ORIGINAL RESEARCH

Addressing the Main Barrier to Sarcopenia Identification: Utility of Practical Office-Based Bioimpedance Tools Vs. Dual Energy X-ray Absorptiometry (DXA) Body Composition for Identification of Low Muscle Mass in Older Adults

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ABSTRACT

Background

Sarcopenia is associated with increased morbidity and mortality. Clinically, sarcopenia can be overlooked, especially in obesity. Sarcopenia diagnostic criteria include muscle mass (MM) and function assessments. Muscle function can be readily assessed in a clinic setting (grip strength, chair stand test). However, MM requires dual-energy X-ray absorptiometry (DXA) Body Composition (BC) or other costly tools, not readily available.

Methods

Observational cohort pilot study of independently mobile, community dwelling older adults, comparing MM using two office-based, direct-to-consumer bioimpedance (BIA) scales (Ozeri® [manufactured in China] and OMRON® [OMRON HBF-510® Full Body Sensor, Shiokoji Horikawa, Kyoto, Japan] to DXA. The OMRON differs from the Ozeri scale because the OMRON also includes hand sensors. The European Working Group on Sarcopenia in Older People (EWGSOP) DXA or BIA low MM diagnostic cut-offs were used to classify participants as having low or normal MM.

Results

Fifty participants: 11 men, 39 women. Forty-two completed DXA. Age 75.8 yrs [67–90]. 81% obese based on body fat cut-offs. With DXA [ASM/height^2], 15 had low MM. Using BIA [mmass/height^2], 7 with Ozeri, and 27 with OMRON, had low MM. Positive predictive value for low MM versus DXA (as the gold standard) for Ozeri was 73.3% and OMRON was 92.8%. Good correlation between BIA scales and DXA for body fat estimates.

Conclusions

OMRON captured all low MM participants identified by DXA plus all on DXA diagnostic borderline. Prevalence of obesity was high. Clinically, sarcopenic obese is the most difficult phenotype, as obesity masks low muscle mass. Low cost, readily available, direct-to-consumer BIA BC scales, especially with hand sensors, provide immediate, reliable information on muscle and fat mass. This can prompt appropriate investigation and/or intervention for sarcopenia or sarcopenic obesity.

Key words: seniors, bioimpedance assay, body composition, direct-to-consumer scale, EWGSOP diagnostic criteria

INTRODUCTION

Low muscle mass is known to be associated with a significant increase in morbidity (such as reduced activities of daily living (ADL) function)[(1)] and increased mortality.[(2)] Low muscle mass, in combination with decreased performance in physical tasks (gait speed, grip strength, chair stands), has a greater impact on morbidity and mortality.[(3)] This condition is defined as sarcopenia, and consensus groups have developed cut-offs that can be used to categorize people as: pre/probable sarcopenia (low muscle strength alone); sarcopenia (low muscle strength + low muscle quantity or quality); or severe sarcopenia (low muscle strength, quantity/quality and low physical performance).[(4)] This categorisation has important implications for prognosis. An added complication is the increasing prevalence of obesity. Sarcopenic obesity has a cumulative effect on complications.[(5)]

Sarcopenia can be screened for in a population using the SARC-F tool,[(6)] which is highly sensitive, but poorly specific,

at identifying people with sarcopenia who have poor outcomes.[6-8] It is based on self reporting (Strength, Assistance walking, Rising from a chair, Climbing stairs and Falls), so can be used by all health-care professionals, and can also be completed by the person themself.

Standardized definitions of sarcopenia, based on dual energy X-ray absorptiometry (DXA), computerised tomography (CT), magnetic resonance imaging (MRI) body composition (BC) evaluation of muscle mass, or bioimpedance assay (BIA) evaluations, are needed to ensure both a sensitive and specific diagnosis of sarcopenia.[9] In many circumstances none of these diagnostic tools are accessible—either because of availability, or cost. This significantly limits the ability of clinicians to make an objective assessment of muscle mass as part of their routine clinical evaluation. In somebody with low body weight, decreased muscle mass is usually visually apparent, raising the clinical suspicion for sarcopenia. However, in obese people, low muscle mass can easily be missed, as these people appear outwardly robust.

Like many other chronic diseases, sarcopenia is initially asymptomatic.[10] Therefore, early diagnosis and subsequent intervention are essential. This requires awareness amongst health-care professionals of the condition. In a recent study describing the current knowledge and practice regarding sarcopenia in a group of health-care professionals in Australia and New Zealand, only 14.7% identified sarcopenia as a disease.[11] At baseline, 12% reported making sarcopenia diagnosis part of their practice, and even after an educational program, this number only increased to 14.3%.[11] Barriers to diagnosing and treating sarcopenia in this cohort of Australian and New Zealand health-care professionals were also reported. Lack of diagnostic tools was reported to be the main reason for not diagnosing sarcopenia. Others included it not being seen as their role to diagnose sarcopenia, and inappropriate definitions being applied (e.g., European Society for Parenteral and Enteral Nutrition malnutrition definition, or frailty scales).[11] These findings are in line with a previous study which reported that the availability of diagnostic tools was the most often-reported barrier to implementation of diagnostic criteria among Dutch health-care professionals.[12]

In a recent sarcopenia review, the author concludes, "There is a pressing need to provide better diagnosis, diagnostics, prevention, and individualized health care" in sarcopenia.[13]

This study's objective was, therefore, to look at two types of practical, affordable, readily available, direct-to-consumer BIA BC scales, and compare their diagnostic ability for both muscle and fat mass to the current gold-standard of DXA BC. There are no previous publications of studies using these particular BIA scales.

METHODS

Community-dwelling older adults participating in a 12-month observational cohort study in Edmonton, Alberta, Canada, were invited to participate in this pilot project. Inclusion criteria were: age ≥65 years; English speaking; independent mobility (with or without walking aids); and stable chronic medical conditions. Those with hip or knee arthroplasties were permitted. Exclusion criteria included: pacemaker or other implanted device; unstable medical conditions; stable chronic congestive heart failure; any other cause of peripheral oedema; and inability to stand for 5 minutes without a walking aid with arms elevated. Ethics approval was obtained through the University of Alberta Health Research Ethics Board (Pro00047132).

Study Protocol

Participants had evaluations of BC with the two BIA scales (Ozeri and OMRON) in their baseline study evaluation. Within the next two weeks they had a DXA BC evaluation. Anthropometric data was also evaluated and included height, waist, and hip measurements, and three-site skinfold thickness assessment.

Height measurement was done both at the study visit (using standard professional medical-grade equipment (see below), and at the time of the DXA BC, using a wall-attached stadiometer.

Skinfold thickness was measured using skinfold calipers in millimetres (mm) at three body sites: scapula, anterior pelvis, and triceps, as per instruction manual [Wallace C. Donoghue, Creative Health Products, Ann Arbor, MI, Thirty-Sixth printing August, 2012]. Percentage fat was calculated using age and sex-specific population charts based on total three-site mm measurements.

DXA BC evaluations were done in a standardized way by trained radiology technologists at a Medical Imaging Consultants site in Edmonton, Alberta, Canada.

Ozeri and OMRON BIA BC was done first thing in the morning, wearing light-weight indoor clothing. Participants were asked to have breakfast at least two hours prior to their study visit, with no extra fluids prior to the evaluation.

Equipment Details

BIA assessment: Bioelectrical impedance relies of the fact that muscle, blood vessels, and bones have a high water content that conducts electricity easily. Body fat is tissue that has little electrical conductivity. The scale sends an extremely weak, undetectable, electrical current of 50 kHz or less and 500 μA through the body to determine relative percentage of muscle, bone, and fat. BIA equipment does not measure muscle mass directly, but instead derives an estimate of muscle mass based on this whole-body electrical conductivity. BIA devices use a conversion equation that is calibrated with a reference of DXA, MRI or CT-measured lean mass in a specific population.[14,15] In the case of this study, the Ozeri and OMRON BIA scale equations are considered proprietary, and so are not available.

All measurements were done with the devices on a hard, flat, linoleum floor. Participants had bare feet. For both scales, participants were instructed to stand up straight, look straight ahead, with each foot on the sensors, weight evenly distributed, and with no bent knees. For the OMRON scale,

the arms were held out straight, raised horizontally to 90°, with the display facing upwards.

The Ozeri Touch Total Body Scale (China) combines advanced algorithms with BIA incorporating a person's age, height, sex, and weight, for its measurements. Height, age, and sex are entered into the scale. It has four high-precision GX sensors, with a maximum weight of 200 kg (440 lbs), and is safe for use in those with a pacemaker. It reports weight, percentage fat, percentage "muscle", percentage "bone", and hydration (percentage water). Approximate purchase cost is C$72–C$95. (See Appendix A1).

The OMRON HBF-510® Full Body Sensor Body Composition Monitor and Scale is manufactured for OMRON Healthcare Co. Ltd (Hoffman Estates, IL). Unlike other body composition monitors that rely on foot-to-foot measurements, OMRON measures the whole body (arm to foot), with eight sensors (four feet and four hand grip sensors). OMRON's algorithm focuses on the bioelectrical impedance method as well as height, weight, age, and sex. Height, age, and sex are entered into the scale. It reports weight, percentage body fat, body mass index (BMI), percentage "skeletal muscle", and percentage "visceral fat" (estimated as a relative value and not an absolute value). The OMRON Full Body Sensor Body Composition Monitor and Scale differs from the Ozeri in that it takes measurements from both hands and feet; so theoretically it reduces the impact of diurnal water movement on the body composition results. Maximum weight is 150 kg (330 lb) and height 1.68 m (6.5 ft), and use with a pacemaker or other implanted device is not recommended. Approximate purchase cost is C$132–C$152. (See Appendix A2).

DXA body composition: Hologic® Discovery DXA (Bedford, MA) was used and tests were performed by DXA-trained radiology technologists from Medical Imaging Consultants Diagnostic Imaging, Edmonton, AB, Canada. The dose of DXA ionising radiation is similar to normal background radiation received over one day at sea level.[16] Participants lay on the DXA table and were positioned according to standard protocol with their feet internally rotated and secured in a device. The whole body is scanned to measure whole-body bone mass and soft-tissue composition. Appendicular skeletal muscle mass (ASM) and percentage fat are the only DXA parameters reported in this study. ASM has been shown to accurately quantify skeletal muscle mass in vivo,[17] and has been validated against Magnetic Resonance Imaging.[18] Because muscle mass is correlated with body size, once ASM has been calculated it is then adjusted for the height of the individual and reported as ASM/height^2, which is the parameter used by EWGSOP to assess muscle mass. Appropriate corrections were made for the presence of a hip and/or knee arthroplasty when calculating total ASM. Purchase cost of DXA scan is approximately C$21,000–60,000, plus the cost of trained technologists to operate the machine.

Skinfold calipers: Creative Health Slim Guide 696251 Skinfold Caliper (Ann Arbor, MI). Height assessment: Seca® (Hamburg, Germany) wall-mounted stadiometer.

Study Cut-Offs

For DXA BC, low muscle mass was defined as ASM/height^2 $\leq$ 7.0 kg/m^2 in men and $\leq$ 5.5 kg/m^2 in women. The EWGSOP2 consensus group defined these cut-offs as valid cut-offs associated with clinical outcomes.[4] Using similar, but not identical cut-offs, Bischoff-Ferrari and colleagues compared nine different definitions of sarcopenia, varying by threshold values for appendicular lean mass index (ALMI = ASM/height^2) combined with different strength measures. She showed the sarcopenia definition cut-offs by Baumgartner *et al*.[1] of ALMI < 7.26 kg/m^2 (men) and 5.45 kg/m^2 (women) gave the best prevalence and probability of falls in a prospective study of community dwelling men and women.[19]

For BIA BC, Ozeri- and OMRON-derived muscle mass percentage was converted to kilograms (kg). The BIA-predicted skeletal muscle mass (SM) equation (SM/height^2) was then calculated. The cut-offs used were based on -2 standard deviations (SDs) below the mean of young adults, men: <8.87 kg/m^2; women <6.42 kg/m^2, as recommended by the EWGSOP and Asian Working Group, and validated in older European and Asian populations.[3,20-22]

Obesity was defined as a body fat composition of >25% in men, and >35% in women[4] for both DXA and BIA scales.

Statistical Analysis

Data analysis was completed using SAS 9.0 statistical software (SAS, Version 9.4; SAS 124 Institute Inc., Cary, NC). Data were expressed as mean ± SD for variables showing normal distributions and/or median (interquartile range) for non-parametric variables. The Shapiro-Wilk test was conducted to assess the normality of distribution. Bland-Altman was used to assess agreement between Ozeri-, OMRON-, and DXA-derived values for percentage fat mass. Pearson correlations were also performed, and the Phi coefficient of correction was applied for comparisons between muscle mass.[23] Sensitivity, specificity, positive predictive value (PPV), and negative predictive values (NPV) were determined to evaluate the performance of the surrogate muscle mass measures for correctly identifying sarcopenia in older adults, using DXA as the reference method.[24] A difference with a p value < .05 was considered significant.

RESULTS

Of the 50 participants enrolled in the study, 11 were male and 39 female. All were independent of basic activities of daily living at baseline, and most instrumental activities (some needed assistance with driving, finances). Table 1 shows the demographic data of the participants. Prior to DXA BC evaluation, eight dropped out (three males), six no longer being interested after visit one; one due to caregiver responsibilities; and one due to declining physical health. Forty-two participants completed the DXA body composition.

By EWGSOP diagnostic criteria (ASM/height^2) with DXA, 15 (5 males, 10 females) were classified as low muscle mass. Using BIA cut-offs[20] (muscle mass/height^2) with

TABLE 1.
Baseline demographic data by sex; data are mean ± SD and/or median (interquartile range), where [a] denotes statistical significance

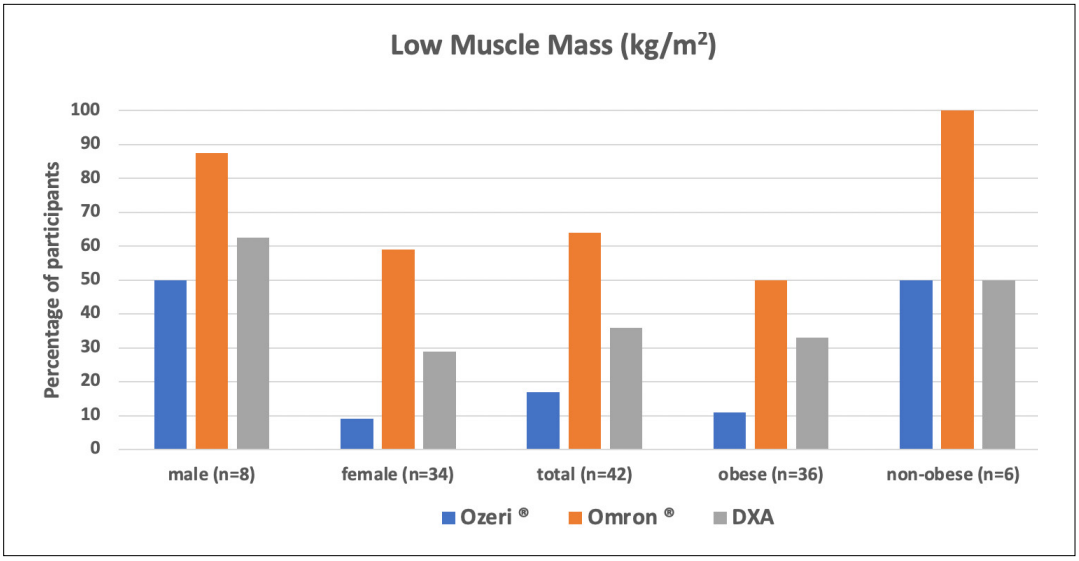
Variable Name	*Male (n = 11)*	*Female (n = 39)*	*P value*
Age (yrs)	78.9 ± 5.1	74.9 ± 4.6	.02[a]
Weight (kg)	76.1 ± 12.2	72.7 ± 12.6	.09
Height (m)	173 ± 7.0	159 ± 5.4	<.00[a]
BMI	28.9 ± 4.8	27.8 ± 5.4	.53
Waist to hip	1.00 ± 0.06	0.84 ± 0.08	.001[a]
% Fat (skinfold)	28.9 ± 5.8	41.3 ± 5.9	<.001[a]
% Fat (DXA)	30.8 ± 5.2	40.7 ± 6.8	.004[a]

[a]Denotes statistical significance.

Ozeri, seven participants (four males, three females), and with OMRON 27 (seven males and 20 females) had low muscle mass (see Figure 1). In those participants categorised as obese (n=36), the performance of the BIA scales versus DXA was similar, with the OMRON scale again measuring more participants with low muscle mass.

Sensitivity, specificity, positive (PPV), and negative predictive values (NPV) for the diagnosis of low muscle mass with the BIA scales versus DXA BC are shown in Table 2. The sensitivity, specificity, and accuracy of both the Ozeri and OMRON scales improved in those with concomitant obesity. The number of participants without obesity was too small (n=6) for analysis.

The Phi coefficient of correlation between DXA and BIA scales for low muscle mass is shown in Tables 3A and 3B. The Phi value comparing Ozeri and OMRON was 0.343, $p = .026$. Phi values >0.310 for this number of participants



Ozeri® = Ozeri bioimpedance assay scale; Omron® = OMRON bioimpedance assay scale; DXA = dual-energy X-ray absorptiometry; n = number; kg/m^2 = weight/height^2.

FIGURE 1. Comparisons between DXA and BIA BC scales (Ozeri and OMRON) for identification of low muscle mass

TABLE 2.
Percentage of diagnostic specificity, sensitivity, and predicative value of BIA scales Ozeri and OMRON vs. DXA body composition for low muscle mass in all participants, and in those with concomitant obesity

	Specificity (%)	*Sensitivity (%)*	*Positive predictive value (%)*	*Negative predictive value (%)*	*Accuracy (%)*
All Participants (n=42)					
Ozeri	92.6	40	75.2	73.3	73.8
OMRON	48.2	93.3	50.3	92.8	64.3
Obese Participants (n=36)					
Ozeri	100	60	100	83.5	81.9
OMRON	79.8	100	70.9	100	85.5

are considered significant associations, with those >0.407 very significant.[23]

Obesity, based on DXA body fat cut-offs, was present in 86% of the participants. The comparison between three-site skinfold measurement for Ozeri, OMRON, and DXA for percentage body fat diagnostic cut-offs for obesity is shown in Figure 2. There was good agreement between DXA BC and BIA scales for percentage fat cut-offs, but the agreement was better for the OMRON scale. Bland-Altman calculated mean percentage difference between DXA percentage fat and Ozeri was 14.6 ± 8.3% and OMRON was 2.4% ± 8.2%, respectively. (See Figure 3 for Bland-Altman graph.)

DISCUSSION

This pilot study shows the utility of simple, affordable, office-based BIA tools in the identification of low muscle mass in older adults, even in those with concomitant obesity. The Ozeri had high specificity but poor sensitivity (92.6% and 40%, respectively), and the OMRON had lower specificity but higher sensitivity (48.2% and 93.3%, respectively), for detecting low muscle mass. In a clinical setting the latter ensures fewer missed cases. The study also shows the high agreement of OMRON with DXA for diagnosing obesity based on percentage fat mass. Interestingly, in those participants with concomitant obesity, the sensitivity and specificity of the identification of low muscle mass was increased for both scales, with the OMRON scale again performing better then the Ozeri scale. This suggests that for BIA, the extra hand sensors may help to improve diagnostic accuracy.

Comparing DXA derived muscle mass and BIA derived muscle mass is felt to be valid,[25] and has been done in other older adult populations. BIA has been found to be a valid surrogate when DXA, MRI or CT are not practical.[14] Although the latter are more accurate methods of assessing low muscle mass, they need specially trained users, are expensive, require a large amount of time to perform the test (MRI), and potentially have adverse events such as radiation exposure (CT and DXA). Hence, the interest in BIA as a more practical and portable alternative.

This data adds to, and agrees with, the published data in other community population cohorts where BIA tools have been used. For example, Cheng and colleagues assessed participants in Hong Kong using BIA (InBody 720® direct-to-consumer

TABLE 3A.
The correlation between diagnostic cut-offs for low muscle mass between DXA body composition and Ozeri and OMRON BIA scales

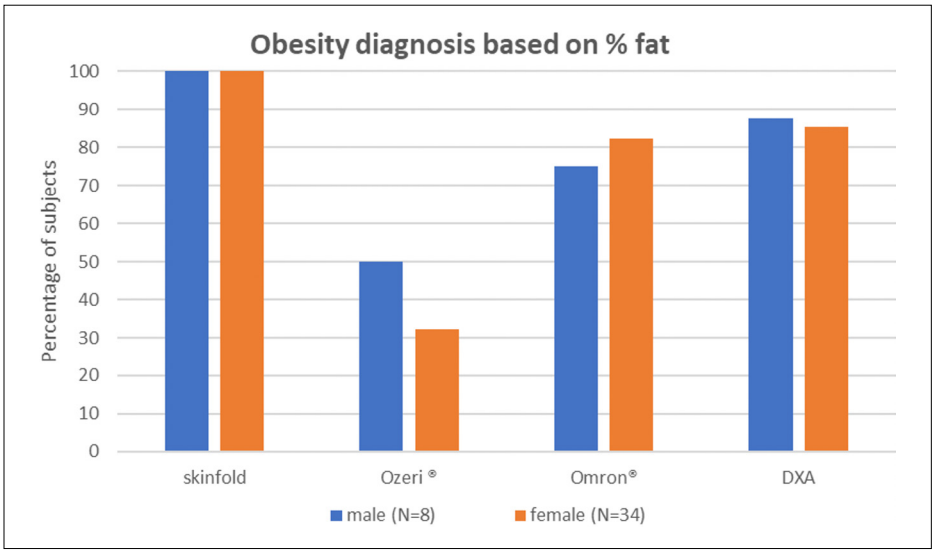
	Phi Coefficient of Correlation	*P value*
Ozeri low muscle mass	0.398	.01[a]
OMRON low muscle mass	0.422	.006[a]

[a]Denotes statistical significance.

TABLE 3B.
The correlation between diagnostic cut-offs for low muscle mass between Ozeri and OMRON BIA scales

	Phi Coefficient of Correlation	*P value*
Ozeri vs. OMRON	0.343	.026[a]

[a]Denotes statistical significance.



skinfold = calculated percentage fat from three-site skinfold test; Ozeri® = Ozeri bioimpedance assay scale; Omron® = OMRON bioimpedance assay scale; DXA = dual-energy X-ray absorptiometry; N = number; % = percentage.

FIGURE 2. Comparison between three-site skinfold measurement, BIA scales (Ozeri and OMRON), and DXA for the diagnosis of obesity

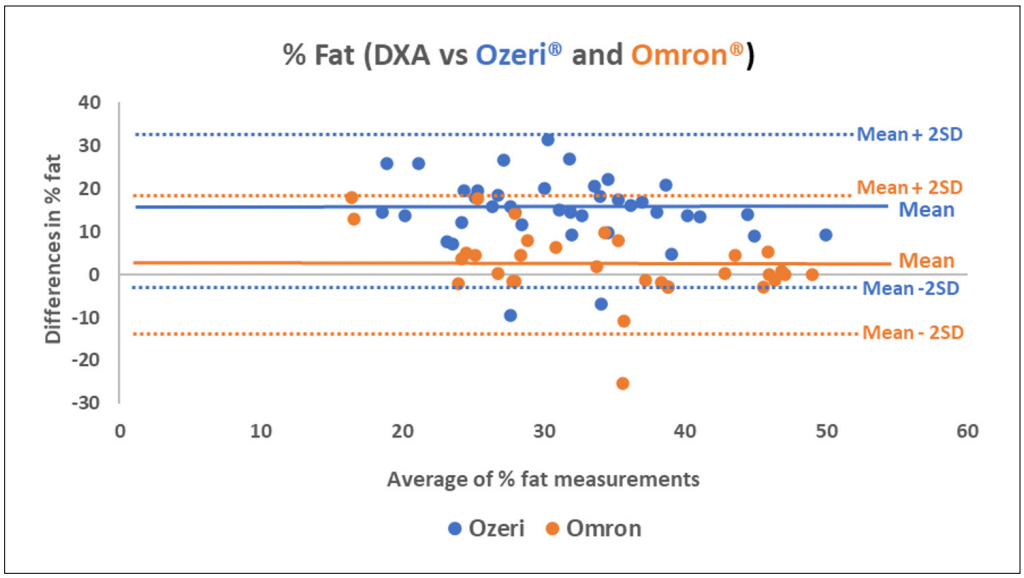


FIGURE 3. Bland-Altman calculation comparing DXA body fat composition and Ozeri/OMRON BIA scales

scale, similar eight-sensor design to OMRON) versus DXA to diagnose low muscle mass and sarcopenia.[26] They found this BIA tool also overestimated the prevalence of low muscle mass compared to DXA in their population. Yu and colleagues evaluated an Australian community dwelling population (aged 18–83 years) using a supine four-sensor BIA tool (Quantum II Body Composition Analyzer®)[27] Compared to DXA, the BIA tool's performance for detecting low muscle mass was variable depending on the body composition equation/algorithm used. The issues with different BIA devices are that the various BIA prediction models for fat-free mass differ according to the characteristics of the sample in which they have been derived and validated. BIA tools can both under- and over-estimate the presence of low muscle mass, and their accuracy is found to be population-dependent. Ideally a BIA device needs to be validated in the specific age, sex, and ethnicity being investigated.[25] Nonetheless, low lean muscle mass, whether measured by DXA, BIA or CT, is significantly associated with all-cause mortality.[28]

The definition of sarcopenia with cut-offs for low muscle mass is now well delineated by several consensus groups,[3,4,29] yet clinical assessment remains limited, particularly in community settings.[30] Clinicians cite access to diagnostic tools for assessing muscle mass is a major obstacle.[11,12] This results in a care-gap[13] that is particularly concerning given the rising age demographic in many countries, and the clear risk of aging for low muscle mass and sarcopenia. The potential costs (financial and emotional) of this under-diagnosis and associated increased morbidity and mortality[28] is concerning, albeit hard to quantify.[31]

The availability of an objective, in-office tool, which can be utilised by all health-care professionals is likely to enhance the consideration for, and identification of, low muscle mass. Those most likely to be "missed" clinically as having low muscle mass are people with concomitant obesity. Research in every disease has shown that, once a test is shown to be abnormal, it is more likely to prompt further appropriate investigations and management.[32] Early recognition and intervention are key to improving outcomes, so should be a "routine part of health-care visits" in older adults.[33,34] Until this early recognition and awareness happens, it seems unlikely that educational interventions alone will have much impact.[11]

Limitations

All participants were Caucasians, living in one city. This may affect the applicability of the results to other populations. The Taiwanese sex-specific low muscle mass cut-offs were used, as these are the ones recommended by the EWGSOP2 consensus group and have been used by other research groups in non-Asian populations.[35] The study group was predominantly female. Because of the small number of males, there was insufficient power to detect sex differences for the sensitivity and specificity of the BIA scales. In addition, the BIA algorithms used by the Ozeri and OMRON BIA scales to calculate the different components of body composition are unknown, as these are considered proprietary and are, therefore, not disclosed.

Strengths

To our knowledge, there are no other studies in the literature using these particular direct-to-consumer BIA BC tools. As in other studies, this study shows the variability of BIA tools. However, using the manufacturers pre-set algorithms, the OMRON scale (utilising additional hand sensors) was a low-cost, readily available, easy-to-use means to identify all participants found to have low muscle mass by DXA, as well as those with borderline low muscle mass. In addition, there was good correlation with DXA for percentage fat mass, allowing accurate diagnosis of obesity, thereby addressing

the limitations of BMI alone for obesity diagnosis. This pilot study also suggests that the BIA scales may perform even better in older adults with concomitant obesity in identifying low muscle mass.

CONCLUSIONS

The challenge of assessing muscle mass remains, given the recommended standard of DXA, MRI or CT body composition. However, BIA is a viable non-invasive, portable, easy-to-use, relatively low cost, radiation-free alternative. Given that assessment with a portable BIA scale can easily be done as part of a routine visit, it is also more convenient for the patient. It can provide rapid, useful clinical information on both muscle and fat mass, and raise the suspicion of sarcopenia, particularly in patients with concomitant obesity. In this pilot population, the OMRON device was clinically more useful as it would miss fewer cases of low muscle mass, even in those with concomitant obesity. Use of these BIA scales may be particularly helpful in smaller or rural settings where CT, DXA or MRI is not easily available. Raising the suspicion of possible low muscle mass will hopefully prompt further assessment and management of sarcopenia.

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CONFLICT OF INTEREST DISCLOSURES

We have read and understood the *Canadian Geriatrics Journal*'s policy on disclosing conflicts of interest and declare that we have none. In particular, the choice of BIA BC scales (Ozeri and OMRON) was done independently by the PI. The manufacturers were not aware of the study.

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APPENDIX A1. Ozeri Touch Total body scale

APPENDIX A2. OMRON HBF-510 Full Body Sensor Body Composition Monitor and Scale