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Applied nutritional investigation

Handgrip strength and its dialysis determinants in hemodialysis patients

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A B S T R A C T

Objective: To evaluate muscle function (MF) of patients on hemodialysis (HD) and to investigate the dialysis determinants of maximal voluntary handgrip strength (HGS).
Methods: Forty-three patients on HD (25 men, six diabetics, 54.5 ± 12.2 y of age, 62.2 ± 51.4 mo on dialysis) were studied. HGS was measured three times with a mechanical dynamometer (Jamar) before and after HD sessions on the non-fistula side and the highest value was used for analysis. HGS values lower than the 10th percentile of an age-, gender-, and region-specific reference were considered MF loss. Biochemical and dialysis variables (ultrafiltration, interdialytic body weight gain, urea clearance, urea before and after HD, systolic and diastolic blood pressures before and after HD, and difference in systolic and diastolic blood pressures) were also examined.
Results: The HGS values before and after HD values were significantly higher in men but were not statistically different before and after the HD sessions (29.8 ± 10.3 and 30.2 ± 9.9 kg for men, 14.1 ± 7.0 and 14.5 ± 6.3 kg for women). MF loss was observed in 24 patients (55.8%), 12 women and 12 men. Dialysis variables were not different between patients with and without MF loss and did not correlate with HGS measured before or after an HD session.
Conclusions: Patients using HD presented a high prevalence of MF loss as assessed by HGS, and it was not influenced by dialysis variables. HGS may be used as a reliable nutritional marker in HD, measured before or after HD sessions.

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Introduction

Protein–energy wasting (PEW) is common in patients with chronic kidney disease and is associated with increased morbidity and mortality [1,2]. There are several clinical, nutritional, and biochemical parameters that may be indicative of PEW in patients using hemodialysis (HD). According to the International Society of Renal Nutrition and Metabolism (ISRNM) expert panel, PEW is diagnosed if there are low serum levels of albumin, transthyretin, or cholesterol, a decreased body mass (low or decreased body/fat mass or body mass loss with low intake of protein and energy), and decreased muscle mass (muscle wasting or sarcopenia, decreased midarm muscle circumference) [2].

Decreased muscle mass appears to be the most valid criterion for the presence of PEW [3]. However, it is often difficult to diagnose decreased muscle mass or muscle loss accurately [4]. In this setting, functional tests may be the most sensitive and relevant indicator of nutritional status alterations [5].

Handgrip strength (HGS), a measurement of the maximal voluntary force of the hand/arm, has been described as a useful tool in assessing muscle function (MF) because it is a non-invasive, rapid, objective, and inexpensive procedure [6]. This technique has been related to mortality and complications in surgical patients [7] and in the elderly [8].

Many studies have assessed HGS in the HD population. Qureshi et al. [9] and Carrero et al. [10] showed a good association between HGS and the Subjective Global Assessment.

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Stenvinkel et al. [11] identified a strong correlation between HGS and lean body mass, as assessed by dual-energy x-ray absorptiometry (DXA), in patients with chronic kidney disease before the beginning of the dialytic therapy. However, no study has classified the MF of patients using HD based on HGS reference data from a healthy population, and only a few studies have evaluated the influence of dialysis variables on HGS. Thus, the present study was designed to evaluate the MF of patients on HD using HGS and to investigate the dialysis determinants of maximal voluntary HGS.

Materials and methods

Subjects

The study was a cross-sectional analysis of 43 patients on HD (25 men) treated at a private clinic (RenalCor Clinic) in Rio de Janeiro, Brazil. Subjects had to be 18 to 75 y of age and been on maintenance HD for at least 6 mo before the study. The dialysis sessions were 3.5 to 4.5 h three times per week, with a blood flow greater than 300 mL/min, a dialysate flow of 600 mL/min, and a bicarbonate buffer.

Patients with inflammatory diseases, known malignancies, or any upper limb malformation were excluded. The main causes of chronic kidney disease were hypertensive nephrosclerosis (58.1%) followed by diabetic nephrosclerosis (13.9%), polycystic kidney disease (9.3%), chronic glomerulonephritis (9.3%), and other diseases or unknown cause (9.3%).

The institutional review board of the Faculty of Medicine of the Fluminense Federal University approved all procedures of the study, which were explained to the patients who gave their written informed consent.

Handgrip strength

Handgrip strength was measured on the non-fistula side before and after a dialysis session in the same individuals using Jamar mechanical dynamometers (Sammons Preston, Masan, Korea) with a precision of 0.5 kg. Subjects were instructed to self-adjust the dynamometer so that it fit comfortably to their hand size to obtain the best performance. Before data collection, a warmup section was conducted so that the subjects could become acquainted with the instrument and procedures and choose the best adjustment. Subjects were instructed to grip the dynamometer with maximum strength in response to a voice command. The subjects stood with both arms extended sideways from the body with the dynamometer facing away from the body. Three trials were performed with a rest period of at least 1 min between trials and the highest HGS value, before and after the HD session, was used in the analyses. The HGS measurement was highly acceptable and no subject refused to participate. HGS values after HD less than the 10th percentile of a population-based reference study conducted in Rio de Janeiro were considered MF loss [12]. The HGS measurement was performed in the right arm in 70.8% of subjects with MF loss and 68.4% of those with preserved MF.

Each patient's medical chart was reviewed by a researcher who obtained all relevant clinical (time on dialysis and history of diabetes) and dialytic session data (ultrafiltration, interdialytic body weight gain, urea clearance [Kt/V], urea before and after HD, systolic and diastolic blood pressures before and after HD, and difference in systolic and diastolic blood pressures).

Nutritional assessment

Anthropometric measurements were obtained immediately after the HD session by a trained researcher. Body mass index (BMI) was calculated as body mass divided by stature squared. The ISRNM panel recommends that a BMI lower than 23 kg/m^2 is a marker of PEW [2]. Biceps, triceps, subscapular, and suprailiac skinfold thicknesses were measured to the nearest millimeter using a Lange Skinfold Caliper (Beta Technology Incorporated, Cambridge, Maryland, USA). Biceps and triceps skinfolds, upper midarm circumference (MAC), and forearm circumference were measured on the non-fistula side using standard techniques [13]. Three sets of measurements at each site were averaged and used in the analyses. Muscle mass area (MMA) was calculated using the following equation: $MMA = ([MAC\ \{cm\} - \pi \times \text{triceps skinfold}\ \{cm\}]^2/4\pi) - n$, where $n = 10$ for men and 6.5 for women [14]. Body composition variables (lean body mass and percentage of body fat [%BF]) were assessed according to the method of Durnin and Womersley [15] in all subjects and DXA scans were conducted in 31 subjects (Prodigy Advanc Plus, Lunar Corp., Madison, WI, USA).

Biochemical variables

Blood samples were obtained from the arterial HD line before the start of the session (cortisol, at 08:00 h) and after the patients had fasted overnight, and serum was immediately frozen at −80°C until analyzed. Serum albumin (bromcresol green method), hemoglobin, and urea were measured using standard laboratory methods. Serum cortisol was determined by competitive immunoassay.

Statistical analysis

Results were expressed as mean ± standard deviation, median (minimum to maximum), or percentage of change, as applicable. Student's *t* test was used to examine the difference between means and the Mann-Whitney test was used for non-parametric data. Pearson's or Spearman's correlation coefficient was calculated to examine the relation between variables. Statistical significance was accepted as $P < 0.05$. The statistical analyses were conducted using SPSS 11.0 (SPSS, Inc., Chicago, IL, USA).

Results

Age, time on dialysis, BMI, triceps skinfold, MAC, MMA, and %BF were not significantly different between men and women (Table 1). The HGS values of men were significantly higher than of those of women but were not statistically different before or after HD session. Thus, HGS values after HD were used to assess MF because the anthropometric measurements were made after the dialysis session.

Loss of MF was observed in 24 patients (55.8%), 12 men and 12 women. The subjects with preserved MF were younger and had higher values of forearm circumference, MAC, and MMA. Biochemical variables and dialysis factors, ultrafiltration, interdialytic body weight gain, Kt/V, urea before and after HD, systolic and diastolic blood pressures before and after HD, and the difference in systolic and diastolic blood pressures (before HD minus after HD) were not different between subjects with preserved MF and loss of MF (Table 2).

Handgrip strength after HD was not correlated with biochemical and dialytic variables, but it correlated significantly with forearm circumference ($r = 0.50$), lean body mass assessed by anthropometry ($r = 0.55$), and by DXA ($r = 0.51$), age ($r = -0.37$),

Table 1
Anthropometric and demographic measurements of subjects*

	All ($n = 43$)	Men ($n = 25$)	Women ($n = 18$)	*P* for comparison between genders
Age (y)	54.5 ± 12.2	54.4 ± 12.3	54.7 ± 12.5	0.953
Time on dialysis (mo)	62.2 ± 51.4	59.6 ± 51.9	65.8 ± 51.9	0.700
HGS before HD (kg)	23.2 ± 11.9	29.8 ± 10.3	14.1 ± 7.0	<0.0001
HGS after HD (kg)	23.6 ± 11.5	30.2 ± 9.9	14.5 ± 6.3	<0.0001
Body mass (kg)	67.5 ± 15.2	74.4 ± 13.7	57.9 ± 11.6	<0.0001
Stature (m)	1.64 ± 0.11	1.72 ± 0.06	1.54 ± 0.06	<0.0001
BMI (kg/m^2)	24.6 ± 4.2	24.9 ± 4.0	24.3 ± 4.6	0.632
FAC (cm)	22.7 ± 3.2	24.3 ± 2.7	20.5 ± 2.6	<0.0001
MAC (cm)	27.7 ± 3.9	27.9 ± 3.8	27.3 ± 4.2	0.604
TSF (mm)	14.9 ± 6.1	13.3 ± 4.9	17.2 ± 7.1	0.072
MMA (cm^2)	34.5 ± 11.6	35.9 ± 12.8	32.3 ± 9.6	0.337
%BF—anthropometry	30.1 ± 7.2	27.5 ± 6.6	34.2 ± 6.4	0.004
%BF—DXA†	28.2 ± 9.2	26.2 ± 8.4	30.9 ± 9.4	0.161
LBM—anthropometry (kg)	47.3 ± 10.4	53.3 ± 7.9	37.7 ± 5.3	<0.0001
LBM—DXA (kg)†	43.5 ± 10.9	50.6 ± 7.9	33.8 ± 6.7	<0.0001

%BF, percentage of body fat; BMI, body mass index; DXA, dual-energy x-ray absorptiometry; FAC, forearm circumference; HD, hemodialysis; HGS, handgrip strength; LBM, lean body mass; MAC, upper midarm circumference; MMA, midarm muscle area; TSF, triceps skinfold thickness

* Values are presented as mean ± SD.
† $n = 31$ (18 men and 13 women).

Table 2
Determinants of muscle function, assessed by HGS after HD, of subjects*

	Muscle function loss (HGS <10th) ($n = 24$)	Preserved muscle function (HGS >10th) ($n = 19$)	P for comparison between muscle functions
Men (%)	50.0	68.4	—
Diabetic patients (%)	16.7	10.5	—
HGS before HD (kg)	16.1 ± 8.9	32.1 ± 8.9	<0.0001
HGS after HD (kg)	16.3 ± 7.6	32.8 ± 8.8	<0.0001
Age (y)	57.9 ± 8.9	50.2 ± 14.5	0.038
Time on dialysis (mo)	66.6 ± 57.6	56.7 ± 43.1	0.573
BMI (kg/m^2)	24.0 ± 4.1	25.5 ± 4.5	0.263
FAC (cm)	21.9 ± 3.7	23.7 ± 2.1	0.049
MAC (cm)	26.4 ± 3.2	29.2 ± 4.2	0.023
MMA (cm^2)	30.7 ± 10.3	39.0 ± 11.8	0.022
BMI (kg/m^2)	24.0 ± 4.1	25.5 ± 4.5	0.263
%BF—anthropometry (%)	31.3 ± 5.9	28.7 ± 8.4	0.280
%BF—DXA (kg)†	29.8 ± 8.7	26.3 ± 9.4	0.293
LBM—anthropometry (kg)	44.7 ± 10.1	50.3 ± 10.1	0.094
LBM—DXA (kg)†	41.0 ± 9.1	46.5 ± 12.4	0.167
Albumin (g/dL)	3.8 ± 0.2	3.8 ± 0.2	0.630
Hemoglobin (g/dL)	11.1 ± 1.9	11.1 ± 2.3	0.969
Cortisol (μg/dL)	23.8 ± 6.1	21.2 ± 3.5	0.140
Urea before HD (mg/dL)	145.9 ± 31.4	144.0 ± 33.0	0.844
Kt/V	1.50 ± 0.25	1.44 ± 0.27	0.473
Interdialytic weight gain (kg)	4.3 ± 1.8	3.7 ± 2.2	0.308
SBP before HD (mmHg)	130 (100–160)	130 (100–180)	0.763
DBP before HD (mmHg)	80 (60–100)	80 (70–110)	0.109
SBP after HD (mmHg)	120 (90–150)	120 (60–160)	0.502
DBP after HD (mmHg)	80 (60–100)	80 (60–100)	0.333
Difference in SBP (mmHg)	10 (−20 to 50)	10 (−10 to 40)	0.589
Difference in DBP (mmHg)	0 (−10 to 30)	0 (−20 to 40)	0.739

%BF, percentage of body fat; BMI, body mass index; DXA, dual-energy x-ray absorptiometry; FAC, forearm circumference; HD, hemodialysis; HGS, handgrip strength; Kt/V, urea clearance; LBM, lean body mass; MAC, upper midarm circumference; MMA, midarm muscle area; DBP, diastolic blood pressure; SBP, systolic blood pressure

* Values are presented as percentage, mean ± SD, or median (minimum–maximum).

† $n = 31$ (18 men and 13 women).

and %BF evaluated by anthropometry ($r = -0.37$; Table 3). HGS after HD correlated with stature and body mass but not with BMI. BMI values ranged from 16.7 to 34.2 kg/m^2 and 16 patients (37.2%) presented with PEW (BMI <23kg/m^2). Interestingly, the HGS of eutrophic men and women (29.9 ± 9.3 and 13.0 ± 6.2 kg, respectively) was not greater than of subjects with PEW (31.0 ± 12.0 kg for men, 16.0 ± 6.4 kg for women).

Discussion

Handgrip strength has been recognized as a useful tool in assessing the MF and nutritional status of hospitalized patients [16,17]. Although some studies in patients on HD [9,10] used HGS normalized for age- and gender-matched healthy individuals, HGS has never been used to assess the nutritional status of patients on HD using a population-based set of reference values. In general, reference values are obtained in convenient samples of healthy young subjects. Schlüssel et al. [12] established reference data of right and left HGS values in a representative sample of healthy adults from a municipality of Brazil. Using these reference data, most patients on HD in the present study presented MF loss using an arbitrary cut-off point (10th percentile). In fact, there is no definition of a cut-off point that defines malnourishment or normality. Klidjian et al. [16] used a value equal to 85% of HGS mean values observed in a healthy sample as the cut-off point to identify the patients at risk of complications in the post-surgical period. Matos et al. [18] assumed that HGS values in

Table 3
Matrix of Pearson's correlation coefficients among HGS, anthropometric, and body composition variables

Variable	HGS after HD	HGS before HD	Stature	Body mass	BMI	TSF	MMA	FAC	%BF-Ant	%BF-DXA	LBM-Ant
HGS before HD	0.97§										
Stature	0.58§	0.58§									
Body mass	0.40‡	0.43‡	0.64§								
BMI	0.07	0.11	0.05	0.79§							
TSF	−0.14	−0.10	−0.18	0.32†	0.55§						
MMA	0.27	0.29	0.17	0.61§	0.65§	0.15					
FAC	0.50‡	0.51‡	0.53§	0.77§	0.59§	0.26	0.43‡				
%BF–Ant	−0.37†	−0.33†	−0.33†	0.26	0.58§	0.74§	0.23	0.13			
%BF–DXA*	−0.23	−0.10	−0.19	0.44†	0.70§	0.51‡	0.52‡	0.30	0.71§		
LBM–Ant	0.55§	0.56§	0.79§	0.90§	0.54§	−0.02	0.53‡	0.72§	−0.18	0.18	
LBM–DXA*	0.51‡	0.50‡	0.81§	0.80§	0.46‡	0.04	0.50‡	0.61§	−0.09	−0.03	0.87§

Ant, anthropometry; %BF, percentage of body fat; BMI, body mass index; DXA, dual-energy x-ray absorptiometry; FAC, forearm circumference; HD, hemodialysis; HGS, handgrip strength; LBM, lean body mass; MAC, upper midarm circumference; MMA, midarm muscle area; TSF, triceps skinfold thickness

* $n = 31$ (18 men and 13 women).

† $P < 0.05$.

‡ $P < 0.01$.

§ $P < 0.001$.

the lower end of a distribution were indicative of some functional loss. In their study, improved performance of HGS as a screening method for nutritional risk was found in subjects with lower strength, allocated in the first quartile, with higher sensitivity than specificity compared with higher cut-off values of HGS (second and third quartiles).

Few studies evaluating HGS in patients on HD have described the details of the protocols used, which makes comparisons between results very difficult to perform. It is recognized that full extension of the arm allows individuals to produce higher values of HGS compared with values obtained when the elbows are flexed at 90°. Moreover, HGS has been found to be greater while standing. Further, HGS values depend on the model of dynamometer used, the appropriate calibration, the number of measurements performed, the rest periods between measurements, and a warm-up practice before the test [6]. Specifically in subjects on HD, other factors such as day of assessment (dialysis or non-dialysis day) or period of assessment (before or after an HD session) may also influence the results.

In the present study, HGS was performed on the dialysis day, before and after an HD session. HGS values before and after HD were not different and dialysis variables were not correlated with HGS values measured before or after the HD sessions. Thus, HGS measurements can be performed before or after an HD session.

Various studies have shown that HGS is lower in malnourished patients on HD [9,19]. In some of these studies, the HGS mean values were similar to the values found in the present study. Constatin-Teodosiu et al. [20] reported HGS values of 26.4 ± 1.5 kg in male (58 ± 2 y of age) and 14.1 ± 1.1 kg in female (60 ± 2 y of age) patients on HD. Based on the Subjective Global Assessment, the HGS values of mildly malnourished patients (24 ± 9 kg for men and 13 ± 7 kg for women) reported by Qureshi et al. [9] are very similar to the values of the present sample of patients on HD.

Similar to healthy samples [12,21,22] and as documented in patients on HD [9,11,19,20], men had higher HGS mean values than women and age was negatively correlated with HGS. Apart from age and gender, other factors such as muscular weakness caused by uremia can also affect HGS [23–25]. However, contrary to our expectations, adequacy of dialysis, defined by Kt/V, and the other dialytic and biochemical variables were not associated with HGS. Qureshi et al. [9] also did not find a correlation between HGS and Kt/V in patients on HD. In contrast to Wang et al. [23], no correlation between hemoglobin and HGS was found in the present study.

In patients on HD, serum cortisol levels seem to be higher than in age- and gender-matched healthy subjects [26]. Although negative effects on muscle strength have been found after long-term exposure to high levels of cortisol [27], in the present study cortisol was not correlated with HGS. Serum cortisol levels are more sensitive to fluctuations during the day and with stress than other measurements of free cortisol, such as salivary cortisol. Thus, different associations with muscle parameters may be found for different time points and techniques of cortisol measurement [28].

As expected, body mass and stature were correlated with HGS. Stature is directly correlated with HGS, possibly because it is the factor that is more closely related to lean body mass [21]. However, in the present study, BMI was not correlated with HGS. In fact, the literature has documented a weak correlation between BMI and HGS [21], which can be explained by the inability of BMI to differentiate lean from fat mass [29,30].

Interestingly, %BF assessed by anthropometry was negatively correlated with HGS. Cordeiro et al. [31] also founded lower HGS values in patients on HD with higher estimates of abdominal fat deposition. Thus, it seems that low muscle mass can occur despite fat accumulation, and one possible explication for this would be the proinflammatory phenotype presented by individuals with abdominal fat deposition. This confirms that subjects can have normal or higher BMI and have a depletion process, thus increasing the need for screening procedures related to functional status. Therefore, HGS may be an early screening tool for MF loss in individuals who present normal anthropometric values. Vaz et al. [32] showed that HGS should be able to distinguish between anthropometrically similar groups who have different functional nutritional statuses as is the case between individuals who are underweight and those who are constantly energy deficient.

Handgrip strength is a simple, quick, non-invasive, inexpensive, rapid, and objective procedure. In addition, it has other advantages as a diagnostic/screening tool in patients on HD. First, HGS is correlated with estimates of body composition assessed by DXA [11,33], one of the most reliable methods for lean body mass monitoring [34]. Second, HGS does not appear to be influenced by hydration status and inflammation, unlike serum albumin, the most common nutritional marker used in patients on HD [18,23,33]. Third, HGS provides important prognostic information to patients on HD [11,23,33]. However, HGS relies on the motivation of the subjects [6], and therefore it is imperative that researchers and clinicians are sufficiently trained in HGS assessment.

The present study is limited. The lack of some expected correlations may be the result of a small sample, and the cross-sectional design not permit an evaluation of any causal associations between dialysis variables and MF.

Conclusion

Patients on HD presented a high prevalence of MF loss assessed by HGS. Early detection of MF loss, even in the presence of overweight, may allow the implementation of appropriate therapeutic measures. Indeed, HGS may be used as a reliable nutritional marker during HD because it is not influenced by dialysis variables.

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