Original Article

Body composition of chronic renal patients: anthropometry and bioimpedance vector analysis[1]

Viviane Soares[2]
Ivan Silveira de Avelar[2]
Sara Rosa de Sousa Andrade[2]
Marcus Fraga Vieira[3]
Maria Sebastiana Silva[3]

Objective: to compare the body composition of patients undergoing hemodialysis with that of healthy individuals using different methods. Method: cross-sectional study assessing male individuals using anthropometric markers, electrical bioimpedance and vector analysis. Results: the healthy individuals presented larger triceps skinfold and arm circumference (p<0.001). The bioimpedance variables also presented significant higher values in this group. Significant difference was found in the confidence interval of the vector analysis performed for both the patients and healthy individuals (p<0.0001). The tolerance intervals showed that 55.20% of the patients were dehydrated, 10.30% presented visible edema, and 34.50% were within normal levels of hydration. Bioimpedance and vector analysis revealed that 52% of the patients presented decreased cell mass while 14.00% presented increased cell mass. Conclusions: the differences in the body composition of patients and healthy individuals were revealed through bioimpedance and vector analysis but not through their measures of arm circumference and arm muscle area.

Descriptors: Anthropometry; Electric Impedance; Renal Dialysis.

Corresponding Author:
Viviane Soares
Rua Amazonas, 294
Centro
CEP: 75024-080, Anápolis, GO, Brasil
E-mail: ftviviante@gmail.com

Introduction

The number of studies addressing the body composition of chronic renal patients undergoing hemodialysis (HD) due to changes in fat tissue and muscle metabolism, and consequently, presenting water-electrolyte imbalances that pose the risk of mortality and morbidities, has recently increased[1-2].

The methods commonly used to assess body compartments are skinfold thickness, bioelectrical impedance (BIA), and bioelectrical impedance vector analysis (BIVA) for being simple, fast, reproducible and less costly[3]. The triceps skinfold associated with arm circumference has been used to verify arm circumference and muscle area, which are important parameters in assessing the nutritional state of patients undergoing HD[4]. BIA is a method based on regression equations to estimate one's total body water, lean, fat and cell mass. Some studies report that results may be overestimated when BIA is employed in hemodialysis patients[3,5].

BIVA, on the other hand, based on the length of vector impedance and on its phase angle, measured in 50hz, may be subject to impedance measuring error and be affected by the patients' physiological variability. BIVA's measurement variables are resistance (R) and reactance (Xc), which are the same measures as BIA, only that here they are normalized by height and plotted as vectors in the RXc plane. The vector's length reflects the individual's level of hydration, so that the higher the vector the lower the quantity of water and the greater the resistance (R), while a larger phase angle is associated with a better nutritional state[6]. This technique permits assessing the patient's level of hydration and distinguishing body tissues with greater contents of water (muscles) and those with lower contents of water (fat tissue, lungs and bones)[3]. Reactance (Xc) expresses the capacity of cell membranes to store energy since they act as electrical capacitors when an electrical current passes through. Cell membranes act as conductors and cell content acts as dielectric material, storing the charge when the current passes between intra and extracellular compartments[3].

Studies on BIVA report advantages on the monitoring and planning of therapy for HD patients with water-electrolytes imbalance without the need to make assumptions about one's body composition[7]. This method is reliable to detect changes occurring in the level of hydration and cell mass, as well as to indicate survival in this population[8-10]. Other studies indicate BIVA has an excellent correlation with laboratory parameters: albumin, normalized protein nitrogen appearance (nPNA) and dialysis adequacy (Kt/V)[11].

Due to the importance of anthropometric methods and bioelectrical impedance in the assessment of body composition of different populations, our hypothesis in this study was that the body composition of individuals with chronic renal disease undergoing hemodialysis is different from that of healthy individuals when measured through skinfold, resistance, capacitance and phase angle. Therefore, this study's objective was to compare the body composition of patients with chronic renal disease undergoing hemodialysis with the composition of healthy individuals through different methods usually employed in clinical research.

Method

This cross-sectional and analytical study was conducted with 47 male patients with chronic renal disease cared for by a hemodialysis service in Goiania (GO), Brazil. A total of 29 patients were included in the study after applying the inclusion criteria: being 18 years old or older, under treatment for more than three months, and having hypertension and/or diabetes mellitus under control; and exclusion criteria: having a chronic lung disease, severe cardiac disease, or cognitive deficit. In order to compose the control group (CG), a stratified randomization was performed of 40 individuals 18 years old or older, but in the same age group, without significant differences in terms of weight, height, and BMI, and without chronic lung disease or severe heart disease. The Institutional Review Board at the Federal University of Goiás approved the study (No. 294/11). All the 29 male patients and 40 healthy male individuals signed free and informed consent forms according to Resolution 196/96, Brazilian Council of Health.

An identification form addressing the subjects' age, duration of hemodialysis, marital status, education, income, cause of disease and smoking was completed. Filizola scales with capacity for 150 kg together with a SANNY portable stadiometer were used to collect anthropometric data. Arm circumferences were measured with an inextensible metrical tape and the triceps skinfold thickness with a Lange caliper. A monofrequency bioelectrical impedance device (50 kHz) (Quantum II da RJL systems, CA, USA) with a tetrapolar electrode system with accuracy of resistance and reactance between 0-1000 ohms was used to analyze body composition.

All the procedures were performed concomitantly with the routine laboratory exams. Hematocrit, hemoglobin and Kt/V were used to characterize the sample in clinical terms. Arm circumferences (AC) were measured at the midpoint between the acromion and olecranon. The following formula was used to compute the arm muscle circumference (AMC) and arm muscle area (AMA): AMC (mm) = AC – π(TSF) and AMA= [AC - π(TSF)]²/4π. The TSF was clamped at a pressure of 10 g/mm² of surface area contact[12]. BMI was calculated by dividing weight and height squared after HD and classified according to WHO[13]. All the measures were taken after the weekly intermediary hemodialysis session and always on the upper arm opposed to the arteriovenous fistula. The average of the three measures was used for the analysis.

Bioimpedance was performed with the patient in supine position on a nonconductive surface with limbs approximately 30 degrees apart. The patients and healthy subjects were advised not to exercise eight hours before and not to drink alcohol 12 hours before the exam, not to apply any kind of body lotion, and watch for spiking fever. BIA was taken between 20 and 30 min after the weekly intermediate dialysis session. Electrodes were placed on the opposite site of the vascular access on the dorsal hand region (one between the head of the ulna and the radius and another on the proximal phalanx of the third finger) and on the dorsal foot region (one electrode between the medial and lateral malleolus and another in the region of the third metatarsal). Skin in these sites was cleaned with alcohol. Three measurements were taken of R and Xc in all patients and healthy individuals included in the study. The highest value was used to calculate the phase angle (PA) (Xc/R x 180º/π).

The estimates of total body water (TBW), fat mass (FM), fat free mass (FFM) and phase angle (PA) were obtained through software developed by RLJ Systems, Quantum II (CA, USA). The estimate of body cell mass (BCM) was obtained with the formula [(TBW-EW)/0.732][14]. The BIA's components, R and Xc, obtained from both CG and PG were analyzed through vector impedance (BIVA), where the components (R/H and Xc/H), normalized by height, were plotted. These measures were dotted ellipse shaped in the RXc plane both for the confidence and tolerance intervals[9].

Statistical procedure. Data are expressed as average, standard deviation and frequency. Independent variables were: age and duration of hemodialysis while dependent variables included: BMI, AC, AMC, TSF, R, Xc, PA, BCM, FFM, and TBW. Normality of data was verified by Shapiro-Wilk test. The t-test was used for independent samples to compare the anthropometric variables and the BIA variables of both groups. Associations of PA and BCM with the anthropometric variables and body composition of the PG were verified using Person's coefficient correlation. The coefficient of correlation was also found between R/H and Xc/H. Vectors were analyzed by Hotelling's T-squared test and univariate analysis (F test). The level of significance adopted was $p \leq 0.05$. Data were analyzed in Statistical Package for the Social Sciences (SPSS) and BIVA software 2002.

Results

The participants' profiles show that 55% of the PG were former smokers, 69% had an income below five times the minimum wage, 62% completed primary school, 72% were married, and 52% were 60 years old or younger. In the CG, 53% were former smokers, 65% had income below five times the minimum wage, 45% completed primary school, 46% were married, and 58% were 60 years old or younger. The groups did not significantly differ in terms of age, height and weight (Table 1).

The PG's BMI indicated that 62% were within expected values, 31% were pre-obese and 6.4% presented level I obesity. In the CG, 83% were with normal weights and 13% were pre-obese. The average BMI was higher in the CG than in the PG, though without significant differences. The clinical parameters indicating anemia and dialysis adequacy are presented in Table 1. The confidence intervals (CI) of hematocrit, hemoglobin and dialysis adequacy were: 23.50-42.40%., 7.80-14.50 mg/dL, 0.83-3.00 (Table 1), respectively.

In the anthropometric assessment, the groups' triceps skinfold (TSF) (PG: CI between 9.42 – 22.9 mm; CG: CC between 13.38-37.94 mm) and arm circumference (AC) (PG: CI between 25.31-32.65 cm; CG: CI between 28.74-36.94 cm) presented significant differences (Table 2). The measures that reflect muscle mass, AMC and AMA, were higher in the CG, though with no significant differences. The healthy individuals presented higher and significant values in relation to BIA's variables, resistance, reactance, and phase angle when compared to patients. The CG also presented higher average values of body mass index (BMI), fat free mass (FFM) and total body water (TBW): 11.60%, 11.52% and 15.22%, respectively (Table 2).

Table 1 - Demographic and clinical characteristics of the group of patients and the control group

	Group of Patients (n=29)	Control Group (n=40)	p
Age (years)	54.52±13.53	52.90±14.20	0.63
Weight (kg)	69.15±10.71	73.36±11.01	0.12
Height (m)	1.69±0.07	1.68±0.06	0.58
Body Mass Index (kg/m²)	24.22±3.75	25.94±3.69	0.06
Hemodialysis (months)	64.41±43.81	-	-
Hematocrit (%)	33.70±4.26	-	-
Hemoglobin (g/dL)	11.03±1.50	-	-
Dialysis adequacy (Kt/V)	1.72±0.51	-	-

Table 2 - Anthropometric characteristics and body composition (BIA) of the patient and the control groups

	Group of Patients (n=29)	Control Group (n=40)	p
Triceps skinfold (mm)	16.16±6.74	25.66±12.28	0.001*
Arm circumference (cm)	28.98±3.67	32.84±4.1	0.001*
Arm muscle circumference (cm)	23.91±3.12	24.78±5.81	0.50
Arm muscle area (m)	4560.51±1235.25	5079. 25±2293.10	0.30
Resistance (ohm)	587.10±87.89	482.37±49.03	0.001*
Reactance (Xc) (ohm)	64.48±15.34	52.20±8.01	0.01†
Phase angle (º)	6.30±1.35	6.83±0.83	0.05†
Body cell mass (kg)	28.96±3.41	32.32±3.55	0.001*
Fat free mass (kg)	48.80±6.72	54.42±6.30	0.01†
Total body water (L)	35.35±5.33	40.73±4.70	0.001*

* $p \leq 0.05$; † $p < 0.001$

The impedance vector analysis performed using BIVA software 2002 indicated that the body composition of patients was altered according to Picoli's classification (1994)[9]. Figure 1A presents the confidence interval between R/H and Xc/H of the PG (black ellipsis) and of the CG (dotted ellipsis). Hotelling's T (T²=36.1) and F test (F=17.8) show significant differences (p=0.0001) between groups. Figure 1B shows the intervals of tolerance (50%, 75% and 95%) of the CG, which was considered a reference population for the PG. In terms of hydration, the tolerance intervals revealed that 55.20% of the patients were out of the upper ellipsis with a larger axis indicating dehydration; 10.30% were in the lower quadrant, which indicates visible edema; while 34.50% presented normal hydration within the ellipsis' 75% and 95%. The BIA's vector analysis shows that 52% of the patients presented reduced cell mass, while 14.00% presented increased cell mass.
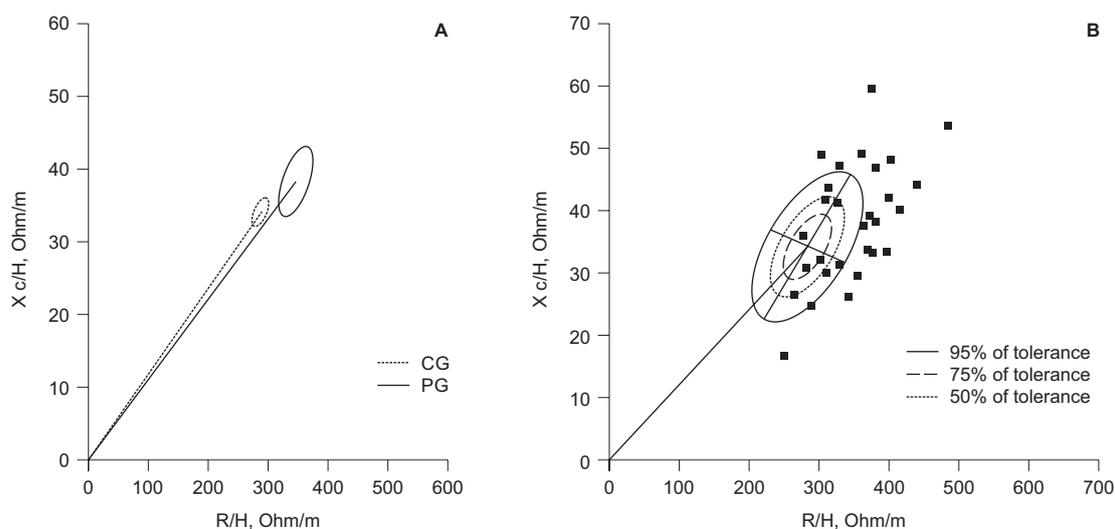

Figure 1 - (A) Confidence interval for vector bioelectrical impendence: Patient Group (dotted ellipsis) and Control Group (black ellipsis). Statistical difference between the groups p< 0.001. (B) Interval of tolerance for percentiles 50%, 75% and 95% of the PG

The analysis of correlation indicates negative and significant association between PA-age (r=-0.70, p<0.001) and positive significant association between PA-Xc (r=0.80, p<0.001). When BCM was correlated with BMI (r =0.63, p<0.001), with AC (r=0.74, p<0.001), with AMC (r=0.52, p<0.001), and with AMA (r=0.53, p<0.001), associations were positive and significant (Table 3).

Table 3 - Correlation between Phase angle and Body cell mass, anthropometric markers and body composition

Variables	Phase angle (º)		Body cell mass (kg)	
	r	p	R	p
Age (years)	-0.70	0.001*	-0.10	0.65
Dialysis adequacy (Kt/V)	0.03	0.90	0.04	0.85
Duration of hemodialysis (months)	0.02	0.90	-0.11	0.60
Body Mass Index (kg/m²)	0.24	0.22	0.63	0.001*
Triceps skinfold (mm)	-0.10	0.62	0.20	0.12
Arm circumference (cm)	0.20	0.11	0.74	0.001*
Arm muscle circumference (cm)	0.20	0.08	0.52	0.001*
Arm muscle area (mm²)	0.23	0.06	0.53	0.001*
Reactance (ohms)	0.80	0.001*	-0.40	0.05†
Resistance (ohms)	- 0.12	0.54	-0.82	0.001*

*p<0.001; †p≤0.05

Discussion

The anthropometric measures along with BIA and BIVA variables obtained from the chronic renal patients undergoing hemodialysis and the healthy individuals were significantly different. BIVA was a unique method used to assess hydration and cell mass and showed considerable variability of vectors for the PG. Additionally, the anthropometric variables from the patients submitted to hemodialysis were significantly associated with body cell mass, (BCM) while no association was found between these and the phase angle (PA) (Table 3).

According to NKF (National Kidney Foundation)[15], the anthropometric measures of patients undergoing HD produce semi-quantitative estimates of body components, provide information regarding the patients' nutritional state and can also be compared to NHANES II (National Health and Nutrition Examination Survey II) or to data from healthy individuals. This study's results revealed significant differences for the triceps skinfold (TSF) and arm circumference (AC), but not for the arm muscle circumference (AMC) and arm muscle area (AMA). It indicates that both groups present a similar quantity of muscle tissue, though TSF, which is related to fat tissue, was higher in the CG. It is also important to note that the measure TSF in the PG was within the expected considering the patients' ages. The average values found in the PG were similar to those found in the literature[16], though only one study[17] presented the results stratified by gender, which enabled a better comparative analysis.

The principle of BIA is that body tissues provide different oppositions to electric current passage(6). Its integral components, resistance (R) and reactance (Xc), are usually related to body water content and the capacity of cells to store energy, respectively. Clinically, R expresses the level of hydration and Xc reflects the nutritional state[3]. Some studies, addressing chronic renal patients undergoing HD, report R and Xc values similar to those found in this study, 434.5-691 ohms and 31-55 ohms, respectively[11,17]. There is, however, a study conducted with 58 Brazilian patients reporting R above 700 ohms[16].

The Phase angle is a parameter that can be obtained directly from BIA and does not depend on regression equations to be estimated, which eliminates potential sources of error[18]. It is considered a useful tool in the prognosis of renal patients[19] and its reference values, according to age, have already been described in the literature[20]. In this study, 55.2% of the PG presented PA below the expected, while 85% of the CG presented values within the expected. PA is directly related to cell membranes, which is represented by reactance. PA values below the expected are consistent with decreased reactance, cell death and rupture of selective cell membranes, which suggest worse nutritional state[17]. A strong and significant correlation between

age and PA was confirmed and is in agreement with other studies, though significant correlation with BMI was not found. Individuals with higher BMI also present a higher quantity of cells (muscle and fat cells) and their results also reflect higher PA. Additionally, PA can also be considered a functional index and general health indicator, especially as age advances[20].

The two groups presented similar demographic characteristics and reliably characterize the differences found in the body composition of patients with chronic renal disease. Total body water (TBW), measured using BIA, indicated the CG had a greater volume of water compared to the PG. This information is noteworthy since assessment was performed in the weekly intermediary session and after therapy, which usually takes from three to four hours and aims to eliminate all the excess fluid and urea, among other substances, that were acquired between dialysis sessions. BCM was lower in the PG indicating a smaller reserve of muscle tissue, a fact that may be verified by the positive correlation with AC, AMC, AMA, and BMI. BCM is clinically important because it facilitates finding the appropriate "dry" weight and helps identifying individuals at risk of malnutrition. Because it is a parameter that indicates concentration of total protein and intracellular water and is also considered a metabolically active compartment, changes can lead to reduced muscle tissue and dehydration in addition to cardiovascular and respiratory alterations, which in the long run can contribute to mortality among these individuals[21]. The greatest advantage of using BCM is that it does not include extracellular water by estimation, which is increased in individuals with chronic renal disease, and frequently causes overestimation of the nutritional value, that is, it may falsely indicate hydration[21]. These results can clinically contribute to diet planning, both during intervention and monitoring, aiming to improve patients' nutritional state.

Vector analysis revealed that the PG vector was longer and more inflected than the CG vector, in addition to significant differences in hydration and cell mass (Figure 1). BIVA is a valuable tool for clinical use given its safety, simple use, low cost and accuracy[5] and can assist in the detection and monitoring of changes in the body composition of HD patients. Monitoring the hydration states of these patients contributes to the control of PA, the severity of left ventricular hypertrophy and residual renal function, which are risk factors for mortality[22-23].

A study[9] verified good sensitivity and specificity for the threshold of visible edema in HD patients in the low portion of the ellipsis of tolerance of 75%. Five patients were found in this study within this ellipsis with edema. Even though the measures were taken after treatment, many factors explain fluid retention, such as increased fluid intake, which limits the removal of overweight during a single hemodialysis.

When data were plotted in the RXc graph, we noted a large variation in most patients that remained out of the ellipsis boundaries. Since BIA was not performed before the HD session, analysis of these vectors' behavior was not possible. Some factors, such as dialysis adequacy, calculation of "dry" weight and duration of hemodialysis, can influence water-electrolytes balance and lead to changes in hydration, as observed in this study[10].

Conclusions

This study revealed differences in the body composition of patients and healthy individuals with similar anthropometric characteristics (age, weight, height and BMI). Anthropometry (AMC and TSF) failed to establish differences in the measures of muscle tissue between the two groups, unlike BIA and BIVA, which safely reported differences. The results obtained through vector analysis suggest this method can detect changes in the body composition of HD patients and favor monitoring of these patients in clinical practice. Even though the bioimpedance parameters are not the best markers for assessing body composition, the method is reliable, practical and low costand able to detect and assess changes in the level of hydration and body cell mass of renal chronic patients undergoing hemodialysis.

Study limitations

A limitation of this study is the fact that BIA was performed only after the hemodialysis session. If BIA had been performed before the HD session, it could overestimate the patients' level of hydration, not consistent with their actual condition. Hence, an analysis performed both before and after hemodialysis with weekly or monthly monitoring would enable a better clinical assessment of the patients' hydration and nutritional states. We also believe that vector analysis pre and post BIA would help the clinical management and efficacy of the hemodialysis treatment, since some studies show its use in the calculation of "dry weight".

Another limiting factor that should be noted is the low adherence of patients to the study and monitoring of patients in longitudinal studies.

Even though not generalizable, this study's results are relevant because they were obtained from a stratified sample and can be used in meta-analyses to determine the levels of scientific evidence and degree of recommendation of BIA to clinically assess patients with chronic renal disease undergoing hemodialysis.

We stress the need for more controlled studies with a larger number of individuals, including studies specific for females, due to the histological and physiological differences of muscle fibers. Other factors that should be addressed and controlled for in studies on body composition are climate change and seasonality of foods.

References

1. Beddhu S, Pappas LM, Ramkumar N, Samore M. Effects of body size and body composition on survival in hemodialysis patients. J Am Soc Nephrol. 2003;14(9):2366-72.

2. Wizemann V, Wabel P, Chamney P, Zaluska W, Moissl U, Rode C, et al. The mortality risk of overhydration in haemodialysis patients. Nephrol Dial Transplant. 2009;24(5):1574-79.

3. López-Gómez J. Evolución y aplicaciones de la bioimpedancia en el manejo de la enfermedad renal crónica. Nefrologia. 2011;31(6):630-4.

4. Frisancho AR. Triceps skin fold and upper arm muscle size norms for assessment of nutrition status. Am J Clin Nutrition. Oct 1974;27(10):1052-8.

5. Guldrís SC. Aplicaciones futuras de la bioimpedancia vectorial (BIVA) en nefrología. Nefrología. 2011;31(6):635-43.

6. Eickemberg M, Oliveira CCd, Roriz AKC, Sampaio LR. Bioimpedância elétrica e sua aplicação em avaliação nutricional. Rev Nutrição. 2011;24:873-82.

7. Piccoli A, Rossi B, Pillon L, Bucciante G. Body fluid overload and bioelectrical impedance analysis in renal patients. Min Electrol Metabolism. 1996;22(1-3):76.

8. Agostini P, Calvert R, Subramanian H, Naidu B. Is incentive spirometry effective following thoracic surgery? Interactive Cardiovasc Thoracic Surg. 2008 Apr;7(2):297-300.

9. Piccoli A, Rossi B, Pillon L, Bucciante G. A new method for monitoring body fluid variation by bioimpedance analysis: the RXc graph. Kidney Int. 1994;46(2):534-9.

10. Piccoli A. Identification of operational clues to dry weight prescription in hemodialysis using bioimpedance vector analysis. Kidney Int. 1998;53(4):1036-43.

11. Mushnick R, Fein PA, Mittman N, Goel N, Chattopadhyay J, Avram MM. Relationship of bioelectrical impedance parameters to nutrition and survival in peritoneal dialysis patients. Kidney Int. 2003;64:S53-S6.

12. Gibson RS. Principles of nutritional assessment. USA: Oxford University Press; 2005.

13. World Health Organization. Obesity: Previning and managing the global epidemmic. Report of a WHO consultation on obesity. Geneva; 1998.

14. Buchholz AC, McGillivray CF, Pencharz PB. Differences in resting metabolic rate between paraplegic and able-bodied subjects are explained by differences in body composition. Am J Clin Nutrition. 2003;77(2):371-8.

15. National Kidney Foundation. Kidney Disease Outcomes Quality Initiative. Clinical Practice Guidelines for Chronic Kidney Disease: Evaluation, Classification, and Stratification. Am J Kidney Dis. 2002;30(Suppl 1):1-226.

16. Kubrusly M, Oliveira CMC, Santos DCO, Mota RS, Pereira ML. Análise comparativa entre a albumina pré- e pós-dialise como indicadores do risco nutricional e de morbimortalidade em hemodiálise. J Bras Nefrol. 2012;34:27-35.

17. Oliveira C, Kubrusly M, Mota RS, Silva CAB, Choukroun G, Oliveira VN. The phase angle and mass body cell as markers of nutritional status in hemodialysis patients. J Renal Nutr. 2010;20(5):314-20.

18. Barbosa-Silva MCG, Barros AJD, Post CLA, Waitzberg DL, Heymsfield SB. Can bioelectrical impedance analysis identify malnutrition in preoperative nutrition assessment? Nutrition. 2003;19(5):422-6.

19. Maggiore Q, Nigrelli S, Ciccarelli C, Grimaldi C, Rossi GA, Michelassi C. Nutritional and prognostic correlates of bioimpedance indexes in hemodialysis patients. Kidney Int. 1996;50(6):2103-8.

20. Barbosa-Silva MCG, Barros AJD, Wang J, Heymsfield SB, Pierson RN Jr. Bioelectrical impedance analysis: population reference values for phase angle by age and sex. Am J Clin Nutr. 2005;82(1):49-52.

21. Dumler F, Kilates C. Use of bioelectrical impedance techniques for monitoring nutritional status in patients on maintenance dialysis. J Renal Nutr. 2000;10(3):116.

22. Machek P, Jirka T, Moissl U, Chamney P, Wabel P. Guided optimization of fluid status in haemodialysis patients. Nephrol Dial Transplant. 2010; 25(2):538-44.

23. Cheng LT, Chen W, Tang W, Wang T. Residual renal function and volume control in peritoneal dialysis patients. Nephron Clin Practice. 2006;104(1):c47-c54.

Erratum

Issue v21n6, page 1245

For

This study did not reveal differences in the body composition of patients and healthy individuals with similar anthropometric characteristics (age, weight, height and BMI).

Read

This study revealed differences in the body composition of patients and healthy individuals with similar anthropometric characteristics (age, weight, height and BMI).