Clinical and Experimental Rheumatology 2020; 38: 985-988.

Ultrasound measurement of muscle thickness at the proximal forearm in a rheumatologic setting

G. Smerilli[1], S. Castell[2], E. Cipolletta[1], S. Farah[1], M. Carotti[3], F. Salaffi[1], W. Grassi[1], E. Filippucci[1]

[1]Rheumatology Unit, Polytechnic University of Marche, Department of Clinical and Molecular Sciences, Carlo Urbani Hospital, Jesi, Ancona, Italy; [2]Rheumatology Department, Hospital del Mar, Barcelona, Spain; [3]Radiology Department, Polytechnic University of Marche, Ancona, Italy.

Gianluca Smerilli, MD
Sonia Castell, MD
Edoardo Cipolletta, MD
Sonia Farah, EngD
Marina Carotti, MD
Fausto Salaffi, MD, PhD
Walter Grassi, MD, PhD
Emilio Filippucci, MD, PhD

Please address correspondence to:
Gianluca Smerilli,
Dipartimento di Scienze Cliniche e Molecolari,
Ospedale Carlo Urbani,
Via Aldo Moro 25,
60035 Jesi (AN), Italy.
E-mail: smerilli.gianluca@gmail.com

Received on September 28, 2019; accepted in revised form on January 15, 2020.

Key words: ultrasonography, sarcopenia, frailty, rheumatic diseases

Competing interests: E. Filippucci has received speakers fees from AbbVie, Bristol-Myers Squibb, Celgene, Novartis, Pfizer, Roche and Union Chimique Belge Pharma; M. Carotti has received speakers fees from Roche, Novartis, Abbvie, Pfizer and Bristol-Myers-Squibb; F. Salaffi has received speakers fees from Roche, AbbVie, Novartis, Bristol-Myers Squibb, Pfizer and Merck Sharp & Dohme Italia; W. Grassi has received speakers fees from AbbVie, Celgene, Grünenthal, Pfizer and Union Chimique Belge Pharma; the other authors have declared no competing interests.

ABSTRACT

Objective. *To provide a detailed description of the ultrasound (US) scanning protocol to measure the muscle thickness in the forearm and to test its feasibility and interobserver reliability.*

Methods. *Four rheumatologists trained in musculoskeletal US carried out the examinations in 45 subjects (30 consecutively enrolled patients and 15 healthy subjects). Each of the four rheumatologists took two measurements of each forearm (radial muscle thickness and ulnar muscle thickness) and the time needed to complete the bilateral US assessment was recorded.*

Results. *The mean time required to acquire all measurements in each subject was less than four minutes. We found an excellent interobserver reliability of the proposed scanning protocol, with an intraclass correlation coefficient (ICC) among the four sonographers of 0.97 (CI 0.95–0.98) for the right ulnar muscle thickness, an ICC of 0.97 (CI 0.94–0.98) for the left ulnar muscle thickness, an ICC of 0.93 (CI 0.89–0.96) for the right radial muscle thickness and an ICC of 0.95 (CI 0.91–0.97) for the left radial muscle thickness.*

Conclusion. *The results of this study provide evidence in favour of interobserver reliability and feasibility of US measurement of the forearm muscle thickness.*

Introduction

According to the European Working Group on Sarcopenia in Older People (EWGSOP), the term sarcopenia defines a syndrome characterised by low muscle mass and either low muscle strength (usually measured by handgrip strength) or low physical function (1).

Sarcopenia overlaps the concept of frailty and has been linked to increased falling, fragility fractures and lower mineral bone density (2). This condition has a considerable impact on direct and indirect healthcare costs (3). Rheumatic patients, even young adults, are especially predisposed to develop sarcopenia in light of the underlying proinflammatory state, inactivity and pain (4, 5).

Dual x-ray absorptiometry (DXA) is the gold standard modality for the assessment of skeletal muscle mass, but has some issues concerning radiations, accessibility and low sensitivity to small changes (6).

Ultrasound (US) has the potential to be a good alternative to DXA because is safe, portable and easily accessible in many different care settings. Moreover, it has proven to be a reliable technique in the assessment of muscle size (7).

A recent systematic review by Nijholt *et al*. investigating the validity of US to quantify muscles in the elderly confirmed the reliability of the technique but highlighted that information regarding the scanning procedure was unclear in most of the studies (8).

Two studies by Abe *et al*. demonstrated that there is a correlation between US measurement of muscle thickness (MT) at the proximal forearm and handgrip strength, which is, as mentioned above, one of the main features of sarcopenia (9, 10). These studies were conducted in older people as well as in young adults but unfortunately did not accurately explain how to perform the US measurements and did not assess the inter-rater reliability of this technique.

The aims of the present study were to provide a detailed description of the scanning protocol to measure the MT in the forearm and to test its feasibility and interobserver reliability.

Materials and methods

Participants

We enrolled consecutive patients at the Rheumatology Unit of Carlo Urbani Hospital, in Jesi (Ancona, Italy) and healthy volunteers recruited from among our staff. Exclusion criteria were inability to sit and age <18 years.

Ethics committee approval was not required as all the patients underwent clinical and US evaluation according to our local protocols. All the patients gave their informed consent. No specific funding was received from any bodies in the public, commercial or not-for-profit sectors to carry out the work described in this manuscript.

Ultrasound assessment

Four rheumatologists (SC, EC, EF and GS) trained in musculoskeletal

US, with a different degree of experience, carried out the US examinations using a MyLab ClassC (Esaote SpA) equipped with a broadband linear probe (frequency range 4–13 MHz). All subjects sat in front of the sonographer with their hands supinated and the forearms resting on the examining table in a relaxed position. The probe was placed on the skin with an appropriate amount of gel in order to reduce the pressure on the scanned tissues. First, the coronoid process was imaged according to the "longitudinal scan of the coronoid recess" as indicated by the 2017 EULAR standardised procedures for US imaging in rheumatology (11). Second, the probe was moved distally following bony cortex until the ulnar tuberosity was identified (Fig. 1a-a'). Immediately distally to the ulnar tuberosity the bone turns flat and sharp, and this was taken as the anatomical reference to slowly obtain a perpendicular transverse view, keeping the hyperechoic bone in the center of the image without losing it. During the rotation the proximal third of the diaphysis of the radius was imaged. Once that the 90° rotation was completed, with the US beam perpendicular to the examination table, two MTs were measured, the ulnar muscle thickness (UMT) and the radial muscle thickness (RMT), between the subcutaneous tissue-muscle interface and the muscle-bone interface of each bone respectively (Fig. 1b-b'). The measurement of UMT and RMT of both arms were registered, as well as the scanning time of all the examiners.

Tips and tricks

Employing minimal pressure during acquisition of the image is fundamental because muscles are easily compressible, hence MT can relevantly change. An indirect sign of low compression is patency of superficial veins (Fig. 1b').

Identifying correctly the subcutaneous tissue-muscle interface is not always easy at first glance. It can be therefore helpful moving the probe proximal and distal to the measurement landmark in order to differentiate muscle from the upper layer of adipose tissue.

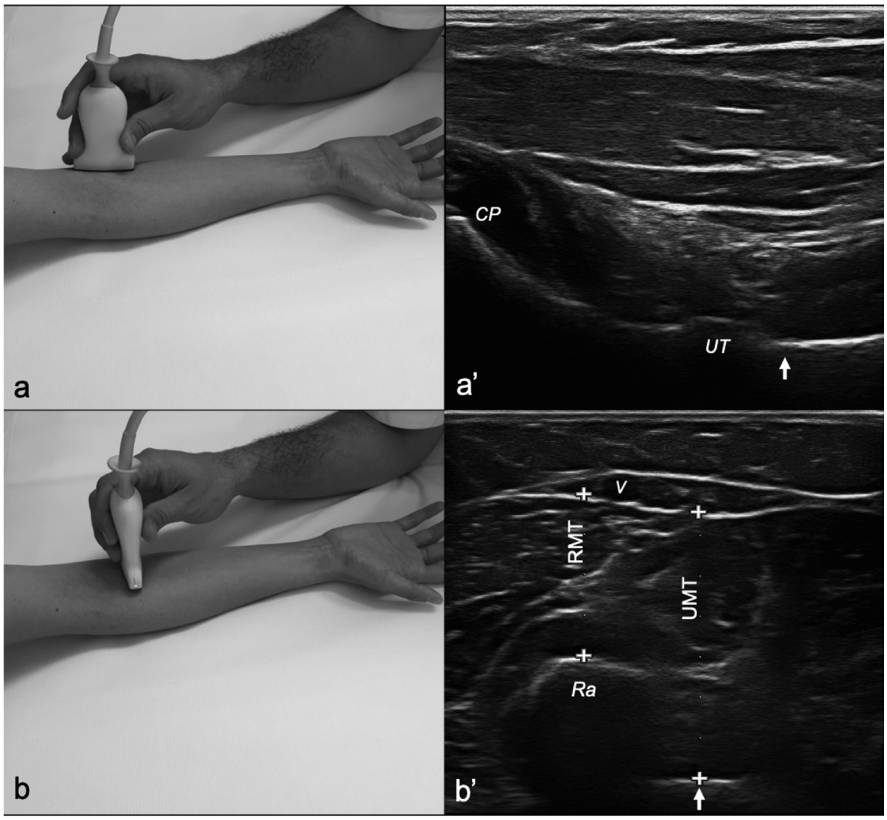

Fig. 1. Representative images of the scanning protocol.
a-a': longitudinal scan over the proximal ulna (in a' right is distal). The bone contour of the ulna is imaged from the coronoid process (CP) to the anatomical reference (arrow) used to obtain a transverse view, slightly distally to the ulnar tuberosity (UT).
b-b': transverse scan obtained at the level indicated by the arrow in a', note the patent vein (V). To measure the radial muscle thickness (RMT) and the ulnar muscle thickness (UMT) the callipers were placed between the correspondent bony cortex and the most superficial muscle fascia.
Ra: radius; RMT: radial muscle thickness; UMT: ulnar muscle thickness.

Statistical analysis

Demographic data were analysed using descriptive statistics. Mean with standard deviation (SD) and medians with interquartile ranges were used to describe these differences. Feasibility was estimated using the average time taken to carry out US examination in each subject. Differences are reported using both intraclass correlation coefficients (ICC) average measures, with 95% confidence intervals (CI), and visually by plotting the difference in change of scores against the mean change by both raters for determination of the Smallest Detectable Difference (SDD). The ICC is regarded as excellent if above 0.75, if between 0.4 and 0.75 reliability is defined as fair to good, and below 0.4 reliability is poor (12). The SDD is a statistical method for defining measurement error based on the 95% limits of agreement, as described by Bland and Altman (13). The SDD is reader and sample specific and represents the smallest change in score that can be discriminated from the measurement error of the scoring method. Using the SDD as the threshold level for a definite change in score ensures that the changes observed are not due to reading variability.

Results

A total of 45 subjects were enrolled: 15 healthy volunteers recruited from among our staff, and 30 patients consecutively referred because affected by psoriatic arthritis (n=5), rheumatoid arthritis (n=4), polymyalgia rheumatica (n=4), fibromyalgia (n=4), spondyloarthritis (n=2), systemic lupus erythematosus (n=2), small-vessel vasculitides (n=2), calcium pyrophosphate deposition disease (n=1), reactive arthritis (n=1), systemic sclerosis (n=1), over-

lap SLE/SSc (n=1), Sjögren syndrome (n=1), antisynthetase syndrome (n=1) and undifferentiated connective tissue disease (n=1). The mean±SD age was 49.7±15.4 years and the mean±SD BMI was 25.9±4.2 kg/m^2.

The mean time required to acquire all measurements in each subject was less than four minutes: SC mean time ± SD was 3.9±1.4 min, EC mean time ± SD was 3.6±1.5 min, EF mean time ± SD was 3.9±1.5 min and GS mean time ± SD was 3.6±1.5 min.

The mean UMT was 36.1±4.2 mm and the mean RMT was 19.7±3.6 mm.

We found an excellent interobserver reliability, with an intraclass correlation coefficient (ICC) among the four sonographers of 0.97 (CI 0.95–0.98) for the right ulnar muscle thickness, an ICC of 0.97 (CI 0.94–0.98) for the left ulnar muscle thickness, an ICC of 0.93 (CI 0.89–0.96) for the right radial muscle thickness and an ICC of 0.95 (CI 0.91–0.97) for the left radial muscle thickness.

The Bland-Altman plots illustrating differences of UMT and RMT measurements between the three less experienced operators (SC, EC and GS) and the expert one (EF) are showed in Figure 2 (for UMT measurements) and Figure 3 (for RMT measurements).

The smallest detectable difference (SDD) of UMT measurements calculated between the three less experienced operators and the expert sonographer was similar (4.7 mm for SC, 4.8 mm for EC and 3.8 mm for GS). The smallest detectable difference (SDD) of RMT measurements between the three less experienced operators and the expert was 5.4 mm for SC, 4.8 mm for EC and 4.8 mm for GS.

The SDD, expressed in percentage of the range of the variable, ranged from 10.5% to 13.2% for UMT and from 24.4% to 27.4% for RMT.

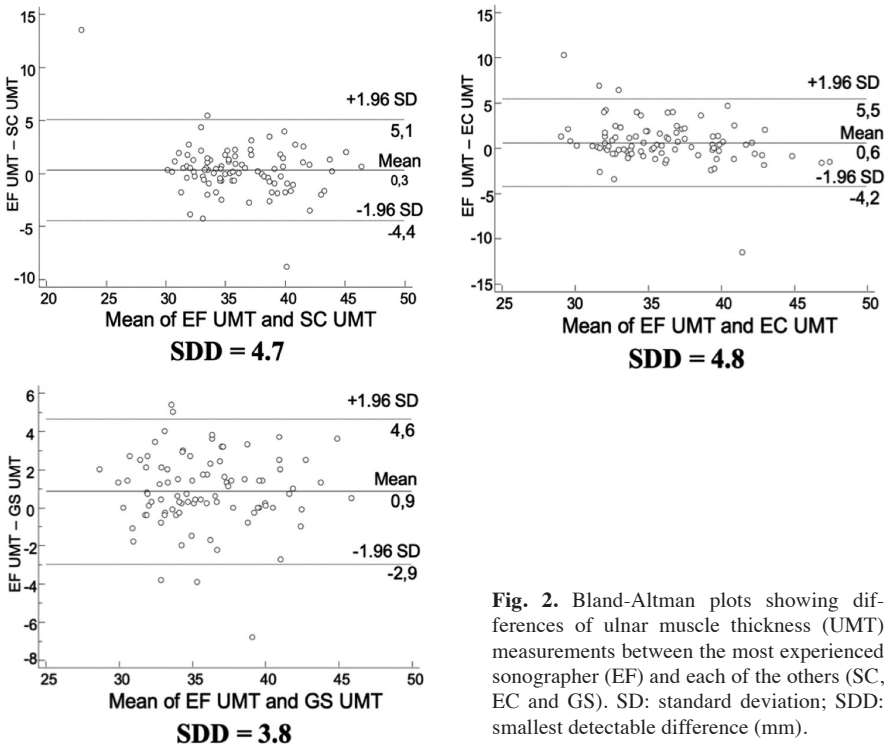

Fig. 2. Bland-Altman plots showing differences of ulnar muscle thickness (UMT) measurements between the most experienced sonographer (EF) and each of the others (SC, EC and GS). SD: standard deviation; SDD: smallest detectable difference (mm).

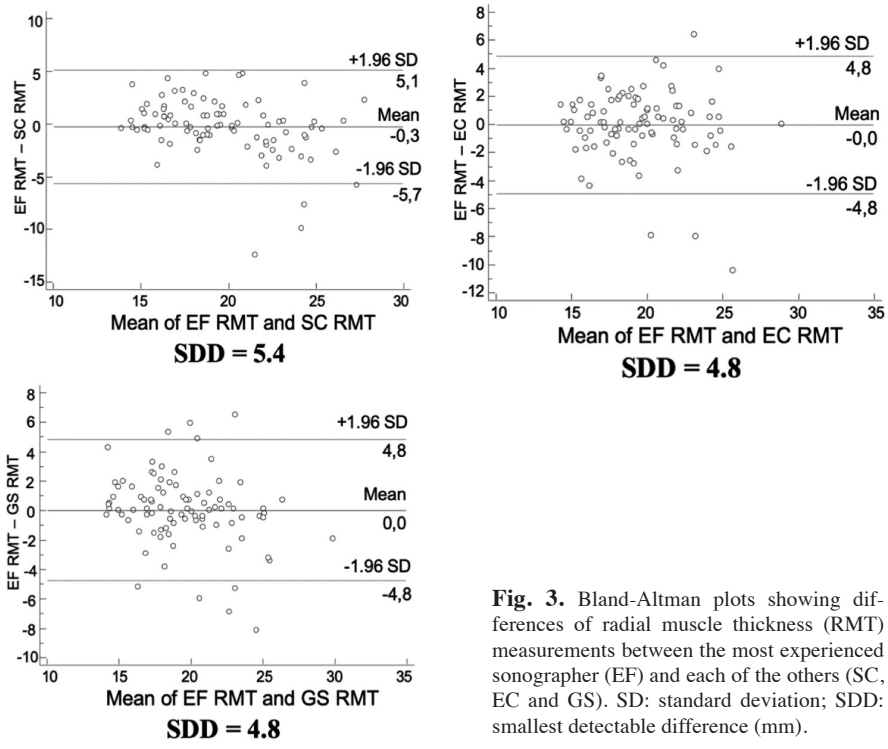

Fig. 3. Bland-Altman plots showing differences of radial muscle thickness (RMT) measurements between the most experienced sonographer (EF) and each of the others (SC, EC and GS). SD: standard deviation; SDD: smallest detectable difference (mm).

Discussion

Sarcopenia is a common condition among older population, and is even more prevalent in patients affected by rheumatic diseases.

In particular, Santos *et al*. studied body composition phenotype with bioelectrical analysis in systemic lupus erythematosus and found that sarcopenia has a higher prevalence compared to age-matched healthy subjects (5). Similar results were found in a cohort of ankylosing spondylitis and psoriatic arthritis (14). Sarcopenia is also a common feature of systemic sclerosis patients, especially those with malnutrition (15). However, most of the recent efforts are focused on sarcopenia and frailty among rheumatoid arthritis (RA) patients and this is a growing hot topic due to high prevalence and impact on adverse outcomes (16-19).

Thus, it is expected that the accuracy in the assessment of muscle mass will be an important issue to address, in rheumatologic and non-rheumatologic settings. To date, there are only a few studies assessing the ability of US to measure the muscle mass and both scanning technique and validity require further investigations.

In the present study we proposed a scanning protocol, based on US landmarks, which proved to have excellent feasibility and interobserver reliability, especially for the assessment of ulnar muscle thickness. We hope that the conciseness of this technique, explained in detail in this paper, will prompt other researchers and clinicians, even without major experience in musculoskeletal US, to reproduce it.

The main limitation of this study is that we only assessed muscle mass at forearm level, without exploring the correlation between our measurements and a reference standard (DXA, CT or MRI). The choice of this anatomic area was determined by its accessibility and by the fact that a correlation between forearm muscle thickness (in particular ulnar muscle thickness) and handgrip strength has been demonstrated in healthy subjects (9).

Further research is needed to clarify the correlation between US measured forearm muscle thickness, handgrip strength and frailty in rheumatic patients.

References

1. CRUZ-JENTOFT AJ, BAEYENS JP, BAUER JM *et al*.: Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010; 39: 412-23.
2. DI MONACO M, VALLERO F, DI MONACO R, TAPPERO R: Prevalence of sarcopenia and its association with osteoporosis in 313 older women following a hip fracture. *Arch Gerontol Geriatr* 2011; 52: 71-4.
3. STEFFL M, SIMA J, SHIELLS K, HOLMEROVA I: The increase in health care costs associated with muscle weakness in older people without long-term illnesses in the Czech Republic: results from the Survey of Health, Ageing and Retirement in Europe (SHARE). *Clin Interv Aging* 2017; 12: 2003-7.
4. GUPTA S, DHILLON RJS, HASNI S: Sarcopenia: a rheumatic disease? *Rheum Dis Clin North Am* 2018; 44: 393-404.
5. SANTOS MJ, VINAGRE F, CANAS DA SILVA J, GIL V, FONSECA JE: Body composition phenotypes in systemic lupus erythematosus and rheumatoid arthritis: A comparative study of Caucasian female patients. *Clin Exp Rheumatol* 2011; 29: 470-6.
6. COOPER C, FIELDING R, VISSER M *et al*.: Tools in the assessment of sarcopenia. *Calcif Tissue Int* 2013; 93: 201-10.
7. PRETORIUS A, KEATING JL: Validity of real time ultrasound for measuring skeletal muscle size. *Phys Ther Rev* 2008; 13: 415-26.
8. 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: 702-12.
9. ABE T, THIEBAUD RS, LOENNEKE JP, OGAWA M, MITSUKAWA N: Association between forearm muscle thickness and age-related loss of skeletal muscle mass, handgrip and knee extension strength and walking performance in old men and women: a pilot study. *Ultrasound Med Biol* 2014; 40: 2069-75.
10. ABE T, COUNTS BR, BARNETT BE, DANKEL SJ, LEE K, LOENNEKE JP: Associations between handgrip strength and ultrasound-measured muscle thickness of the hand and forearm in young men and women. *Ultrasound Med Biol* 2015; 41: 2125-30.
11. MÖLLER I, JANTA I, BACKHAUS M *et al*.: The 2017 EULAR standardised procedures for ultrasound imaging in rheumatology. *Ann Rheum Dis* 2017; 76: 1974-79.
12. CICCHETTI DV: Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment* 1994; 6: 284-90.
13. BLAND JM, ALTMAN DG: Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; 1: 307-10.
14. AGUIAR R, SEQUEIRA J, MEIRINHOS T, AMBRÓSIO C, BARCELOS A: SARCOSPA-Sarcopenia in spondyloarthritis patients. *Acta Reumatol Port* 2014; 39: 322-6.
15. CAIMMI C, CARAMASCHI P, VENTURINI A *et al*.: Malnutrition and sarcopenia in a large cohort of patients with systemic sclerosis. *Clin Rheumatol* 2018; 37: 987-97.
16. SALAFFI F, DI CARLO M, FARAH S, DI DONATO E, CAROTTI M: Prevalence of frailty and its associated factors in patients with rheumatoid arthritis: a cross-sectional analysis. *Clin Rheumatol* 2019; 38: 1823-30.
17. SALAFFI F, DI CARLO M, FARAH S, CAROTTI M: The Comprehensive Rheumatologic Assessment of Frailty (CRAF): development and validation of a multidimensional frailty screening tool in patients with rheumatoid arthritis. *Clin Exp Rheumatol* 2020; 38: 488-99.
18. ANDREWS JS, TRUPIN L, WYSHAM KD, HOUGH CL, YELIN EH, KATZ PP: The impact of frailty on changes in physical function and disease activity among adults with rheumatoid arthritis. *ACR Open Rheumatol* 2019; 1: 366-72.
19. HAIDER S, GRABOVAC I, BERNER C *et al*.: Frailty in seropositive rheumatoid arthritis patients of working age: a cross-sectional study. *Clin Exp Rheumatol* 2019; 37: 585-92.