

Estimating the Prevalence of Muscle Wasting, Weakness and Sarcopenia in Haemodialysis Patients

Authors

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Authors' contributions

JR is the principle investigator of this study. All authors have assisted in the design of the study. CM and JR completed data collection. AS completed data analysis. AS, JR and CM completed the initial draft of this manuscript. All authors read and approved the final manuscript.

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Ethics

This study received ethical approval and consent from the Office of Research Ethics Committees Northern Ireland (ORECNI) (REC: 16/NI/0233).

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Abstract

Haemodialysis (HD) patients suffer from nutritional problems, which include muscle wasting, weakness, and cachexia, and are associated with poor clinical outcomes. The European Working Group for Sarcopenia in Older People (EWGSOP) and Foundations for the National Institute of Health (FNIH) have developed criteria for the assessment of sarcopenia, including the use of non-invasive techniques such as Bioelectrical Impedance Analysis (BIA), anthropometry, and Hand Grip Strength (HGS) dynamometry. This study investigated the prevalence of muscle wasting, weakness, and sarcopenia using the EWGSOP and FNIH criteria.

BIA was performed in 24 females (f) and 63 males (m) in the post-dialysis period. Total skeletal muscle mass (TSMM) and appendicular skeletal muscle mass (ASMM) were estimated and index values (i.e., muscle mass divided by height² [kg/m²]) were calculated (Total Skeletal Muscle Index (TSMI) and Appendicular Skeletal Muscle Index (ASMI)). Mid-arm circumference and triceps skin-fold thickness were measured and mid-upper arm muscle circumference (MUAMC) calculated. HGS was measured using a standard protocol and Jamar dynamometer. Suggested cut-points for low muscle mass and HGS were utilized from EWGSOP and FNIH criteria, with prevalence estimated, including sarcopenia.

The prevalence varied depending on methodology: low TSMI (moderate and severe sarcopenia combined) was 55% for whole group: 21% (f) and 68% (m). Low ASMI was 32% for whole group: 25% (f) and 35% (m). Low MUAMC was 25% for whole group: 0% (f) and 30% (m). ASMI highly correlated with body mass index (BMI) ($r = 0.78$, $P < .001$) and MUAMC ($r = 0.68$, $P < .001$). Muscle weakness was high regardless of cut-points used (50-71% (f); 60-79% (m)).

Internationally, this is the first study comparing measures of muscle mass (TSMM and ASMM) by BIA and MUAMC) and muscle strength (HGS) using this specific methodology in a haemodialysis population. Future work is required to confirm findings.

Introduction

Suffering from a range of comorbidities and nutritional problems is a universal challenge for haemodialysis (HD) patients across the globe. Such problems include a higher prevalence of malnutrition, protein-energy wasting, cachexia, fatigue, muscle wasting, muscle weakness, sarcopenia, and frailty.¹⁻⁶ This is due to multiple factors including restrictive dietary patterns, low physical activity, the impact of disease itself (e.g., hormonal abnormalities, acidosis, inflammation, and proinflammatory cytokines), the HD process, and other interacting factors such as aging and prescribed medications.^{2,7}

The term “sarcopenia” was originally defined as the age-related loss of muscle mass.⁸⁻¹⁰ However, more recently it has been redefined to specifically incorporate the decline in muscle function (e.g., walking speed) and strength (e.g., grip strength), alongside muscle loss and found to be associated with poor clinical outcomes.⁸⁻¹¹ Sarcopenia can also be classified as primary (age related) or secondary (related to inactivity, chronic disease, or malnutrition).⁸ Different definitions exist, such as those developed by the European Working Group for Sarcopenia in Older People (EWGSOP) and the Foundation for the National Institutes of Health sarcopenia project (FNIH), with different suggested assessment methodologies.^{8,12} Whether the application of these criteria for sarcopenia can be applied to the HD population is not clear at present. It is known that prevalence of sarcopenia increases with worsening or progression of kidney disease (although dependent on methodology used) and increases the risk of death.

Interestingly however, Isoyama et al. found that muscle strength, but not muscle mass, was a significant predictor of mortality in HD patients, as did Kittiskulnam et al.^{16,17} Indeed, this deviation between the associations of muscle mass with muscle strength and physical functionality and clinical outcomes (e.g., disability and death) is something of interest and debate in the international scientific community.^{5,10,18} Manini and Clark¹⁸ defined the term “dynapenia” as “the age-related loss of muscle strength and power with aging,” hence differentiating the loss of muscle mass with strength (p. 28). Both sarcopenia and dynapenia are major components of the physical frailty phenotype, and this in turn may increase the risk of hospitalization and death.^{5,6}

With regard to assessment techniques, a number of methods exist for the measurement of skeletal muscle mass (SMM). These include gold standard techniques such as magnetic resonance imaging (MRI) and computed tomography and reference standard techniques such as dual energy X-ray absorptiometry (DEXA).^{5,19,20} However, MRI and DEXA are not readily accessible and both are expensive.⁸ Bioelectrical Impedance Analysis (BIA) has been discussed extensively in the literature for the assessment of fat-free mass and SMM, although it is well known that errors can be associated with this technique due to issues such as fluctuations in body fluid hydration status, and the specificity of BIA prediction equations.^{5,19,21} In the HD population, this is especially relevant and hence it has been suggested that BIA should be performed in the post-dialysis period to minimize the impact of fluid abnormalities on BIA readings.⁵ Furthermore, being able to apply the appropriate disease-specific prediction equations using BIA could provide an extremely useful alternative to MRI or DEXA.

Janssen et al.²² developed a BIA equation for total skeletal muscle mass (TSMM) using MRI (gold standard technique comparator) in a group of Caucasian participants aged 18-86 years. This equation for TSMM was then used on a large United States NHANES (National Health and Nutrition Examination Survey) data set (n = 4,449, aged ≥60 years) to investigate specific TSM index (TSMI normalized for height, kg/m²) cut-points and disability risk.²³ More recently, appendicular skeletal muscle mass (ASMM) has been suggested to be more closely related to muscle function and mobility than TSMM.⁵ Sergi et al.²⁴ recently developed a BIA equation for ASMM using DEXA in a Caucasian older (60+ years) population group. Yu et al.²⁵ recently compared this equation to 4 others for ASMM in a group of healthy Australian Caucasian participants (n = 195, age range = 18-83 years, mostly from European decent).

Another common methodology for body composition assessment is anthropometry, e.g., measurement of the mid-upper arm muscle circumference (MUAMC), which can be used to estimate relative SMM. MUAMC measures have been shown to correlate with DEXA measurements of lean body mass.²⁶ In addition, Stosovic et al.²⁷ also showed that MUAMC (alongside other parameters) was a significant predictor of mortality (P < .01) in HD patients. Hand grip strength (HGS), as a measurement of muscle strength, is a key component for the assessment of sarcopenia, dynapenia, and physical frailty.^{8,9,12,18} HGS has shown to be a marker of nutritional status and clinical outcomes in end-stage renal disease (ESRD) patients, as recently outlined in a narrative review article.²⁸

There is currently a debate on how to best measure sarcopenia using different methods, techniques, and cut-points, especially in patients with ESRD. Therefore, the aim of this study is to investigate the prevalence of muscle wasting and weakness in an HD population using 3 different estimates of muscle mass by BIA (TSMI-Janssen and ASMI-Sergi [ASMI: Appendicular Skeletal Muscle Index]), MUAMC, and different cut-points for HGS (EWGSOP and FNIH). Furthermore, the prevalence of sarcopenia (defined as a combination of muscle wasting and weakness) was estimated.

Methods

Study Population

This study is part of a larger program of work, the protocol for which is published elsewhere.⁴ Participants were adult HD patients (n = 87) who attended one of the 2 HD units within the United Kingdom. All patients were Northern Europeans. Patients were eligible for inclusion if they had a confirmed diagnosis of Stage 5 ESRD (estimated glomerular estimation rate <15 mL/min/1.73 m²) were receiving HD; were able to read and write English; and were over 18 years of age. Patients were excluded from this analysis if they had any electrical implanted device. All patients were receiving a minimum of HD 3 times per week.

Data Collection

Clinical characteristics, and measures of muscle strength and muscle mass were taken by a single trained research assistant across the 2 HD units.

Clinical Characteristics

Age, sex, height, post-dialysis weight, dialysis vintage, and number comorbidities (using the Charlson Comorbidities Index Score) ²⁹ were recorded.

Muscle Strength

HGS was measured using a standard protocol and Jamar hand grip dynamometer (Jamar dynamometer; Patterson, Nottingham, UK). The EWGSOP cut-points <30 kg for males and <20 kg for females were applied. ⁸ Body mass index (BMI) was also categorized following Fried, Tangen, Walston et al. guidelines as suggested within the EWGSOP (Table 1). ⁸

Table 1. Fried-BMI Hand grip strength cut-point stratified for gender and adjusted for BMI in sarcopenia diagnosis.

Men <30 Kg	≤ 24 kg/m ² – ≤ 29 kg
	24.1-26 kg/m ² - ≤ 30 kg
	26.1-28 kg/m ² - ≤ 30 kg
	> 28 kg/m ² - ≤ 32 kg
Female <20 Kg	≤ 23 kg/m ² – ≤ 17 kg
	23.1-26 kg/m ² - ≤ 17.3 kg
	26.1-29 kg/m ² - ≤ 18 kg
	> 29 kg/m ² - ≤ 21 kg

Finally, the FNIH sarcopenia project cut-points were also applied to the data set: < 26 kg for males and <16 kg for females. ¹² BMI was calculated as weight divided by height squared (kg/m²). Normal weight was defined as BMI of 20-24.9 kg/m², overweight as BMI of 25-29.9 kg/m², and obesity as BMI of 30 kg/m² or more. ¹²

Muscle Mass

Two methods were utilized for the estimation of SMM: first, using BIA estimation of muscle mass (TSMI and ASMI) and second, MUAMC calculation.

Bioelectrical Impedance Analysis (BIA)

BIA was performed using a calibrated dual frequency (5 and 50 kHz) Bodystat 1500 MDD device (Bodystat, Isle of Man, British Isles) by a single trained research assistant. A standard protocol was followed with all assessments taken in the post-dialysis period with an aim to control for fluid abnormalities. Measurements were taken in the supine position, with electrodes attached on the hand and foot, as suggested by the manufacturer, and at constant room temperature. Resistance (R in ohms) and reactance (Xc in ohms) measurements at 50

kHz were recorded. Patients with any implantable electronic devices (such as pacemakers) were excluded as per the manufacturer's guidelines.

Total Skeletal Muscle Index (TSMI)

The most appropriate measurement of TSMM by BIA is Janssen et al. equation,²³ as it was developed in a Caucasian population:

$$\text{SM mass (kg)} = [(\text{Ht}^2/\text{R} \times 0.401) + (\text{gender} \times 3.825) + (\text{age} \times -0.071)] + 5.102,$$

where Ht is height in centimetres; R is BIA resistance in ohms; for gender, men = 1 and women = 0; and age is in years.

TSMM measurements were then corrected for height² and a TSMM index calculated (TSMI) in kg/m². Suitable cut-points for low muscle mass were considered using the EWGSOP paper,⁸ i.e., data specifically from the study by Janssen et al.²³ Therefore, cut-points were normal muscle (≥ 6.76 kg/m² for females and ≥ 10.76 kg/m² for males), moderate sarcopenia (5.76-6.75 kg/m² for females and 8.51-10.75 kg/m² for males), and severe sarcopenia (≤ 5.75 kg/m² for females and ≤ 8.50 kg/m² for males).

Appendicular Skeletal Muscle Index (ASMI)

ASMM was estimated using the specific BIA equation developed by Sergi et al.²⁴:

$$\text{ASMM (kg)} = -3.964 + (0.227 \times \text{RI}) + (0.095 \times \text{weight}) + (1.384 \times \text{gender}) + (0.064 \times \text{Xc}),$$

where RI is the resistance index (Ht² in cm/R in ohms); for gender, men = 1 and women = 0; Xc is reactance in ohms.²⁴ With regards to specific cut-points indicating a low muscle mass, suggested EWGSOP cut-points for ASMI (kg/m²) were utilized (<7.26 kg/m² for men and <5.45 kg/m² for women).³⁰

Mid-Upper Arm Muscle Circumference (MUAMC)

Mid-arm circumference (MAC) and triceps skinfold (TSF) thickness (TSF in triplicate and the average calculated) were measured using a tape measure and Harpenden skinfold caliper set, respectively. MUAMC (cm) was calculated using the formula:

$$\text{MAMC (cm)} = \text{MAC (cm)} - 0.314 \times \text{TSF (mm)}.$$

With regards to suitable cut-point values, a study by Stosovic et al. that used HD patients designated 5th percentile as a suitable cut-point for low MUAMC and used normal values from Bishop et al. (i.e., <23.8 cm for men and <18.4 cm for women).^{27,31}

Analysis

Descriptive statistics were presented as means \pm standard deviation and range for selected variables for the whole patient group as well male and female participants. The prevalence of

muscle wasting and weakness is presented as percentages and used to determine and compare between genders. Kolmogorov-Smirnov normality test was performed on data to assess normality. Correlations were performed using Pearson's correlation. Comparison between 2 groups for nominal variables were made by independent t-test. P value below .05 was considered as statistically significant. All data were analyzed using the computer-based statistical software package SPSS version 24 (IBM Corporation, SPSS, Inc., Chicago, IL).

Ethical Considerations

Governance approval for the study was obtained from the host institutions and Office for Research Ethics Committees Northern Ireland approval was gained prior to the study commencing (Research ethics committee reference: 16/NI/0233). Fundamental principles of good clinical practice including the provision of user-friendly information sheets, informed consent, voluntary participation, and confidentiality and data protection procedures were applied as a minimum standard within this study. Professional gatekeepers established primary contact with potential participants for study recruitment.

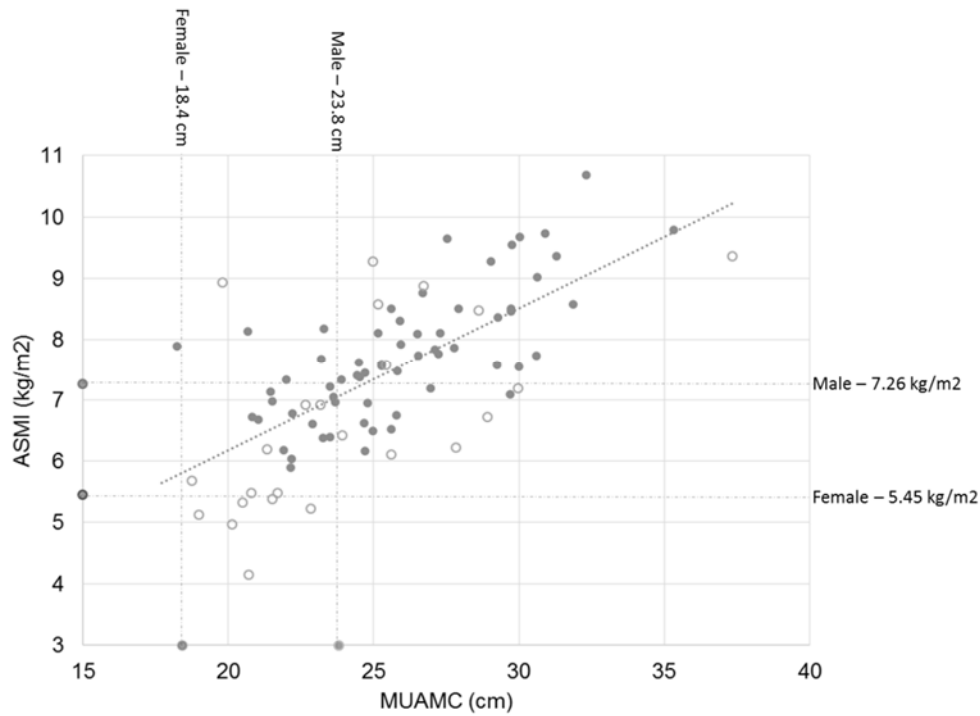
Results

Eighty-seven patients (23 female and 63 male) were studied. The main characteristics of the whole patient group were age (65.9 ± 13 years), dialysis vintage (5.14 ± 6.5 years), comorbidity score (6.06 ± 7.5), height (1.69 ± 0.10 m), and weight (81.4 ± 19.4 kg) (Table 2). The group also had a particularly high prevalence of overweight and obesity (BMI 28.4 ± 6.8 kg/m²), with no significant differences between males and females. In addition, dialysis vintage or comorbidities were not significantly different between males and females. T-test results showed a significant difference between females and males for age ($P < .01$), height, weight, RI, TSMI, ASMI, HGS ($P < .001$), and MUAMC ($P < .05$).

Table 2. Demographic and clinical characteristics of adult maintenance haemodialysis patients who participated in the study of the prevalence of muscle wasting and weakness

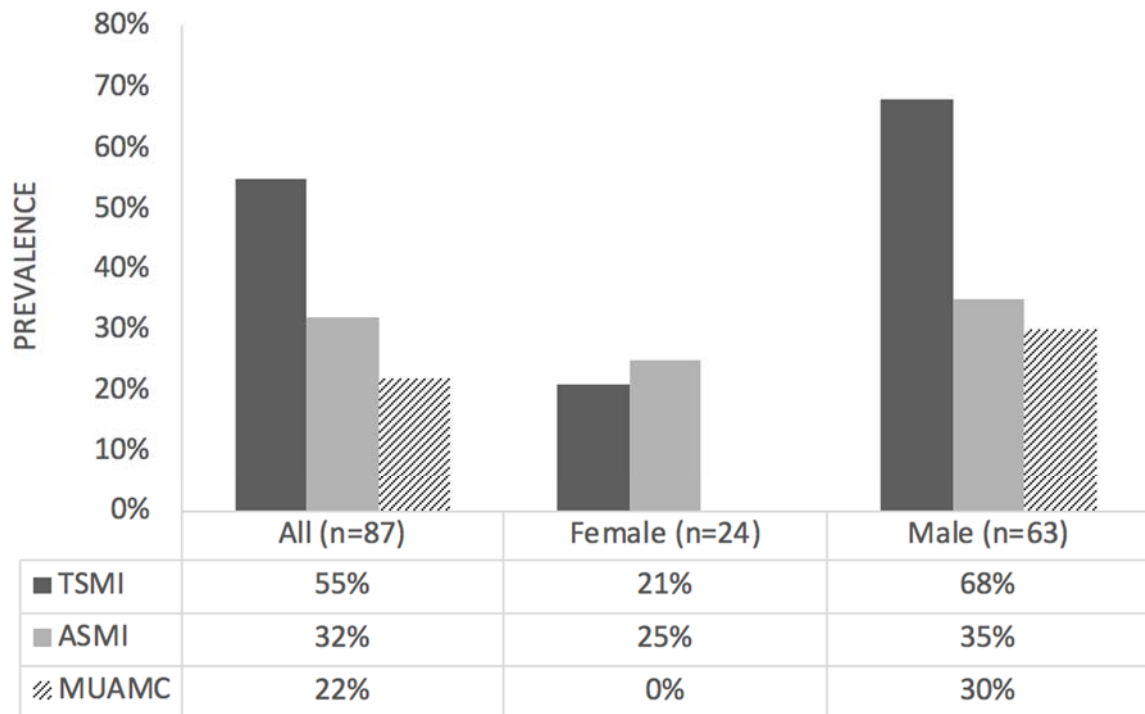
	All (n = 87)	Females (n = 24)	Males (n=63)
Age (years)	65.9 +/- 13.0 (34-86)	59.1 +/- 14.6 (34-86)**	68.6 +/- 11.4 (46-85)
Dialysis vintage	5.14 +/- 6.5 (<1-16)	6.06 +/- 7.5 (<1-16)	4.77 +/- 6.0 (<1-13)
Charlson Comorbidities Index score	6.06 +/- 2.3 (2-15)	6.66 +/- 2.6 (2-13)	5.82 +/- 2.2 (2-15)
Height (m)	1.69 +/- 0.1 (1.47-1.88)	1.60 +/- 0.1 (1.47-1.77) ***	1.73 +/- 0.1 (1.54-1.88)
Weight (kg)	81.4 +/- 19.4 (45.6-136)	73.3 +/- 21.2 (45.6-120.9) ***	84.5 +/- 17.9 (54.4-136.0)
BMI (kg/m²)	28.4 +/- 6.8 (18.2-46.6)	29.0 +/- 8.2 (18.2-46.6)	27.9 +/- 5.6 (18.9-44.4)
Resistance at 50 khz (Ω)	485.2 +/- 92.8 (291-711)	543.0 +/- 111.5 (291-711)	463.2 +/- 73.4 (328-660)
Reactance at 50 khz (Ω)	42.2 +/- 11.8 (13.4-74.7)	44.2 +/- 14.5 (13.4-74.7)	41.4 +/- 10.5 (22-73.1)
RI (cm²/Ω)	61.8 +/- 14.8 (33.8-94.7)	49.3 +/- 12.6 (33.8-94.7)***	66.5 +/- 12.6 (42.3-94.7)
TSMI (kg/m²)	9.7 +/- 1.8 (5.9-14.1)	8.2 +/- 1.8 (5.9-14.1)***	10.2 +/- 1.4 (7.8-13.5)
ASMI (kg/m²)	7.4 +/- 1.3 (4.2-10.7)	6.7 +/- 1.5 (4.2-9.4)***	7.7 +/- 1.0 (5.9-10.7)
MUAMC (cm)	25.4 +/- 3.8 (18.2-37.4)	24.1 +/- 4.3 (18.7-37.4)*	25.9 +/- 3.4 (18.2-35.3)
HGS (kg)	21.9 +/- 8.8 (7.1-47.1)	16.9 +/- 7.6 (7.1-41.5)***	23.8 +/- 8.5 (7.3-47.1)
*P<.005; ** < 0.01, ***P < 0.001 between females (F) and males (M); Resistive Index (RI); Total Skeletal Muscle Index(TSMI); Appendicular Skeletal Muscle Mass Index (ASMI); Body Mass Index (BMI); Mid Upper Arm Muscle Circumference (MUAMC); Hand Grip Strength (HGS)			

Figure 1. Scatterplot of ASMI (kg/m^2) against MUAMC (cm) for females (white circles) and males (grey circles) with cut-points depicted and intersections marked by dotted blue lines. Linear trendline for the whole group is depicted.



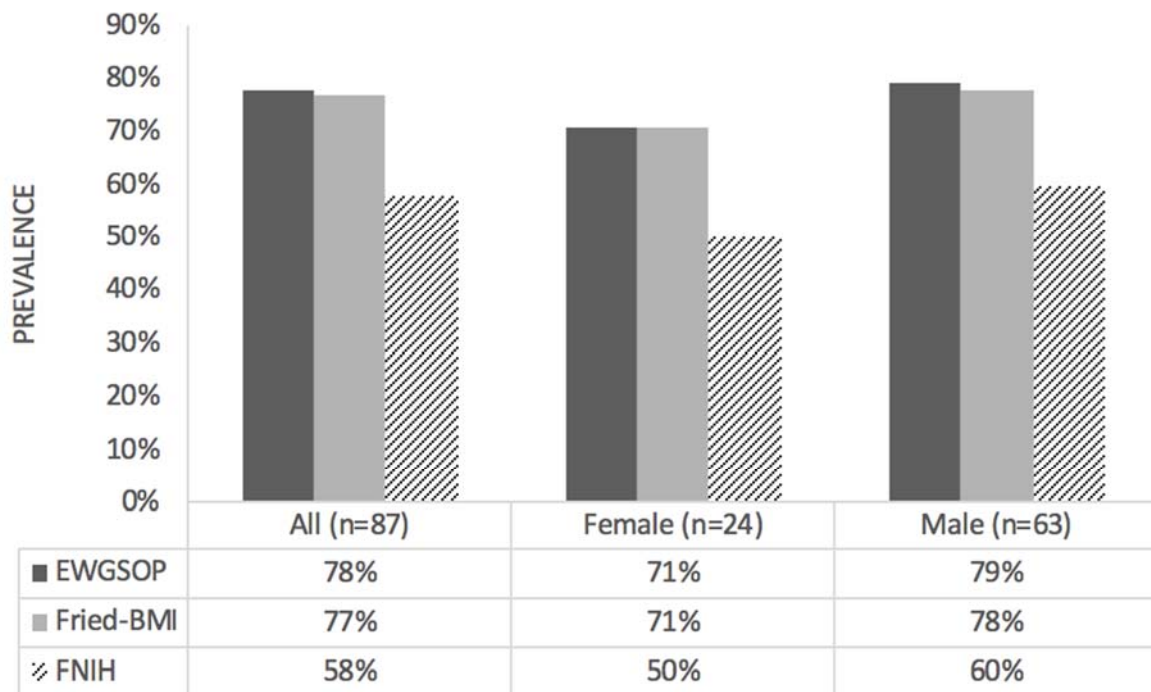
Pearson correlations analyses were performed for the whole group (males and females) on key variables of interest (see supplement file 1). Scatterplot graph presents (Figure 1) the significant correlations ($r > 0.6$) between ASMI and MUAMC with relevant cut-points indicating low muscle mass (ASMI and MUAMC) for women and men depicted.

Figure 2. Prevalence of low TSMI (moderate and severe sarcopenia), ASMI and MUAMC for ALL, Females and Males.



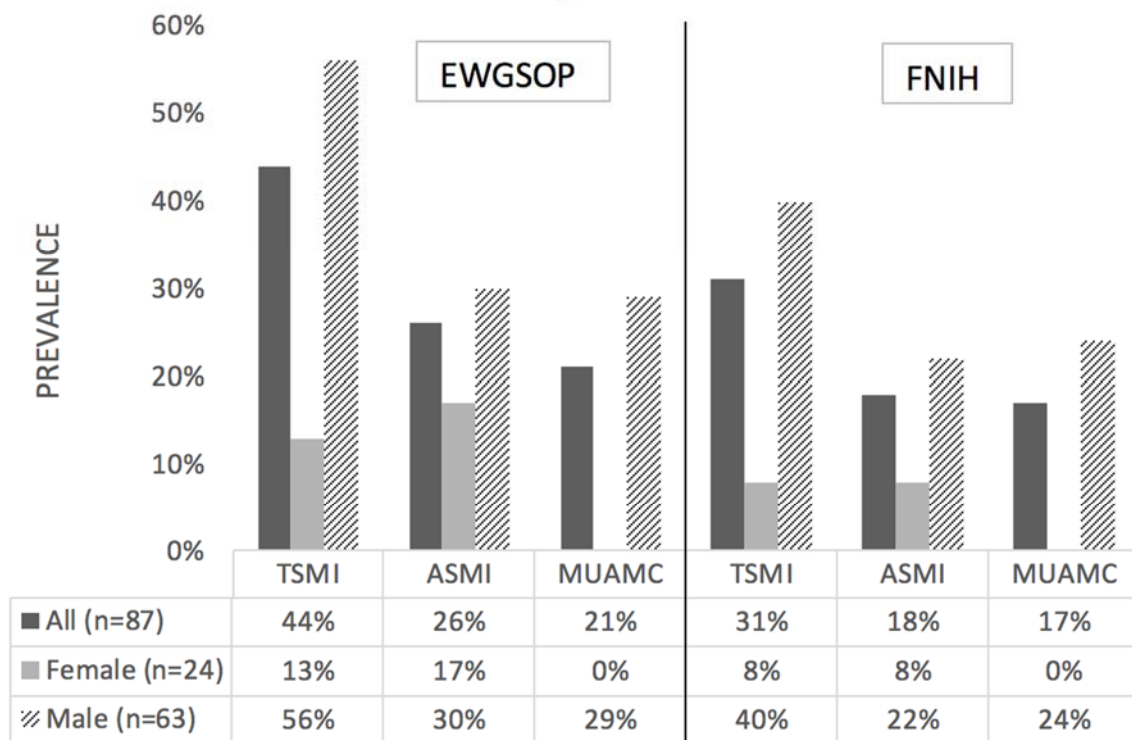
The prevalence of low TSMI (moderate and severe sarcopenia combined), ASMI, and MUAMC are compared (Fig. 2). Low TSMI identified the highest prevalence (55%) followed by low ASMI (32%) and low MUAMC (22%). In females, the TSMI and ASMI methods were concordant for female low muscle mass (21% vs. 25%) but MUAMC identified no females, whereas in males, the ASMI and MUAMC were comparable (35% vs. 30%). A higher number of males were identified applying TSMI (68%).

Figure 3. Prevalence of muscle weakness for ALL, Females and Males using EWGSOP, Fried-BMI categorisation and FNIH cut-points.



The prevalence of muscle weakness was assessed using the 3 different guidelines (EWGSOP, Fried-BMI, FNIH; Fig. 3). In females, the EWGSOP and Fried-BMI methods were similar for muscle weakness, 71%, but the FNIH method indicated only 50% of muscle weakness. Similarly, in males, the EWGSOP and Fried-BMI methods were in agreement for muscle weakness: 79% for EWGSOP and 78% for Fried-BMI, but the FNIH method indicated fewer males had muscle weakness: 60%.

Figure 4. Prevalence of muscle weakness (HGS) for ALL, Females and Males using different combinations of muscle mass measurements (TSMI, ASMI or MUAMC) and using EWGSOP and FNIH cut-points.



The prevalence of muscle weakness was compared using 2 different guidelines (EWGSOP and FNIH; Fig. 4). In females, higher prevalence was identified using EWGSOP cut-points (TSMI: 13%; ASMI: 17%) compared to FNIH cut-points (TSMI: 8%; ASMI: 8%). No differences were noted using MUAMC. In males, higher prevalence was identified using EWGSOP cut-points (TSMI: 56%; ASMI: 30%; MUAMC: 29%) compared to FNIH cut-points (TSMI: 40%; ASMI: 22%; MUAMC: 24%).

Discussion

This is the first study to assess the prevalence of muscle wasting, weakness, and sarcopenia using a comparative methodology in a representative group of HD patients. The RI (cm^2/Ω) which is a strong predictor of muscle mass^{22,24} was found to be significantly higher in males than females (Table 2) as may be expected; however, RI only weakly to moderately correlated with BMI, MUAMC, and HGS (see Appendix S1). TSMI was estimated using a BIA equation developed by Janssen et al.²³ in Caucasian adults.²² TSMI values were significantly higher in males than females and correlated moderately well with BMI and MUAMC, and weakly with HGS. Prevalence of low muscle mass using Janssen et al.²³ cut-points was relatively low (21%) for females and high for males (68%).^{8,23} However, this was calculated as a combination of both “moderate” and “severe sarcopenia.” ASMI was estimated using a specific equation developed for older Caucasian adults.²⁴ ASMI was significantly higher in males than females and correlated well with BMI and MUAMC, and weakly with HGS. The prevalence of low ASMI ($<5.45 \text{ kg/m}^2$ for females and $<7.26 \text{ kg/m}^2$ for males) was estimated to be 25% for females and 35% for males.

Within our study, muscle mass was also measured by MUAMC. Interestingly, there was a significant difference between females and males ($P = .05$). This was in line with the RI, TSMI, and ASMI values which were all significantly different between males and females, as expected, indicating greater muscle mass in men (see Table 2).^{5,20} Analysis also highlighted the high prevalence of overweight (33% females and 38% males) and obesity (29% females and 30% males) by BMI in this study population. Although a higher BMI increases the risk of cardiovascular disease in a normal population, in older people and those with ESRD, a higher BMI has been shown to improve survival outcomes.^{3,32} Using the Janssen et al.²³ BIA methodology and cut-points, it suggests that a higher proportion of patients may have “sarcopenic obesity.” However, using the data and cut-points for ASMI and MUAMC it is more suggestive that a higher BMI is protective in terms of reducing the risk of malnutrition and muscle wasting. However, this is a matter for additional debate and needs to be verified using a gold standard or reference standard technique for muscle mass estimation, such as MRI or DEXA.⁵

There continues to be much debate as to which methods and cut-points should be used in the measurement of muscle mass; and indeed, there are poorly defined normal values and cut-points. It is important to note that there may be differences in the reliability of the Janssen et al.²³ and Sergi et al.²⁴ equations in the patients enrolled in this study. For example, the correlations for ASMI versus BMI and MUAMC provided greater accuracy compared to TSMI correlations (Appendix S1). Both equations were developed in Caucasian adults (similar to the current study group), although the Janssen equation was in a wider age range (18-86 years) than the Sergi et al. equation (60+ years population). In addition, the Sergi et al.²⁴ equation incorporates body reactance (X_c) measurements which may increase the accuracy of the measurement, especially as X_c specifically relates to the ability of healthy cell membranes (e.g., muscle tissue) to store electrical charge.²¹

Cut-points presented in the EWGSOP paper for “normal muscle,” “moderate sarcopenia,” and “severe sarcopenia”²³ were deemed representative for this study, as they had a large ($n = 4,449$) and mixed-race data set (US NHANES study). In addition, for this study it was

considered low muscle mass as “moderate” + “severe sarcopenia” (i.e., $<10.76 \text{ kg/m}^2$ for men and $<6.76 \text{ kg/m}^2$). One consideration is whether this actually overestimates muscle wasting. However, this cut-point for low TSMI has been previously used in non-dialyzed CKD Stages 3-5 patients¹³ and PD patients.³³ For the ASMI cut-points, values³⁰ were derived from the EWGSOP paper.⁸ Although these relate to DEXA ASMM measurements, the Sergi et al.²⁴ equation was specifically validated using DEXA as the reference method, so it was felt that they were comparable in the absence of published reference values for ASMI values by BIA for healthy Caucasian adults.

Other issues and debates exist regarding the methods for assessment of muscle mass, for example, whether to use an index value, i.e., mass (kg)/height² (m²) or instead muscle mass corrected by BMI, similar to the FNIH method (ALM_{BMI}).¹² The prevalence of sarcopenia in HD patients was assessed in a large cohort (n = 645) in a recent US study.³⁴ Muscle mass was measured using BIA spectroscopy and they concluded that SMM normalized to height² may underestimate the prevalence of low muscle mass, particularly in overweight and obese patients. Their study was different to our study however in that they measured whole body muscle mass using BIA spectroscopy and their participant age group was lower (56.7 ± 14.5 years).

A recent Australian study found that the Sergi et al. equation was the most accurate (of 5 tested) for estimating ASMM using DEXA as the reference standard (in a group of Caucasian adults, 18-83 years of age).²⁵ In addition, they found that the Sergi equation had better predictive ability in overweight and obese individuals (similar to the patient group in this study). In addition, a source of potential error particularly relevant for the HD population is hydration status. In order to minimize this within our study, BIA measurements were taken in the post-dialysis period. However, it is acknowledged that “normal” hydration status may not be achievable in all HD participants, and an unusually high fluid level in a patient may lower body resistance and increase the RI value, resulting in falsely high muscle mass.

Muscle strength was also measured by HGS dynamometry. There was a very high prevalence of muscle weakness (Fig. 3) (e.g., up to 79% for males), regardless of which cut-points were used (e.g., EWGSOP, FNIH, etc.). However, it did vary depending upon definition used. Similar findings have been recently found by Tangvoraphonkchai et al.³⁵ The high prevalence of weakness and the lack of correlation relationship with key variables such as BMI, TSMI, ASMI, and MUAMC (see Appendix S1) may indicate a high prevalence of “dynapenia” in this mainly older patient group. This requires further investigation as it may have implications with the advancement of frailty and clinical outcomes such as falls risk and disability.⁶ Different mechanisms and factors may be implicated such as the loss (apoptosis) and atrophy of type II muscle fibers (fibers implicated in higher force development), prescribed drug medications on HGS such as cardiovascular drugs,³⁶ or measurement error however a standard protocol was followed using a single trained research assistant and suggested Jamar dynamometer. Another factor may relate to the timing of HGS measurements around dialysis. Research suggests the HD session can have a negative impact on grip strength.^{37, 38} Further research looking at HGS prior to or not on HD days would be beneficial to add to the literature on this debate.

Sarcopenia prevalence was estimated in this study population and was defined as a combination of both low muscle mass and strength. The findings from this study demonstrate how sarcopenia prevalence also varies widely using different methodologies (e.g., TSMI-Janssen and EWGSOP cut-points for HGS). Previous research has reported similar discrepancies between methodologies^{33, 39-41} with weakness being a central issue in HD patients and that low muscle mass and sarcopenia prevalence is relatively lower, but also highly variable depending on the methodology used. This requires further investigation as it may be that a combination of known and unknown factors interplay causing this relative dynapenic phenotype, such as physical inactivity, aging, comorbidity and nutritional status.^{35, 41}

The issues raised in this paper need to be urgently addressed, as they may have an impact on clinical outcomes. The clinical importance of having simple, non-invasive, inexpensive techniques such as anthropometry, BIA, and HGS dynamometry in the assessment of HD patients is highly desirable, especially in the community and care home settings. However, issues remain regarding accuracy and repeatability. It may be that such techniques can be used alongside simple methods for the screening and assessment of the functional domains of sarcopenia and frailty such as gait speed walking tests, the short physical performance battery, and the sarcopenia screening questionnaire, the "SARC-F."^{8,11} Furthermore, such work could inform the development of appropriate interventions for this patient cohort.

In conclusion, this is the first study comparing these specific measures of muscle mass (TSMI and ASMI, using BIA and MUAMC) and strength (HGS) from a representative group of HD patients. Estimates of muscle wasting, weakness, and sarcopenia prevalence were made using previously published cut-points. Analysis produced varying results when identifying muscle wasting, weakness, and sarcopenia in this population. Further studies should focus on expanding this work and also applying it to other renal populations (both outside Caucasians and HD patients, such as, e.g., peritoneal dialysis patients). This will contribute to the international literature by refining the most appropriate methods and equations to accurately estimate muscle mass in renal disease.

Practical Application

It is important for clinicians to acknowledge that muscle weakness is prevalent in HD patient populations. However, variations currently exist depending on methodology and cut-points. Validating prediction equations of muscle wasting and weakness for a HD population will provide clinicians with efficient and effective assessment measures not currently available. This has enormous economic and practice implications within dialysis clinics and in HD research.

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Supplementary Data

Supplementary data related to this article can be found at <https://doi.org/10.1053/j.jrn.2019.09.004>

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