JAMDA xxx (2016) 1–11

JAMDA

journal homepage: www.jamda.com

Review Article

Muscle Ultrasound and Sarcopenia in Older Individuals: A Clinical Perspective

Andrea Ticinesi MD [a,b], Tiziana Meschi MD [a,b], Marco V. Narici PhD [c], Fulvio Lauretani MD [a,b], Marcello Maggio MD, PhD [a,b,*]

[a] Department of Clinical and Experimental Medicine, University of Parma, Parma, Italy
[b] Geriatric-Rehabilitation Department, Parma University Hospital, Parma, Italy
[c] MRC-ARUK Centre of Excellence for Musculoskeletal Ageing Research, School of Medicine, University of Nottingham, Derby, United Kingdom

Keywords:
Ultrasonography
skeletal muscle mass
muscle thickness
pennation angle
fascicle length
geriatrics
diaphragm ultrasound

A B S T R A C T

Introduction: A precise quantitative measurement of skeletal muscle mass is fundamental for diagnosing sarcopenia in older individuals. The current techniques of assessment, including dual-energy x-ray absorptiometry (DXA), bioimpedance analysis (BIA), and magnetic resonance imaging (MRI) are either difficult to perform in everyday clinical practice or biased by concurrent clinical confounders. B-mode muscle ultrasound can be helpful in assessing muscle mass and architecture, and thus possibly useful for diagnosing or screening sarcopenia.
Methods: A literature search of published articles on muscle ultrasound and sarcopenia in older individuals as of July 31, 2016, was made on PubMed and Scopus. Manual search and cross-referencing from reviews and original articles was also performed.
Results: Most of the existing studies were carried out on healthy well-fit subjects, with a low prevalence of sarcopenia. The main parameters that can be assessed through muscle ultrasound are muscle thickness, cross-sectional area, echo intensity, and, for pennate muscles, fascicle length and pennation angle. In older subjects, all these parameters show some degree of alteration compared to young adults, particularly in lower limb muscles with antigravitary function, such as the quadriceps femoris and gastrocnemius medialis. Each of these parameters may be theoretically useful for detecting the loss of muscle mass and functionality in geriatric patients. They are also poorly influenced by the presence of acute and chronic diseases and fluid balance, unlike DXA and BIA, but a high degree of standardization in ultrasound protocols is necessary. Frontier applications of ultrasound in the assessment of sarcopenia may include contrast-enhanced and diaphragm ultrasound.
Conclusions: The current literature does not allow to make conclusive recommendations about the use of muscle ultrasound in geriatric practice. However, this technique is very promising, and further studies should validate its applications in the context of sarcopenia assessment.

Why Muscle Ultrasound in Sarcopenia?

Since the first definition,[1] all experts and consensus groups have considered loss of skeletal muscle mass as the key element for diagnosing sarcopenia in older individuals.[2–6] Although functional parameters, such as gait speed and grip strength, have been emphasized in the most recent definitions,[7] quantitative measures of lean mass still represent an important part of the clinical assessment of sarcopenia in geriatric patients. This is particularly important when considering that skeletal muscle is the second largest store of energy in the body and plays an essential role in glucose homeostasis.

From a clinical perspective, the current definitions of sarcopenia may imply several pitfalls, particularly for quantitative measures of muscle mass. First, muscle mass thresholds considerably vary from one definition to another, making it very difficult to correctly classify patients as normal or sarcopenic.[8] The prevalence of sarcopenia in community-dwelling older individuals also depends on the definition adopted for assessment.[8–11]

Second, the method of muscle mass measurement is not completely standardized. Computed tomography (CT) and, most of all, magnetic resonance (MR) imaging are regarded as the gold standard techniques for measuring body composition, and thus for quantifying

The authors declare no conflicts of interest.

* Address correspondence to Marcello Maggio, MD, PhD, Department of Clinical and Experimental Medicine, University of Parma, Via Antonio Gramsci 14, Parma 43126, Italy.
E-mail address: marcellomaggio2001@yahoo.it (M. Maggio).

http://dx.doi.org/10.1016/j.jamda.2016.11.013

lean mass, in humans.[12] This concept also applies to the geriatric setting.[13,14] However, these imaging tests are not applicable in everyday clinical practice, since they are expensive and often uncomfortable for patients, and, according to the current healthcare policies, should not be prescribed for measuring muscle mass except in the context of research protocols.[12–14] Thus, alternative methods such as bioimpedance analysis (BIA) and dual-energy x-ray absorptiometry (DXA) seem preferable, although no wide consensus has been reached in favor of one or another test. For example, the International Working Group on Sarcopenia recommends the use of DXA in older subjects with a reduced gait speed,[6] but the European Working Group on Sarcopenia in Older People (EWGSOP) states that both BIA and DXA can be used interchangeably in this setting,[4] being both significantly related to gold standard measures in elderly people.[15–17]

Both of these techniques however imply a certain degree of inaccuracy in clinical practice. DXA measures may differ according to device manufacturer[18] and their degree of concordance with gold standard techniques may depend on age and gender.[19] BIA accuracy strongly relies on the type of equations used for appendicular skeletal mass estimation,[20] which should be validated in older populations,[21] and depends on the hydration status, with fluid overload acting as a strong confounding factor.[22] As such, the assessment of sarcopenia in hospitalized geriatric patients can be particularly difficult, given the limited availability of DXA and the alterations in fluid balance caused by acute disease and limited mobility. Interestingly, Reiss and colleagues recently reported a suboptimal degree of concordance of BIA and DXA when measuring muscle mass in hospitalized patients according to the EWGSOP algorithm, with a significant underestimation of sarcopenia by BIA, especially in overweight subjects.[23]

In this scenario, innovative tools for measuring muscle mass and quality are needed. Skeletal muscle ultrasound is a standardized and accurate imaging technique that has entered clinical practice for the diagnosis and follow-up of neuromuscular disorders.[24] Its main pros include simplicity, low costs, quickness of execution, and availability at bedside.[12] Conversely, specific training of operators and adherence to strict protocols are needed to obtain reliable and reproducible results.[12] Sonographic and MR assessments of muscle mass at different anatomic sites exhibit a high degree of concordance in both experimental animal models[25] and healthy humans.[26–30]

However, the role of skeletal muscle ultrasound for screening and diagnosing sarcopenia in elderly individuals remains speculative. None of the current definitions of sarcopenia includes it in diagnostic algorithms.[4–6] In spite of this, some experts acknowledge the potential usefulness of muscle ultrasound also in this setting,[12,13,31] basing mainly on pioneering studies assessing muscle mass and architecture by this technique on healthy aging subjects.[32–34]

Thus, in the present paper, we review the existing studies on the role of muscle ultrasound for detecting muscle mass loss in older individuals, using a clinically oriented approach in order to highlight possible advantages and pitfalls and areas for future research.

Methods of Literature Search and Results

A literature search of published articles as of July 31, 2016, was made on PubMed and Scopus. "Sarcopenia ultrasound," "muscle ultrasound geriatric," "muscle ultrasound elderly," "muscle echointensity older," "muscle cross-sectional area older," "muscle thickness older," and "pennation angle older" were used as search strings. Articles lacking original data, not in English language, or focused exclusively on young subjects or specific neuromuscular diseases were excluded.

The literature search revealed 44 papers eligible for inclusion, with a wide heterogeneity of aims, outcomes, and settings (healthy active subjects vs outpatients with chronic diseases). Most of the studies were carried out on small groups, thus, despite the scientific relevance, they had limited clinical value. However, because our aim was to provide insights into the possible future applications of muscle ultrasound in geriatrics and gerontology, they were not excluded, but their limitations were critically considered. Therefore, we chose to follow a narrative review approach, identifying 5 areas of interest: "studies of comparison with reference methods," "regional differences in sarcopenia assessment," "ultrasonographical evaluation of muscle structure," "association of muscle ultrasound with functional parameters and clinical outcomes," and "muscle ultrasound in intervention studies." Finally, we identified possible pitfalls in the application of muscle ultrasound for diagnosing sarcopenia and provided a brief overview of frontier topics, such as the possible application of contrast-enhanced muscle ultrasound and diaphragm ultrasound in geriatrics.

Muscle Ultrasound Assessment in Older Individuals: State of the Art

Studies of Comparison with Reference Methods

Only 4 studies have compared muscle ultrasound vs DXA in order to measure muscle mass and detect sarcopenia (Table 1).[35–38] Three of them were focused on healthy community-dwelling elderly but also included middle-aged subjects,[35–37] whereas one, although aimed at diagnosing sarcopenia, was carried out exclusively on middle-aged females.[38] None of them focused on hospitalized individuals. All these studies agreed that the sonographic measurement of muscle thickness, obtained either at multiple sites or at the thigh, have a high concordance with DXA-predicted estimates of muscle mass.[35–38] In the largest of these studies,[35] the authors demonstrated that in 77 healthy subjects aged 52 to 78, the product of ultrasound-measured muscle thickness at 4 different sites and lower limb length is independently and strongly related to body fat-free mass (FFM) as calculated by DXA.

Three studies have instead compared muscle ultrasound and BIA for detecting muscle mass loss. Minetto et al performed both techniques in a cohort of 44 healthy older subjects aged on average 82, and compared their results with the values obtained, as a reference standard, in 60 young adults. They observed that the prevalence of low muscle mass in older subjects was highly variable, depending on the adopted BIA-derived cut-points and site of ultrasound measurement, being maximal at the proximal muscles of lower limb.[39] Conversely, Kuyumcu et al found that in a cohort of 100 community-dwelling older subjects, gastrocnemius muscle thickness and fascicle length showed high sensitivity and negative predictive value (approaching 100%) in detecting sarcopenia, diagnosed with BIA and handgrip strength as reference standards.[40] Finally, Seymour et al found a significant correlation between rectus femoris cross-sectional area measured by ultrasound and BIA-derived FFM in a cohort of 30 patients with chronic obstructive pulmonary disease (COPD) aged on average 67 years. However, in this study the correlation coefficient, although statistically significant, was not optimal ($r = 0.43$).[41]

Muscle ultrasound has been compared to CT in only one small study, performed on 45 patients (mean age 68) with coronary artery disease. Rectus femoris thickness measured by ultrasound was significantly correlated with CT-derived muscle volume of the midthigh region, although in a suboptimal way ($r = 0.49$).[42] Ultrasound was compared with CT also in a small subsample (18 subjects) of the Seymour et al study,[41] with rectus femoris cross-sectional area well correlated between the 2 techniques ($r = 0.88$).

Finally, 3 studies compared ultrasonographic assessment of muscle mass with MRI,[43–45] but 2 of them also enrolled adult subjects.[43,45] Sanada and colleagues measured muscle thickness by MRI and ultrasound in different anatomic sites of 72 young Japanese subjects. They demonstrated significant and strong site-matched skeletal