J Nutr Health Aging
Volume 18, Number 7, 2014

PREVALENCE OF SARCOPENIA IN ELDERLY MAINTENANCE HEMODIALYSIS PATIENTS: THE IMPACT OF DIFFERENT DIAGNOSTIC CRITERIA

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Abstract: The prevalence of sarcopenia on elderly maintenance hemodialysis (MHD) has been scarcely investigated. *Objectives:* To investigate the prevalence of decreased muscle mass and strength alone or combined (true sarcopenia) in elderly patients on MHD according to different methods and cutoff limits. Additionally, we evaluated the agreement between dual energy x-ray absorptiometry (DXA) and surrogate methods for the assessment of muscle mass. *Design:* Observational and cross-sectional study. *Participants:* Non-institutionalized 102 elderly (age > 60 years) patients on MHD. *Measurements:* Sarcopenia was considered when the patient fit one criteria for low muscle mass assessed by DXA, bioelectrical impedance (BIA), sum of skinfold thicknesses (SKF), calf circumference and mid-arm muscle circumference (MAMC) and one for low muscle strength evaluated by handgrip dynamometer. *Results:* Decreased muscle strength was found in 85% of the patients. The prevalence of decreased muscle mass varied from 4 to 73.5% and of sarcopenia (decreased muscle mass and strength combined) from 4 to 63%, depending on the method and cutoff limit applied. A small percentage of patients (2 to 15%) were classified as sarcopenic by more than one diagnostic criteria. The agreement between DXA and the surrogate methods to assess muscle mass showed better kappa coefficients with BIA ($r=0.36$; $P<0.01$) and SKF ($r=0.40$; $P<0.01$). *Conclusion:* A wide prevalence of sarcopenia is observed depending on the method and cutoff limit applied. This may limit extrapolate on to clinical practice. BIA and SKF were the surrogate methods to assess muscle mass with the best concordance with DXA in elderly MHD patients.

Key words: Hemodialysis, elderly, sarcopenia.

Introduction

The United States Renal Data System report from 2011 describes an important increase in both the incidence and prevalence of patients on dialysis aged > 65 years during the last decade (1). This finding is in line with the observation that the mean age of patients on dialysis worldwide is often within the range of 60 to 70 years old (2).

Elderly patients on maintenance hemodialysis (MHD) are exposed to conditions related to the disease (increased protein catabolism induced by metabolic acidosis, pro-inflammatory cytokines, hyperparathyroidism, comorbid condition) (3) and to the dialysis procedure (increased protein degradation and reduced protein synthesis, dialysis nutrient loss) (4) in addition to protein energy wasting, myocellular and mechanical changes (5), all of which predispose them to an important loss of muscle mass and muscle strength (5).

The age related loss of muscle mass and function was termed sarcopenia by Rosenberg (6). More recently, the European Working Group on Sarcopenia in Older People (EWGSOP), defined sarcopenia as "a syndrome characterized by progressive and generalized loss of skeletal muscle mass and strength with a risk of adverse outcome such as physical disability, poor quality of life and death" (7). Other specific consensuses on sarcopenia published similar definitions (8-10). It is noteworthy that all the documents agreed that diminished muscle mass in conjunction with low muscle function is mandatory to diagnose sarcopenia (7-10). Although the methods and cutoff points to define low muscle mass and function are still a matter of debate, it can be understood that muscle mass should be preferably assessed by appendicular lean mass index - ALMI (obtained by dual energy x-ray absorptiometry [DXA]) and muscle function by either muscle strength (handgrip dynamometer) and/or performance tests (gait speed tests) (7-10). However, since DXA is not feasible for routine care, information about the performance of surrogate methods that enable assessment of muscle mass in clinical practice, such as by bioelectrical impedance (BIA) and anthropometric measurements, will be appreciated by clinical practitioners. In elderly individuals (aged > 50 years), the prevalence of low muscle mass assessed by BIA and anthropometric measurements varied from 7 to 40% (11-13). When combing both, true sarcopenia, the prevalence varied from 7 to 34% (12, 14). This wide range is clearly reflecting the existence of multiple methods and cutoff points that difficult comparison and harmonization. Such lack of uniformity might have important clinical implications, as it can lead to a misleading diagnose of sarcopenia.

In chronic kidney disease (CKD), the term sarcopenia is often used, but referring to diminished muscle strength (15) or diminished muscle mass (16) or as subjective global assessment indicative of malnutrition (17). To the best of our knowledge, only one study investigated the matter by applying the criteria of concurrent diminished muscle mass and muscle strength. Kim et al. (18) in reported a prevalence of sarcopenia in 21% of the hemodialysis patients aged 50 year and older. In order to

Received October 16, 2013
Accepted for publication December 19, 2013

shed more light into uremic sarcopenia and the impact of different diagnostic criteria, the primary aim of this study is to explore the prevalence of decreased muscle mass and strength each one alone and in combination (true sarcopenia) in a setting of elderly patients on MHD by applying different methods and cutoff limits proposed by the specific consensuses on sarcopenia, in addition to methods often applied for routine assessment of muscle mass and strength. As a secondary aim, we also evaluated which surrogate method to measure muscle mass had the highest agreement with the ALMI assessed by DXA, which is considered a preferable method to be used in research and clinical practice.

Subjects and Methods

Study design and Subjects

This is a multicentre, cross-sectional analysis of an ongoing cohort study aiming to assess the nutritional status of elderly MHD patients. From March 2010 until December 2012, a total of 102 elderly patients on MHD treated in five dialyses facilities in Rio de Janeiro (Brazil) were enrolled in the study. The following inclusion criteria were applied: age older than 60 years, not being institutionalized, on MHD for at least 3 months and dialyzing 3.5 - 4 hours three times per week. Patients with amputated limbs, acute infection, cancer, acquired immunodeficiency syndrome, liver diseases, Alzheimer, dementia and Parkinson disease or cognitive dysfunction were not included. From a total 269 patients screened in the visited dialysis facilities, 167 patients fulfilled the inclusion criteria and 102 accepted to be enrolled in the study. Unwillingness to stay in the dialysis center after the HD session for the body composition assessment was the main reason for not accepting to be enrolled in the study. No significant differences were found between patients that accepted (n=102) or refused (n=65) to participate in the study, regarding sex (males 75.2% vs 65.7%; P=0.23); age (70.8 ±7 years vs 72 ±8.3 years; P=0.31; mean ±SD); dialysis vintage (2.25 (1; 5.3) years vs 3.6 (1.7; 5.9) years; P=0.10; median and interquartile range) and body mass index (BMI) (25.5 ±4.9 kg/m^2 vs 24.3 ±3.9 kg/m^2; P=0.13). The Local Research Ethical Committee from Rio de Janeiro State University approved this study and informed consent was obtained from each participant.

Data collection took place at the dialysis center according to the following protocol: (1) patients were invited to participate in the study; (2) 1 to 4 weeks later, anthropometric, BIA and handgrip strength (HGS) assessments were done between 30 to 60 minutes after the dialysis session and before any beverage or food consumption was taken. This is the methodology recommended for MHD to diminish the influence of fluid retention on body composition measurements, particularly for BIA, which is based on the conduction of an electrical current on body fluids to estimate the lean mass (19). Blood sample collection occurred before the dialysis session on the same day of the dialysis routine monthly blood collection. In a subsample of 49 subjects, body composition was also assessed by DXA in the same week that the other measurements were performed.

Methods

Body composition

Anthropometry

Anthropometric measurements included body weight (kg); height (m) skinfold thicknesses (SKF) of triceps, biceps, subscapular and suprailiac (Lange®, Cambridge Scientific Industries, Cambridge, MD, USA), applying standard techniques as previously described (20). The calf circumference were measured with a flexible plastic and non-stretchable tape, according to standardized methodology (20, 21). All measurements were performed by the same trained dietitian in the opposite side of the arm with the arteriovenous fistula (AVF).

BMI was calculated as body weight divided by the squared height (kg/m^2) (21). Mid-arm muscle circumference (MAMC) was calculated using the formula: arm circumference – 0.314 x triceps skinfold thickness (22). Standard percentages of MAMC was obtained using the National Health and Nutrition Examination Survey (NHANES) percentile distribution tables adapted by Frisancho (22) as recommended by the NKF/KDOQI Nutrition guidelines (23).

The assessment of body composition by anthropometry was performed using the sum of SKF (triceps, biceps, subscapular and suprailiac). Body density was calculated according to the formula of Durnin and Womersley (24) and percent of body fat percentage was then derived using Siri's equation (25). Body fat percentage was converted to kilograms (kg) and subtracted from body weight to yield lean body mass (LBM). The lean body mass index (SKF-LBMI) was calculated as LBM (kg) divided by the square height (kg/m^2).

Bioelectrical impedance (BIA)

Single frequency BIA analysis (Biodynamics® 450 - Biodynamics® Corporation, Seattle, WA, USA) was performed with the patient in the supine position, with the arms lying parallel and separated from the trunk and with the legs separated so that the thighs were not touching. Two electrodes were placed on the hand and wrist and other two were positioned on the foot and ankle in the opposite side of the arm with the AVF. An electrical current of 800 μA at 50 kHz was introduced into the subject and resistance and reactance were measured. The software provided by the manufacturer calculated the LBM. The lean body mass index (BIA-LBMI) was calculated as LBM (kg) divided by the square height (kg/m^2).

Dual energy X-ray absorptiometry (DXA)

Forty-nine out of 102 patients accepted to visit the Interdisciplinary Nutrition Assessment Laboratory of the

Nutrition Institute (Rio de Janeiro State University) for DXA scan (IDXA scanner® – GE Medical Systems Lunar, Madison, WI, USA) to assess body composition. Since this a multicentre study, DXA scan was centralized at the university laboratory to ensure that the same methodology was used. The high rate of refusing to come to the University for the DXA scan lies on the characteristics of the studied patients. First, these are elderly individuals on MHD that have to go to the dialysis facilities 3 times per week. Therefore, taking an extra day of the week for exams is cumbersome. Second, many patients require an accompanying person to take them to exams, which imposed a drawback for the DXA scan. Patients that accepted doing the DXA exam underwent standard soft-tissue examination including whole-body and regional measurements of trunk, arms and legs according to a 3-compartment model that included fat mass, lean tissue and bone mineral content. The ALMI was obtained through the sum of the lean mass (lean soft tissue (kg)) of the arms and legs regions divided by the squared height (kg/m^2) (26).

Handgrip strength (HGS)

HGS was measured using a mechanical dynamometer (Baseline®, Fabrication Enterprises, Elmsord, NY, USA) with a scale of 0 to 100 kg and a precision of 1.0 kg. Subjects were instructed to self-adjust the dynamometer so that it fit comfortably to their hand size to obtain the best performance. The patients were instructed to apply as much handgrip pressure as possible in response to a voice command by using the opposite hand of the arm with the AVF, while standing with arms along the body. Three trials were performed with a rest period of 1 minute between trials. The first trial was discarded and worked as a warm up section. The highest HGS value of the last two trials was recorded.

Sarcopenia criteria

Presence of decreased muscle mass and strength alone or combined (true sarcopenia) was established following the different diagnostic methods proposed by the specific consensuses on sarcopenia (7-10), in addition to those often applied in the routine assessment of dialyzed patients (27). Table 1 provides a detailed description of the different methods and cutoff points tested. For ALMI (DXA) and LBMI (BIA and SKF), we used the normative health population from NHANES study (28) as there are no normative tables for Brazilians. Two cutoffs were tested: below 20th percentile and 2 standard deviation (SD) below mean values for young health population, according to the International Working Group on Sarcopenia (8) and to EWGSOP (7), respectively. The mean values at the age of 40 years was used for comparisons with the elderly on MHD, since the ALMI and LBMI at the age of 40 displayed the highest mean values for both measurements in the NHANES distribution tables (28) and were within the age range used by Baumgartner (26) in the Rosetta Study (18-40 years) to define the thresholds values for sarcopenia. MAMC and calf circumference were also tested due to their high applicability in clinical practice. In addition, MAMC is commonly applied in the setting of dialyzed patients as a marker of muscle mass and calf circumference is a measure of muscle mass used for elderly individuals. For MAMC the threshold recommended for dialyzed patients (27) was applied (Table 1) and for calf circumference, we used the threshold proposed by from Rolland et al (29), which has been applied in a previous study to screen for decreased muscle mass (14). For HGS, normative tables from Niteroi (Brazil) were used as reference values [30] using the cutoff below the 10th percentile of healthy young individuals at the age of 30-39 years (displayed the highest values of HGS among all ages groups). This cutoff was chosen to be equivalent to below 20th percentile as applied for ALMI and LBMI, as well as to be aligned to a previous study with MHD patients that also had this same cutoff to define low muscle strength (31). Sarcopenia was then diagnosed by 8 different combinations of methods and cutoff limits including one for low muscle mass and one for low muscle strength as described in Table 2.

Table 1

Methods and cutoff points applied to define low muscle mass and low muscle strength

Criterion	Measurement method	Cutoff point
Low muscle mass	DXA	
	ALMI	< 20th percentile of young individuals from NHANES (men: < 8.12 kg/m^2; women: < 6.08 kg/m^2) (28)
	ALMI	< 2 SD below means of young individuals from NHANES (men: < 6.95 kg/m^2; women: < 5.16 kg/m^2) (28)
	BIA	
	LBMI	< 20th percentile of young individuals from NHANES (men: < 18.1 kg/m^2; women: < 14.6 kg/m^2) (28)
	LBMI	< 2 SD below means of young individuals from NHANES (men: < 15.9 kg/m^2; women: < 12.8 kg/m^2) (28)
	SKF	
	LBMI	< 20th percentile of young individuals from NHANES (men: < 18.1 kg/m^2; women: < 14.6 kg/m^2) (28)
	LBMI	< 2 SD below means of young. individuals from NHANES (men: < 15.9 kg/m^2; women: < 12.8 kg/m^2) (28)
	MAMC	< 90% of standard gender and age specific values from NHANES (22)
	Calf circumference	< 31 cm (29)
Low muscle strength	Handgrip strength	< 10th percentile of young individuals from Brazilian cohort (men: right < 36.6 kg and left < 34.7 kg; women: right < 20.7 kg and left < 20.1 kg) (30)

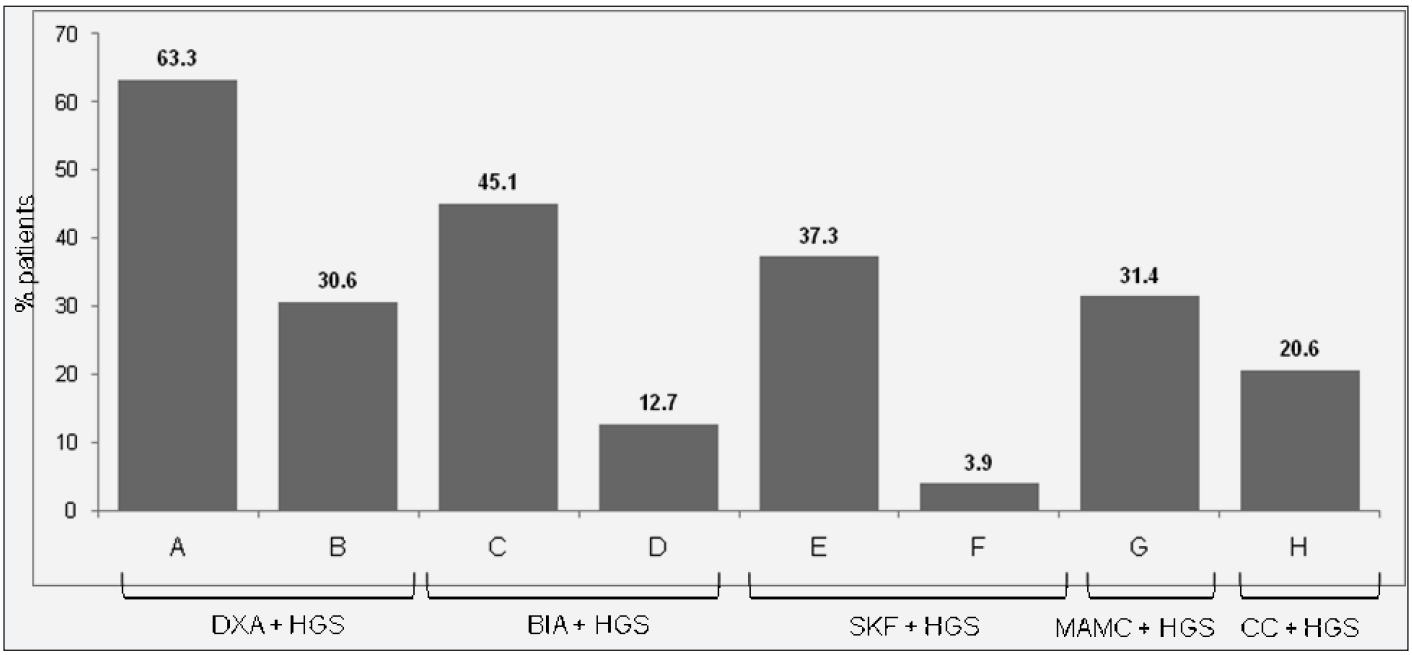
DXA: dual energy x-ray absorptiometry; ALMI: appendicular lean mass index; BIA: bioelectrical impedance; SKF: skinfold thicknesses; MAMC: mid-arm muscle circumference; NHANES: national health and nutrition examination survey.

Table 2
Measurements, methods and cutoff limits to diagnose sarcopenia

Code	Measurements methods	Measure and cutoff limits
A	DXA + HGS	ALMI < 20th percentile of young individuals + HGS < 10th percentile of young individuals
B		ALMI < 2 SD below means of young individuals + HGS < 10th percentile of young individuals
C	BIA + HGS	LBMI < 20th percentile of young individuals + HGS <10th percentile of young individuals
D		LBMI < 2 SD below means of young individuals + HGS < 10th percentile of young individuals
E	SKF + HGS	LBMI < 20th percentile of young individuals + HGS < 10th percentile of young individuals
F		LBMI < 2 SD below means of young individuals + HGS < 10th percentile of young individuals
G	MAMC + HGS	MAMC < 90% standard values + HGS < 10th percentile of young individuals
H	Calf circumference + HGS	Calf circumference < 31 cm + HGS < 10th percentile of young individuals

DXA: dual energy x-ray absorptiometry; ALMI: appendicular lean mass index; BIA: biolectrical impedance; LBMI: lean body mass index; SKF: skinfold thicknesses; MAMC: mid-arm muscle circumference; HGS: handgrip strength; SD: standard deviation.

Figure 1
Prevalence of sarcopenia in elderly patients on MHD by different diagnostic criteria (n=102, excepet for DXA + HGS n=49). Codes are described in Table 2



DXA: dual energy x-ray absorptiometry; HGS: handgrip strength; BIA: bioelectrical impedance; SKF: skinfold thicknesses; MAMC: mid-arm muscle circumference; CC: calf circumference.

Statistical analysis

Values are presented as mean ± SD or as median and interquartile range, as appropriate. Categorical variables are shown as absolute numbers with percentages. The Kurtosis test was applied in all variables to test normality. The Chi-square test was used for comparing categorical variables and independent *t* test for continuous variables. Pearson's linear correlation coefficients were calculated to evaluate the association between the ALMI and surrogate methods to assess lean mass. Kappa test was applied to examine the agreement in the diagnosis of low muscle mass between the ALMI and the surrogate markers. A P value < 0.05 was used for statistical significance. All analyses were performed using the SPSS software package (Version 18.8; SPSS®, Chigago, IL, USA).

Results

The mean age of the patients was 70.7 ±7 years (male: 71.7 ±6.9 and female: 68.2 ±6.8 years; P=0.02); 75 (73.5%) were men and with dialysis vintage of 2.25 (1; 5.3) years. Hypertension was the most common comorbidity (n=78; 76.5%), followed by diabetes (n=31; 34%). Table 3 depicts comparison of body composition measurements stratified by gender. Except for BMI, MAMC and calf circumference that

Table 3
Main characteristic of elderly on maintenance hemodialysis, stratified by gender

Variables	Men (n=75)	Women (n=27)	P[a]
BMI (kg/m²)	25.3 ±4.5	26.2 ±6.1	0.407
ALMI (kg/m²) by DXA[b]	7.29 ±1.0	6.16 ±1.3	0.002
LBMI (kg/m²) by BIA	18.1 ±2.9	16.5 ±3.2	0.02
LBMI (kg/m²) by SKF	18.4 ±2.1	16.1 ±2.6	<0.001
MAMC (cm)	25.6 ±3.6	24.3 ±3.8	0.11
Calf circumference (cm)	34.2 ±4.1	33.1 ±3.8	0.24
Handgrip strength (kg)	27.1 ±8.0	15.2 ±7.1	<0.001

Data presented as Mean ±SD. a. Test *t* student test for independent samples. b. n= 49; BMI: body mass index; ALMI: appendicular lean mass index; LBMI: lean body mass index; BIA: bioelectrical impedance; SKF: skinfold thicknesses; MAMC: mid-arm muscle circumference.

Table 4
Prevalence of low muscle mass and low muscle strength by the different methods and cutoff points in elderly patients on maintenance hemodialysis (n=102)

	Measurements methods	Measure and cutoff limits	Prevalence (n; %)
Low muscle mass	DXA[a]	ALMI < 20th percentile of young individuals	36 (73.5)
		ALMI < 2 SD below means of young individuals	16 (32.7)
	BIA	LBMI < 20th percentile of young individuals	52 (51)
		LBMI < 2 SD below means of young individuals	14 (13.7)
	SKF	LBMI < 20th percentile of young individuals	45 (44.1)
		LBMI < 2 SD below means of young individuals	4 (3.9)
	MAMC	MAMC < 90% standard values	35 (34.7)
	Calf circumference	Calf circumference < 31 cm of young individuals	22 (21.8)
Low muscle strength	HGS	HGS < 10th percentile of young individuals	86 (85.1)

a. n=49. DXA: dual energy x-ray absorptiometry; ALMI: appendicular lean mass index; BIA: biolectrical impedance; HGS: handgrip strength; SD: standard deviation; LBMI: lean body mass index; SKF: skinfold thicknesses; MAMC: mid-arm muscle circumference.

were similar among men and women, all measurements were significantly higher in men than in women. The prevalence of either low muscle mass and low muscle function by the different methods and cutoffs proposed are described in Table 4. The prevalence of low muscle mass ranged from 3.9 to 73.5% depending on the method and cutoff point applied. Low muscle function was present in 85.1% of the patients.

Concordance analyses were performed in a subpopulation of 49 patients that additionally underwent DXA examination, being DXA-ALMI estimated taken as the reference. The highest correlation coefficient with DXA-ALMI was found for BIA-LBMI (r=0.87; P<0.001), followed by SKF-LBMI (r=0.856, P<0.001), MAMC (r=0.65; P<0.001) and calf circumference (r=0.58; P<0.001). The results regarding the surrogate method with the highest agreement with the DXA-ALMI below the 20th percentile and 2 SD below the mean of the standard population are shown on Table 5. For DXA-ALMI < 20th percentile the highest kappa coefficient was found for SKF-LBMI and BIA-LBMI. For DXA-ALMI < 2SD the highest agreement was found for BIA-LBMI followed by MAMC and calf circumference.

The prevalence of sarcopenia diagnosed by low muscle mass and low muscle function according to the different diagnostic criteria is shown in Figure 1. When sarcopenia is diagnosed using the cutoff limits of low muscle mass < 20th percentile for DXA, BIA and SKF in addition to HGS < 10th percentile (definitions A, C and E), the prevalence varied from 63.3 to 37.3%. When low muscle mass is diagnosed with cutoff limits of < 2 SD for DXA, BIA and SKF with the same HGS cutoff (definitions B, D, F), it drastically decreased to 3.9 to 30.6%. The prevalence of sarcopenia by the other definitions (G and H) varied from 20.6 to 31.4%.

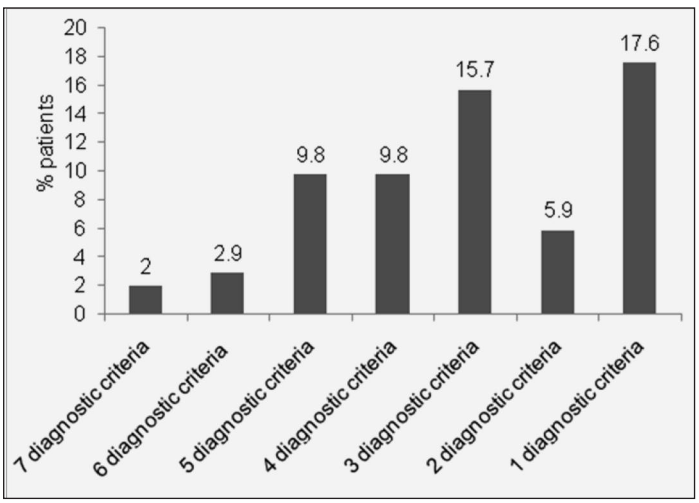
We examined how many patients were identified as sarcopenic by at least one diagnostic criteria (Figure 2). None of the patients was classified as sarcopenic by 8 diagnostic criteria and a low prevalence of patients were classified as sarcopenic by 2 or more diagnostic criteria. Sarcopenia was not found by any of the diagnostic criteria in 36.3% (n=37) of the studied population.

Table 5
Concordance between appendicular lean mass index and surrogate methods for diagnosing low muscle mass (n=49)

	Kappa coefficient	
	ALMI < 20th percentile of young individuals	ALMI < 2 SD below means of young individuals
BIA-LBMI < 20th percentile	0.36 (P=0.007)	----
BIA-LBMI < -2 SD of young	----	0.38 (P=0.001)
SKF-LBMI < 20th percentile	0.40 (P<0.001)	----
SKF-LBMI < -2 SD of young	----	0.08 (P=0.15)
MAMC < 90% standard values	0.18 (P=0.03)	0.38 (P=0.006)
Calf circumference < 31 cm	0.16 (P=0.04)	0.32 (P=0.02)

ALMI: appendicular lean mass index; LBMI: lean body mass index; BIA: bioeletrical impedance; SKF: skinfold thicknesses; MAMC: mid-arm muscle circumference.

Figure 2
Prevalence of elderly patients on MHD classified as sarcopenic according to the number of diagnostic criteria fulfilled (n=102)



Discussion

Sarcopenia is a recently revisited concept among the elderly (7-10), which implies concurrent low muscle mass and function (i.e., strength and performance). Defining low muscle mass and muscle function is a major challenge when addressing sarcopenia diagnosis. Although several methods and cutoff limits have been proposed, it is not currently known which can better distinguish those at risk for its adverse outcomes, including worse quality of life, frailty and higher mortality rates (7). In this study, we tested the prevalence of sarcopenia in a population of elderly patients undergoing MHD by 8 different diagnostic criteria combining the condition of low muscle mass and low muscle strength. We found that the prevalence of sarcopenia varied from 3.9% to 63.3%. Moreover, only 2 to 15.7% of the patients were classified as sarcopenic by more than 2 diagnostic criteria, suggesting a low rate of agreement among these.

Discriminating elderly MHD patients with inadequate muscle mass and or muscle function is surely a challenge. In our study, low muscle strength was assessed by one single method (handgrip strength) and one cutoff (< 10th percentile of normative population), based on reference values from the Brazilian population (30). The reason behind this decision lies on the observation that handgrip strength in MHD patients is an effective discrimination tool for patients at risk (32-34). Thus, differences in diagnoses in our study are to be attributed to variability in methods and cutoffs to define low muscle mass. Certainly, methods to assess muscle mass in MHD patients are subjected to error by abnormal fluid status (i.e. over or dehydration). To some extent, this may also apply to elderly populations in general, where reduced renal function is a common finding present in more than 45% of screened individuals (35). In our study, muscle mass was assessed by BIA and anthropometry (sum of SKF, calf circumference and MAMC) 30 minutes after the dialysis session in order to diminish this error, but we cannot rule out completely the occurrence of fluid overload. DXA was performed in a subsample of patients, but although DXA is considered a standard method to assess body composition, it could also be influenced by overhydration (36). By using different methods and cutoffs to screen patients with decreased muscle mass, a wide range in the prevalence was found (3.9% to 73.5%; Table 4). Of note, cutoff values values below -2 SD yielded the lowest prevalence regardless of the method (3.9 to 32.7%). A similar wide range also in prevalence was observed in a study of Dutch non-CKD individuals aged 45 years and older, whereby the prevalence of low muscle mass varied from 0.3 to 31.4% subject to the cutoff limits tested (37). In elderly non-CKD individuals, the prevalence of low muscle mass varied from 7.8 to 30% when assessed by either DXA, anthropometry or BIA (11-13). In our study the high prevalence of decreased muscle strength assessed by HGS is in accordance with 2 previous investigations in MHD patients that found prevalence of 55 to 60% (18, 31). The even higher prevalence observed by us can be explained by the studied population, comprised exclusively by individuals aged > 60 years and older. In MHD patients aged > 50 years, the prevalence of sarcopenia assessed by BIA (lean tissue index < -2 SD) combined with low HGS (< 30 and 20 kg in men and women, respectively) was of 21%

(18), which is higher than what we found in classification D (12%), which would be the classification matching their criteria. Altogether, these results suggest that the screening method for low muscle mass should be carefully chosen and that the cutoff limit is likely to vary from one population to other, meaning that diagnosis of low muscle mass is certainly difficult.

It is important to highlight that in the current study we are not examining the condition of cachexia, which has been defined as a complex metabolic syndrome associated with underlying illness and characterized by loss of muscle with or without loss of fat mass (7). In the present study no investigation was made regarding loss of fat mass.

Additionally, we tried to disentangle which surrogate method to asses muscle mass showed a better concordance and higher correlation coefficient with ALMI as assessed by DXA, suggested by the EWGSOP as a preferable method to research and clinical practice (7). Our results suggest that BIA-LBMI and SKF-LBMI showed the best agreement with ALMI-DXA when using the cutoff < 20th percentile. When testing the surrogate with highest agreement with ALMI-DXA cutoff < -2 SD, BIA-LBMI and MAMC had the highest kappa coefficients. This result is in accordance with previous investigation showing that the agreement between DXA and BIA and SKF in MHD are comparable and small differences were observed between these two surrogate methods (38).

Several limitations of our study should be acknowledged to appropriately interpret our findings. The unwillingness of the patients to do DXA measurements limited our sample with DXA measurements (n=49), which impaired a better analysis of the prevalence of decreased muscle mass and sarcopenia in our study, as well as examining the surrogate marker with highest agreement with DXA. Second, the study lacks a control group of elderly individuals with normal renal function. Instead, we focused only on comparison with reference populations. Third, we had no functional outcome measures (i.e. the performance tests based on gait speed) available. The strength of the present study, in other hand, is that the currently used diagnostic criteria of sarcopenia were applied to one study population allowing the observation of the magnitude of variation in the diagnoses of sarcopenia depending on the methods and cutoff limit applied.

To conclude, the prevalence of sarcopenia varies widely depending on the applied diagnostic criteria. BIA and SKF were the surrogate methods to assess muscle mass with the best concordance with DXA. Our findings emphasize the need to conduct searches on adult and elderly MHD patients investigating methodology and criteria to appropriately discriminate muscle stores and thus, diagnosis and management of sarcopenia.

Acknowledgements: This research received a specific Grant from Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) (Grant number E-26/111.653/2010). JCDR, FGB and RLF were supported with scholarship from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) during the study. JJC acknowledges grant support from the Swedish Research Council, the Westman Foundation and the Centre for Gender Medicine at Karolinska Institutet.

Conflict of interest statement: None declared.

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