Comparison of multifrequency bioimpedance measured lean mass to that calculated from anthropometric measurements in patients with chronic kidney disease

Sarju Raj Singh Maharjan1 MRCP, Keruo Jiang2 MSc, Adrian Slee3 PhD, Andrew Davenport1 FRCP

1 UCL Department of Nephrology, Royal Free Hospital, University College London, London NW3 2PF, UK
2 UCL Clinical and Public Health Nutrition
3 UCL Division of Medicine, Faculty of Medical Sciences, Gower Street, London WC1E 6BT

Sarju Raj Singh Maharjan srsingh9@hotmail.com
Keruo Jiang nicolejkr8899@gmail.com
Adrian Slee a.slee@ucl.ac.uk
Andrew Davenport andrewdavenport@nhs.net

Address for correspondence contact andrewdavenport@nhs.net orchid 0000-0002-4467-6833
UCL Department of Nephrology, Royal Free Hospital, University College London, Rowland Hill Street, London NW3 2PF
tel 44-2074726457 fax 44-2073178591

short title measuring muscle mass in patients with chronic kidney disease
key words chronic kidney disease triceps skin fold thickness hand grip strength mid-arm circumference bioimpedance

the authors have no conflicts of interest

word count abstract 150
body 1000
figures 1
tables 1
references 10

Acknowledgements: Dr Sarju Raj Singh Maharjan was in receipt of International Society of Nephrology Kidney Research UK training award
Abstract

Patients with chronic kidney disease (CKD) are at increased risk of sarcopenia. Previous studies have proposed equations to estimate muscle mass based on triceps skin fold thickness and mid upper arm circumference, with or without adjustment for hand grip strength (HGS). We wished to evaluate their usefulness compared to multifrequency segmental bioimpedance (MFBIA) measured appendicular lean mass (ALM). We audited 160 CKD patients attending outpatient clinics, 65.6% male, median age 73 (62-81.5) years. We calculated muscle mass using six proposed equations based on anthropometric measurements. These equations over estimated muscle mass compared to MFBIA with a mean bias ranging from 3.4 to 35.9 kg. Apart from one equation, there was a systematic bias, with bias increasing with increasing fat mass (ranging from r= 0.17, p=0.044 to r=0.65, p<0.001). For CKD patients we found that most of the previously proposed equations based on anthropometric equations over-estimated muscle mass compared to MFBIA.

Body

Patients with chronic kidney disease (CKD) are at increased risk of muscle loss due to multiple factors, including dietary restrictions, metabolic acidosis, inflammation, urinary protein losses and vitamin D deficiency [1]. Pathological loss of muscle mass, termed sarcopenia is associated with increased
mortality. Thus, rapid low-cost screening tests are required to detect sarcopenia to allow for early intervention.

Several equations are used to estimate skeletal muscle mass based on anthropometric measurements of height, weight, and either triceps skin fold thickness (TSF), mid upper arm circumference (MUAC), mid arm muscle circumference (MAMC), or hand grip strength (HGS). These models differ in validating anthropometric estimates of muscle mass by computerized axial tomography (CT) [2], magnetic resonance (MRI) [3] or dual-energy X-ray absorptiometry (DXA) [4,5] imaging. None of these imaging techniques are routinely available for patients attending out-patient clinics. Whereas, multifrequency bioelectrical impedance (MFBIA) devices are now available for clinic use. Previous studies have validated MFBIA measurements of muscle mass with DXA in dialysis patients [6,7]. Over time definitions of body composition have changed with the introduction of newer imaging techniques, and so we wished to retrospectively compare appendicular lean mass (ALM) and the equivalent skeletal muscle mass estimated from anthropometric measurements and HGS.

A single observer made anthropometric measurements in CKD patients attending outpatient clinics. MUAC and TSF were determined using a non-stretch tape measure and the Harpenden skinfold calliper (HSB-BI, Baty International Ltd, West Sussex, UK). The midpoint of the left upper arm between the lateral acromion and distal olecranon was marked with the left arm bent at 90°, and MUAC measured to the nearest 0.1 cm. TSF was measured by
vertically pulling out the skinfold one inch above the midpoint and calliper jaws applied in the centre of the standard mid-point, and the mean of three recordings taken. Corrected mid-upper arm muscle area (CMUAMA) was derived from MUAC and TSF [2]. HGS was measured using the grip-D strength dynamometer (Takei Scientific Instruments Co, Nigata, Japan). Patients were instructed to use the strength gauge, and measurements made according to the manufacturer's recommendations with patients asked to make three maximal voluntary exertions with the dominant (stronger) arm, with the maximum value recorded.

MFBIA were made with an 8 electrode multi-frequency segmental bioimpedance device (InBody 720, Seoul, South Korea) using a standardised protocol [6,7]. The bioimpedance machine was regularly serviced and calibrated. Our retrospective audit complied with the UK National Health Service (NHS) guidelines for clinical audit and service development with all patient data anonymised and complied with UK National Institute for Clinical Excellence (NICE) best practices, www.nice.org.uk/media/796/23/bestpracticeclinicalaudit.pdf.

Patient demographics of the 160 CKD patients are reported in table 1. ALM measured with MFBIA was significantly lower compared to all models (Kruskal Wallis p<0.001), apart from total body muscle mass estimated by the equation proposed by Lee at al [4]. We then compared estimates of muscle mass by Bland Altman (Figure 1). Apart from the Lee equation (Figure 1b), all other models not only over estimated muscle mass, but demonstrated a systematic
bias, with increasing difference as muscle mass increased (Figure 1a, 1c, 1d, 1e, 1f). Analysing the differences between ALM and muscle mass derived from anthropometric equations: the median difference between MFBIA measured ALM and Lee equation 2.2 (-0.13 to 2.88) kg was significantly less compared to the differences with the other equations: Heymsfeld 37.7 (35-40.6), Tian 23.4 (18.8-25.7), Noori 29.3 (26.6-31.8), Noori HGS 30.4 (27.5-32), all p<0.001, and Tian HGS 22 (18.7-24.6), p=0.01.

There was no association with estimated glomerular filtration rate, ratio of extracellular to total body water (ECW/TBW) or age, but as fat mass increased, then the difference between MFBIA-ALM and anthropometric derived estimates of muscle mass increased for the models using TSF and MUAMC (Spearman correlation: Heymsfeld [2] r=0.17, p=0.044; Lee [3] r=0.26, p=0.000; Noori [4] r=0.63, p<0.001; Tian [5] r=0.27, p=0.000), and also for those models using HGS (Noori [4] r=0.65, p<0.001; Tian [5] r=0.51, p<0.001).

Our results would suggest that apart from the equation proposed by Lee at al [3], based on MRI measurements of muscle mass, the other models used to estimate muscle mass all appear to significantly over estimate muscle mass, and as fat mass increased then the difference between MFBIA measured ALM and these anthropometric estimates of muscle mass rose. MRI is better at estimating fat content than CT, as demonstrated by Figueroa-Bonaparte et al using different radiofrequency pulse sequences then MRI can estimate intracellular fat content due to different precession frequencies of hydrogen in fat molecules compared to water [9]. As muscle from CKD patients contains
more intra and extracellular fat [1], then CT scanning will over estimate muscle mass compared to MRI [9].

Whereas the equations proposed by Heymsfield [3] and Lee [4] were derived from healthy non-obese patients, those proposed by Tian [5] were based on patients with CKD, and Noori studied haemodialysis patients [4]. Both sets of equations appear to over-estimate muscle mass compared to MFBIA and MRI, with increasing bias with increasing muscle. All imaging techniques will over-estimate muscle mass when patients are volume overloaded, due to the increased water content of muscle [10]. In the study reported by Tian et al, then the mean ratio of ECW/TBW was 0.45 (normal 0.36-0.4) [5], much higher than in our cohort, with >90% of patients having no recorded signs of ECW excess. As their patients had greater ECW then muscle mass would be over-estimated. Although Noori et al did not provide any estimate of volume status, their patients were recruited from eight dialysis centres, with DXA imaging on a non-dialysis day, so patients would be most likely over-hydrated. As such body composition studies should report hydration status.

Our retrospective audit in patients with CKD demonstrates that the majority of previously reported equations estimating muscle mass based on anthropometric measurements of TSF and MUAC, appear to over-estimate muscle mass compared to segmental MFBIA, with bias increasing with increasing fat mass. Whereas ALM estimated anthropometric equations based on MRI scanning, which can exclude intracellular fat, most closely correlated with segmental MFBIA measured ALM.
The authors have no conflict of interest

References


Figure 1. Bland Altman graphs comparing multifrequency segmental bioimpedance appendicular lean mass (ALM) and muscle mass estimated by Helmsfield et al [2] (Figure 1a); skeletal muscle mass estimated by Lee et al [3] Figure 1b; lean body
mass estimated by Noori et al [4] Figure 1c; lean body mass estimated by Tian et al [5] figure 1d; and anthropomorphic equations including an adjustment for hand grip strength: Noori et al [4] Figure 1e, and Tian et al [5] figure 1f. Graphs show mean bias and 95% limits of agreement (LA).