Association of older women’s limb circumferences and muscle mass as estimated with bioelectrical impedance

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INTRODUCTION

Muscle is essential to daily functioning and health. The status of muscle can be characterized by using measures of its strength and mass\(^1\). Of various methods for measuring muscle mass, the European Working Group on Sarcopenia in Older People (EWGSOP) has recommended dual-energy x-ray absorptiometry (DXA), bioimpedance analysis (BIA), and anthropometry for clinical use\(^1\). The use of DXA is limited by its cost and lack of portability. Both BIA and anthropometry, on the other hand, can be used with older adults in almost any setting. BIA has been validated against DXA; however, it requires that a small electric current be passed through the body, and is affected by hydration status and the presence of metal implants\(^2\). The chief anthropometric measures used for identifying loss of muscle mass are mid-arm circumference and maximum calf circumference. These circumferences are not specific to muscle; however, they do incorporate muscle and are predictive of mortality\(^3,4\). Calf circumference has been shown to correlate strongly with appendicular muscle mass and fat-free mass\(^4,5\), and has been used in lieu of BIA when BIA testing was contraindicated or not possible\(^6\). Calf circumference is also correlated with frailty and physical performance\(^1,8\). Changes in calf circumferences have been noted among patients undergoing surgery for gastrointestinal cancer\(^9\). These findings regarding circumferential measures notwithstanding, the EWGSOP concluded that “there are relatively few studies validating anthropometric measures in older and obese people\(^1\). The purpose of this study was to describe the relationship between three practical measures used to characterize muscle mass: mid-arm circumference, maximum calf circumference, and muscle mass index determined using bioimpedance analysis. [Subjects and Methods] Thirty-eight ambulatory women residing in a senior center (mean age, 83 years) participated in this cross-sectional study. Their mid-arm circumference and maximum calf circumference were measured bilaterally and they all underwent bioimpedance analysis. Relationships were examined by using Pearson (r) correlations, Cronbach’s alpha, and factor analysis. [Results] Circumferential measures correlated significantly with one another (r = 0.745–0.968) and with the muscle mass index determined with bioimpedance analysis (r = 0.480–0.628). The Cronbach’s alpha for the measures was 0.905. Factor analysis confirmed that all of the measures were reflective of a common construct. [Conclusion] On the basis of their correlations with one another and the muscle mass index determined with bioimpedance analysis, circumferential measures of the mid-arm or calf may be considered crude indicators of reduced muscle mass. Key words: Anthropometrics, Body composition, Muscle

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of this study, therefore, was to determine how well circumferential measures of the limbs reflect muscle mass. Specifically, we sought to describe the relationship in older women, between mid-arm circumference, maximum calf circumference, and muscle mass as determined by using BIA.

SUBJECTS AND METHODS

This was an observational, cross-sectional study conducted during a 2-day period in May 2013. It was approved by the ethics committee of the Faculty of Physical Education and Sport of Charles University in Prague, Czech Republic. The participants were a convenience sample of 38 ambulatory female residents of the Senior Centre in Blansko, Czech Republic. Their inclusion was dependent on their being ambulatory and providing written informed consent. They ranged in age from 72 to 98 years (mean 83 years, SD 6.2 years).

For the purposes of this study, five measurements were obtained. Body mass was measured by using a calibrated digital scale. Height was measured with a digital stadiometer. Body mass index (BMI) was derived by using these measures. Circumferential limb measurements were obtained bilaterally with a cloth tape. Care was taken to maintain full contact between the tape and the limb without compressing the underlying soft tissue. Mid-arm circumference was measured midway between the acromion and elbow crease while each participant was seated with her relaxed arm supported in a horizontal position. The location of the maximum calf circumference was ascertained and measured while each participant was in a supine position, with her relaxed leg slightly elevated from the surface on which she was lying. The BIA (BIA 2000-M; Data Input, Hofheim, Germany) was conducted by using a tetrapolar electrode configuration (i.e., one on the dorsum of each hand and dorsum of each foot) while the participants were supine. On the basis of the electrical resistance measured and on the participants’ height, female sex, and age, the skeletal muscle mass index was calculated by using the equation of Janssen et al10.

All statistical analyses were conducted with the Statistical Package for the Social Sciences (SPSS 20.0), Systat, or MedCalc. After calculating basic descriptive statistics, the relationship between the circumferential measures and BIA-determined muscle mass index was examined by using Pearson correlations, Cronbach’s alpha, and factor analysis.

RESULTS

Table 1 provides summary statistics for the relevant variables from 38 participants in the study. Table 2 shows the correlation between the circumferential measures and muscle mass determined by using BIA. All circumferential measures were highly correlated with one another \( r = 0.745–0.968 \). The highest correlations were between homonymous measurements (i.e., left and right mid-arm \( r = 0.955 \) or left and right calf \( r = 0.968 \)). All circumferential measures correlated significantly

| Variable                  | Mean (SD) | Range     |
|---------------------------|-----------|-----------|
| Height (cm)               | 155.5 (7.1) | 141.0–169.0 |
| Body mass (kg)            | 71.1 (12.1) | 51.3–101.5  |
| Body mass index (kg/m²)   | 29.5 (5.3)  | 19.9–48.3  |
| Mid-arm circumference: left (cm) | 29.4 (3.7) | 21.5–39.0  |
| Mid-arm circumference: right (cm) | 29.8 (3.3) | 23.0–39.0  |
| Calf circumference: left (cm) | 36.4 (4.6) | 26.5–43.0  |
| Calf circumference: right (cm) | 36.5 (4.7) | 26.5–44.2  |
| Muscle mass index (kg/m²) | 6.4 (0.9)  | 4.6–8.9    |

Table 2. Pearson correlations (95% confidence interval) between muscle mass variables*

| Variable                  | Left arm | Right arm | Left calf | Right calf |
|---------------------------|----------|-----------|-----------|------------|
| Right arm                 | 0.955    |           |           |            |
|                          | (0.914–0.976) |            |            |            |
| Left calf                 | 0.757    | 0.764     |           |            |
|                          | (0.576–0.867) | (0.589–0.871) |            |            |
| Right calf                | 0.745    | 0.749     | 0.968     |            |
|                          | (0.559–0.860) | (0.564–0.862) | (0.939–0.984) |            |
| Muscle mass index (kg/m²) | 0.480    | 0.546     | 0.628     | 0.580      |
|                          | (0.189–0.693) | (0.274–0.737) | (0.386–0.789) | (0.319–0.759) |

*All are significant at \( p \leq 0.002 \)
but modestly with muscle mass index ($r = 0.480–0.628$). The Cronbach’s alpha for all of the circumferential and the muscle mass measure was 0.905. Factor analysis showed the measures to reflect a single factor. The principal eigenvalue was 3.900. It explained 78.0% of the variance in the components that had loadings ranging from 0.710 (muscle mass) to 0.940 (left calf circumference). All circumferential measures had component loadings of at least 0.900.

**DISCUSSION**

Given the prevalence and consequences of muscle loss among older adults, clinicians need simple, portable, and inexpensive options for quantifying loss of muscle. Circumferential measurements of the arm and calf are two such measures. Their adequacy, however, is dependent on their ability to accurately reflect muscle mass. Therefore, the degree to which circumferential measures were related to one another and to the muscle mass index derived by using BIA was investigated in this study. The circumferential measures were certainly related to one another—supporting their convergent validity and possibly obviating the need to measure both mid-arm and calf circumference bilaterally. The circumferential measures were also related to the muscle mass index, the correlation of calf circumference with muscle mass index in this study ($r = 0.628$ and 0.580) being relatively comparable to the correlation reported between calf circumference and skeletal muscle index determined by using DXA by Kawakami et al. ($r = 0.69$) and Rolland et al. ($r = 0.63$). On the basis of the magnitude of the correlations and their confidence intervals in this study, no specific circumferential measure could be considered superior to another for indicating muscle mass as indicated by BIA. Notably, circumferential measurements explained far less than half of the variance in the muscle mass index. Perhaps the correlation between limb circumference and muscle mass index would be higher if the circumferential measures were adjusted for edema and subcutaneous fat. Wijnhoven et al. proposed that upper-limb circumference may be a better measure than calf circumference because of fluid retention in the lower limbs. The use of skin-fold measures to adjust for subcutaneous fat of the arm has been described by Moratani and DeVries and others.

When used as indicators of muscle loss or malnutrition, small limb circumferences are telling. Calf circumferences <31 cm or <33 cm have been proposed to be indicative of sarcopenia. Small limb circumferences may be due, in part, to a loss of bone diameter or a reduction in subcutaneous and intramuscular fat, but are unlikely to exist unless muscle mass is also diminished. In cases in which limb circumferences are small, support for low muscle mass as a cause might be found in the concurrent presence of visible atrophy elsewhere (e.g., intrinsics of the shoulder and hand), a low BMI, and decreased voluntary or evoked muscle force production. Future research could focus on the relationship of limb circumference measures with these conditions and in other populations.

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