subject to stand up barefoot on the platform that contains the electrodes and hold a hand-to-hand device).[36]

Use of BIA has been reported in an increasing number of publications over the last decade,[47] mainly because of its advantages of simplicity, portability, rapid processing of information and noninvasiveness, and the fact that it is relatively inexpensive.[36] It is also a safe technique (although not recommended for participants with a pacemaker), thus making it attractive for large-scale studies.[42] An altered hydration status is the main limitation of this method. Factors that may affect the results are eating, intense physical activity, alcohol and fluid intake before the evaluation, states of dehydration or of water retention, use of diuretics, and the menstrual cycle.[36,48] BIA instruments differ in cost, electrode presentation and type of measurement.[13] Under standard conditions (measurement at the same hours, etc.), BIA measurements correlate well with MRI measurements.[6] Standardization of procedures is necessary, but in the future researchers should explore further the use of this method. Table 2 presents 9 studies which correlated BIA results with those of other techniques.

3.4. Anthropometric measurements

Anthropometric measurements are the most basic method of assessing body composition.[44] The use of anthropometry to estimate muscle mass requires the selection

Table 2. Bioelectrical impedance analysis (BIA) studies.

Study	Population	Participants (n)	Criterion measure	r^2
Lohman[51]	Healthy adults (50–70 years)	74	Densitometry	Not reported
Baumgartner et al[11]	Elderly subjects (65–94 years)	98	Multi C	0,91
Kyle et al[52]	Healthy subjects (18–94 years)	343	DXA	0,97
Haapala et al[53]	Elderly women (62–72 years)	93	DXA	0,83
Sun et al[54]	Healthy individuals (12–94 years)	734	4 compartments	0,90
Ling et al[48]	Middle aged individuals	484	DXA	0,95
Deurenberg et al[55]	Elderly subjects (60–83 years)	72	Densitometry	0,88
Buckinx et al[56]	Adult subjects	219	DXA	Not reported
Chen et al[50]	Adult subjects (20–77 years)	40	DXA	0,95

DXA: Dual energy X-ray absorptiometry

of specific body measurements such as weight, height, circumference and skin thickness.[45] The instruments for measuring anthropometric dimensions are portable and inexpensive, and the procedure is noninvasive. It is also important that minimal training is required.[49,50]

Of the studies analyzed in this review, none evaluated the reliability of the measurement tools, 15 evaluated the concurrent validity,[38,48,50,53,55,57,58–65,66] and only one study assessed responsiveness.[57]

Table 3 summarizes the advantages and disadvantages of the SMM measurement methods discussed in this review.

4. CRITICAL REVIEW

From both the clinical and the epidemiological viewpoint, the measurement of body composition is important in the prevention and treatment of various diseases.[56] A wide range of techniques is available for the assessment of SMM.[12] In the choice of measuring method, various different factors need to be taken into account, including validity/reliability, simplicity, degree of training required for the examiner, risk associated with exposure to radiation, cost, accessibility, and specific purpose (clinical or research).[13,36]

The identification of the "gold standard" for the quantitative evaluation of SMM in clinical trials (which is currently lacking) should be based on the criteria of accuracy, precision, reproducibility, sensitivity to change, and accessibility.[18]

The measurement properties of measuring tools for muscle mass, strength and physical performance in community-dwelling older people was critically appraised in 2013.[35] The most frequently used tools for measurement of SMM covered in that review are the same as those identified in the present review (i.e., MRI, CT, DXA and BIA).

Although MRI and CT scans can provide an accurate measure of muscle cross-sectional area and muscle com-

Table 3. Advantages and disadvantages of the available noninvasive methods for measuring skeletal muscle mass in humans.

Method	Advantages	Disadvantages
Computerized tomography (CT)	High accuracy and reproducibility	Expensive equipment, high radiation exposure
Magnetic resonance imaging (MRI)	High accuracy and reproducibility	Expensive equipment, large individuals cannot fit within field-of-view, claustrophobic persons cannot be scanned
Dual energy X-ray absorptiometry (DXA)	Easy to use, low radiation exposure, accurate	Expensive equipment, needing specialized radiology technician required to operate. Body size, sex, fatness, cause problems
Bioelectrical impedance assessment (BIA)	Low cost, easy to use, simple, safe, quick, portable	Population and or equipment specific
Anthropometric measures	Inexpensive, easy to use, portable	Vulnerable to error
Ultrasonography (US)	Portable, may be used to assess muscle quality via tissue characteristics	Limited information from studies, limited experience

position,[41,49] neither is practical for assessment in the routine clinical setting.[68] DXA is currently the most accessible technique for body composition assessment. Its main limitations reside in certain analytical differences between manufacturers and models, and the risk of biased results due to low differentiation between water and bone-free lean tissue. The radiation exposure associated with DXA is minimal, while the exposure associated with CT is higher (i.e., about 15 mrem).[18] DXA also requires patients to travel to a diagnostic center, and must be applied by specialized personnel; therefore, to date it cannot to be considered a routine test in clinical practice.[13]

MRI presents a high agreement with CT findings and provides similar measures, and it does not involve radiation exposure. The major limitations of MRI reside in the higher technical complexity and cost, and in the exclusion of patients with older models of implanted metal devices (e.g., joint prostheses, pace-makers, etc.).[18]

DXA may be the most widely used method for body composition assessment in clinical practice, but because of the high cost of the equipment, operation and maintenance and its non-portable nature, its use may be limited.[56] To overcome the problems of cost, availability and radiation exposure, BIA appears a good technique, which is becoming popular, as it is very simple, low-cost and portable.[36,56] Its use is feasible in the home setting, but its validity is dependent on gender and ethnicity.[35] A critical report presenting the concepts involved in the BIA technique, the available types and the limitations and applications of this method[36] concluded that the BIA technique is important in clinical practice and can provide safe data for health professionals. It is necessary, however, for practitioners to have a good knowledge of the fundamentals of the method and of the equations for the assessment of body composition.[36] Furthermore, muscle mass measurements with BIA can be distorted by the hydration status and presence of edema. To avoid possible variability of results, it is essential that BIA measurements be performed in a careful, standardized fashion (ideally at the same time of the day for sequential measurements).[13]

The development of simple and accurate devices for the measurement of body composition is important for clinical practice and epidemiological research. One study investigated the concordance between body composition evaluations achieved with a portable body composition analyzer and DXA.[56] The subjects were not elderly, with a mean age of 43.7±19.1 years. BIA appeared to overestimate ALM/ht^2 compared to DXA and, consequently, an adaptive formula is needed to obtain measurements of the appendicular lean mass by BIA close to those measured by DXA. These findings were similar to those of other researchers.[66]

Some researchers suggest that diagnostic US may offer a quick cost-effective method for measurement of muscle size.[52,67] In one study 38 postmenopausal women (mean age: 58.9±0.7 years) had their right rectus femoris and biceps brachii imaged by both US and MRI. In another, 85 older men and women (mean age: 65.0±0.4 years) and 10 young men and women (mean age: 26.1±2.4 years) had their right rectus femoris imaged by US and MRI. Based on these studies, it appears that diagnostic US can provide a reliable and cost-effective alternative method for assessing muscle mass.[67,70] It is also useful for bed-ridden or mobility impaired individuals. It is important to note that the US findings are operator-dependent and that to date there is limited information about experience with US in sarcopenia studies.[13]

Anthropometric measurements are noninvasive and the necessary instruments are portable and inexpensive, but they are vulnerable to error and not recommended for routine use in the diagnosis of sarcopenia.[8] The main advantages of anthropometry are simplicity and low cost. In terms of clinical practice, it is useful and easy, but anthropometry has limited accuracy and can be biased by nutritional status and comorbidity.[13] Researchers examined the relationship between calf circumference and muscle mass and found that calf circumference was positively correlated with ASM and SSM. They suggest calf measurement as a surrogate marker of muscle mass for diagnosing sarcopenia, with cut-off values for predicting low muscle mass of <34 cm in men and <33 cm in women.[71]

A study published in 2015 surveyed the use of assessment tools for muscle mass, muscle strength and physical performance by 255 clinicians in 55 countries across five continents. Of these clinicians (rheumatologists, geriatricians, endocrinologists, etc.) 53.3% reported assessment of muscle mass in their daily practice, and the tools they use in clinical practice were different and heterogenous.[72]

SMM assessment is undoubtedly important in clinical practice, but the findings of several longitudinal studies indicate that SMM alone cannot fully explain the loss of muscle strength and physical function in older adults.[7,73] It is important to investigate further the main factors associated with the changes that take place in muscle quality with age, which may well precede changes in SMM. Muscle quality is closely interrelated with muscle strength, as muscle quality is typically defined as muscle strength or power per unit of muscle mass. Non-invasive imaging of muscle by MRI and CT can capture multiple factors related to muscle quality, such as muscle size, in a research setting. In addition, new ways of assessing muscle quality are needed that are practical in clinical practice, and new tools need to be evaluated for reliability and validity.[69]

6. CONCLUSIONS

The purpose of this review was to examine the methods commonly used for measurement of SMM in clinical practice and in the research setting. SMM assessment techniques range from simple anthropometric measurements requiring inexpensive equipment to the use of sophisticated and costly imaging instrumentation.[40] The increase in the elderly population in society generates the need for simple tools for quantification of sarcopenia in the inpatient and outpatient setting.[23] Total-body and regional SMM can now be quantified accurately using MRI, CT, DXA and BIA, or as second choice, anthropometry, depending on the local availability and the purpose (research or clinical) of the assessment.[13] Among the various techniques available for measurement of SMM, BIA and DXA represent an attractive alternative to the more expensive (e.g., MRI) or ionizing radiation-producing (e.g., CT) methods for use in clinical practice.[74] DXA appears to be the most widely used method for body composition assessment,[56] and BIA provides a simpler, portable, and less expensive alternative. BIA appears to be a good option for the clinical setting. Additional research is needed, however, on the use of BIA, to define how to optimize measurement and minimize error.

ΠΕΡΙΛΗΨΗ

Αξιολόγηση μυϊκής μάζας σε ηλικιωμένους στην κλινική πρακτική

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Η ποσοτικοποίηση της μυϊκής μάζας είναι σημαντική στην κλινική πρακτική και υπάρχουν αρκετά μέσα που μπορούν να χρησιμοποιηθούν για μετρήσεις. Ο σκοπός της παρούσας ανασκόπησης είναι η αναγνώριση και η κριτική ανάλυση των μέσων που υπάρχουν και χρησιμοποιούνται για τη μέτρηση της μυϊκής μάζας σε ηλικιωμένους. Δέκα διαφορετικά εργαλεία μέτρησης της μυϊκής μάζας αναγνωρίζονται και περιγράφονται. Η αξονική τομογραφία και η μαγνητική τομογραφία χρησιμοποιούνται ως τυποποιημένος τρόπος (gold standard). Η διπλής ενέργειας φωτονιακή απορροφησιομέτρηση πιθανόν είναι η πιο γνωστή μέθοδος, αλλά εξ αιτίας του κόστους περιορίζεται η χρήση της. Οι συσκευές βιοηλεκτρικής εμπήδησης είναι φορητές, απλές στην εφαρμογή και λιγότερο ακριβές. Ανθρωπομετρικές μετρήσεις έχουν εφαρμογή σε κατ' οίκον επισκέψεις. Ωστόσο, υπάρχουν ελλείψεις στη βιβλιογραφία για την αξιολόγηση της αξιοπιστίας των μέσων μέτρησης μυϊκής μάζας σε ηλικιωμένους. Απαιτούνται νέες ερευνητικές μελέτες για να διερευνηθεί η εφαρμογή και να ελαχιστοποιηθούν τα λάθη στις μετρήσεις μυϊκής μάζας στην κλινική πρακτική.

Λέξεις ευρετηρίου: Αξιολόγηση, Εργαλεία, Μυϊκή μάζα, Σωματική σύσταση

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