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ORIGINAL

Dietary total antioxidant capacity and its association with anthropometric, biochemical, and functional parameters in chronic kidney disease patients on hemodialysis

Capacidade antioxidante total da dieta e sua associação com parâmetros antropométricos, bioquímicos e funcionais em pacientes com doença renal crônica em hemodiálise

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ABSTRACT

Objective

To investigate the association of dietary total antioxidant capacity with anthropometric, functional, and biochemical parameters in chronic kidney disease patients on hemodialysis.

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Methods

This is a cross-sectional study of hemodialysis patients in Western *Bahia*. A structured questionnaire, three 24-hour dietary recalls, anthropometric measurements and clinical and biochemical records were used for data collection. Dietary total antioxidant capacity was estimated using 24-hour dietary recalls data. A database of ferric reducing antioxidant power values for foods was used to evaluate the dietary total antioxidant capacity. Multiple linear regression was applied to assess the relationship between dietary total antioxidant capacity and anthropometric, functional, and biochemical parameters.

Results

A total of 97 patients were evaluated, of which 57.7% were men and 57.7% were aged between 36 and 59 years. After adjusting for gender, education level, and socioeconomic level, inverse associations were found between dietary total antioxidant capacity and body mass index (p=0.008). Handgrip strength (p=0.037) and serum albumin concentration (p=0.047) were positively associated with dietary total antioxidant capacity.

Conclusion

High dietary total antioxidant capacity is associated with low body mass index, high handgrip strength, and high serum albumin concentration in chronic kidney disease patients undergoing hemodialysis.

Keywords: Anthropometry. Antioxidants. Food Consumption. Renal Dialysis.

RESUMO

Objetivo

Investigar a associação da capacidade antioxidante total da dieta com parâmetros antropométricos, funcionais e bioquímicos em pacientes renais crônicos em hemodiálise.

Métodos

Este é um estudo transversal com pacientes em hemodiálise no Oeste da Bahia. Para a coleta de dados, utilizou-se um questionário estruturado, três recordatórios alimentares de 24 horas, aferição de medidas antropométricas e dados clínicos e bioquímicos dos prontuários. A capacidade antioxidante total da dieta foi estimada usando dados de recordatórios alimentares de 24 horas. Utilizou-se um banco de dados com valores de poder antioxidante redutor férrico para alimentos para avaliar a capacidade antioxidante total dietética. A regressão linear múltipla foi aplicada para avaliar a relação entre a capacidade antioxidante total da dieta e os parâmetros antropométricos, funcionais e bioquímicos.

Resultados

Foram avaliados 97 pacientes, sendo 57,7% homens e 57,7% com idade entre 36 e 59 anos. Após ajuste para sexo, escolaridade e nível socioeconômico, foram identificadas associações inversas entre capacidade antioxidante total da dieta e índice de massa corporal (p=0,008). A força de preensão manual (p=0,037) e a concentração de albumina sérica (p=0,047) foram associadas positivamente com a capacidade antioxidante total da dieta.

Conclusões

A capacidade antioxidante total dietética elevada está associada a um baixo índice de massa corporal, alta força de preensão manual e alta concentração de albumina sérica em pacientes com doença renal crônica em hemodiálise.

Palavras-chave: *Antropometria. Antioxidantes. Consumo de Alimentos. Diálise renal.*

INTRODUCTION

Chronic Kidney Disease (CKD) is a clinical condition characterized by gradual and progressive loss of renal function. It is associated with a variety of complications, including impaired excretory function and fluid and electrolyte imbalance, leading to decreased quality of life [1,2]. The number of CKD cases has increased over the past few years, and the disease has been recognized as a public health problem that requires attention [3]. Brazilian estimates from 2016 indicated that more than 10 million people had renal impairment and 100 thousand were on dialysis [4]. However, worldwide and national prevalence estimates of CKD are uncertain, increasing the difficulty of planning preventive and therapeutic interventions [5].

Chronic Kidney Disease induced changes in nutrient metabolism may lead to increased oxidative stress [6,7]. The accumulation of reactive oxygen species leads to nitric oxide inactivation and deficiency, which is a critical antioxidant that protects kidney function by increasing renal blood flow, enhancing pressure natriuresis, regulating tubule glomerular function and preserving fluid and electrolyte homeostasis. Nitric oxide deficiency and high levels of plasma O2 are considered critical promoters of oxidative stress [8]. The antioxidant defense system is a complex network of enzymatic and non-enzymatic antioxidants that mitigate the deleterious effects of reactive oxygen species [9,10]. This complexity implies that the activity of a single antioxidant compound cannot adequately represent the in vivo antioxidant status of the body.

The concept of Total Antioxidant Capacity (TAC) was introduced in the 1990s and considers the antioxidant capacity of all antioxidants present in food or body fluids [11]. TAC has been used as an epidemiological tool for determining the cumulative antioxidant capacity of foods and blood plasma [11,12]. Dietary TAC is an indicator of diet quality and can be used to assess the effects of dietary antioxidants and their interactions [13].

In renal patients, it is observed that traditional dietary restrictions and treatment of the disease have been associated with reduced intake of antioxidants, such as vitamins C, D and E, and with loss of vitamins and trace elements [14-17]. In this sense, Small *et al.* [18]. cite that it is likely that dietary antioxidants may interfere with the development and progression of CKD, promoting compensation for imbalances in oxidative stress.

Although the literature provides extensive data on the relationship among consumption of antioxidant-rich foods, health promotion and prevention of chronic diseases, studies on the association between dietary total antioxidant capacity and clinical parameters of individuals undergoing hemodialysis are scarce; none have been conducted in Brazil [13,19,20]. Research carried out by Asghari *et al.* [21] in patients with dysglycemia showed that a high TAC diet may play a role in reducing the risk of incident CKD. On the other hand, a case-control study carried out by Abbasi *et al.* [22] showed no association between TAC and CKD in patients with type 2 diabetes. This study aimed to investigate the effects of dietary TAC on anthropometric, functional, and biochemical parameters of CKD patients on hemodialysis.

METHODS

This cross-sectional study is part of a project entitled "Sociodemographic, behavioral, clinical, anthropometric, and dietary profile of patients on hemodialysis in Western *Bahia*" conducted in a nephrology clinic in *Barreiras*, BA.

All patients, except pregnant women aged 18 years or older, who underwent hemodialysis in a health care unit in *Bahia*, from June 2018 to August 2019 were invited to participate in the study. A total of 97 patients with CKD were assessed. All participants signed an informed consent form, and data were collected by trained interviewers. The research protocol was approved by the Human Research Ethics Committee of the Federal University of Western *Bahia*.

A structured questionnaire was used to collect the following sociodemographic data: sex; age, categorized into 20-35, 36-59, and ≥60 years; and socioeconomic level, classified into A and B, C and D, and E, according to criteria of the Brazilian Association of Research Companies [23].

Anthropometric data were collected after hemodialysis. Body weight was measured to the nearest 0.05 kg using a portable digital scale with a maximum capacity of 150kg (BF683W Tanita). Height was measured to the nearest 0.1cm using a stadiometer (W300, Welmy). Body Mass Index (BMI) was calculated as weight in kilograms divided by the square of the height in meters. Waist circumference, measured at the midpoint between the iliac crest and the last rib, and neck circumference were measured to the nearest 0.1cm using an inelastic measuring tape (Sanny, *São Paulo*, Brazil) [24]. The triceps skinfolds and subscapular were obtained with a Lange Skinfold Caliper adipometer (England), which exerts a constant pressure of 10g/mm². Measurements were made in triplicate, on the side of the body, in the absence of a fistula or venous access from the body. The final measure was obtained by the average of the three values. Body fat percentage was determined using a bioimpedance analyzer (A-310, Biodynamics Corporation, Seattle, USA).

The Handgrip Strength (HGS) was assessed using the SAEHAN® hydraulic dynamometer (Saehan corporation-SH5001). Patients were instructed to fit the dynamometer comfortably, in order to obtain the best performance, and at the time of measurement they remained seated with the adducted arm, elbow flexed at 90°, without using support. The maximum strength value was taken for analysis.

Information on hemodialysis duration, blood pressure, and levels of serum albumin, hemoglobin, leukocytes and serum iron was obtained from clinical records. It is important to note that the collection of biological material from patients preceded the dialysis session, at the end of the longest interdialytic period.

Dietary TAC was assessed using 24-hour dietary recalls (24HR), applied according to the USDA automated multiple-pass method on three separate days. This method consists of a five-step, structured approach (quick list, forgotten foods, time & occasion, detail cycle, and final probe). A food photo album was used to facilitate dietary data collection [25]. Household measurements used to indicate portion sizes in 24HR were converted to grams or milliliters using a reference table [26]. Subsequently, the antioxidant capacity of each food/preparation consumed was estimated using a list of more than 3,100 foods and preparations from different countries [27]. A database with Ferric Reducing Antioxidant Power (FRAP) values for foods to evaluate the dietary TAC was used. Thus, all foods consumed by patients were assigned TAC values expressed as mmol/100g. The sum of the antioxidant capacity of foods and preparations was calculated for each day, and dietary TAC was determined as the mean of the three days. Supplement antioxidants, if patients used them, were not considered in the calculation of the dietary TAC.

Data analysis was performed using Stata version 13.1 (Stata Corp, College Station, USA). Normality was assessed using the Shapiro-Wilk test. The mean, standard deviation, and amplitude of continuous variables were determined. Pearson and Spearman correlation analyses were used to assess the linear correlation between TAC and anthropometric, biochemical and clinical variables ($p \leq 0.05$). Associations between independent variables and TAC were determined using multiple linear regression. Variables with $p<0.20$ in bivariate linear analysis were included, and only those with $p \leq 0.05$ remained in the model.

RESULTS

A total of 97 CKD patients were evaluated, of which 57.7% (n=56) were men, 59.8% (n=58) had primary education, 57.7% (n=56) were aged between 36 and 59 years, 67% (n=65) were married, 44.3% (n=34) reported having intermediate socioeconomic levels and 68% (n=66) reported not practicing physical activities weekly (data not shown).

Anthropometric, biochemical and clinical parameters are shown in Table 1. The mean TAC of patients was 3.29±1.66mmol/100g. The foods that most contributed to the increase in the antioxidant content of the diet were wine, grapes, mandarin, broccoli and papaya.

Total Antioxidant Capacity had a significant inverse correlation with BMI, waist circumference, body fat percentage, tricipital and subscapular skinfolds and serum leukocyte count. TAC had a significant positive correlation with serum hemoglobin concentration (Table 2).

Table 1 – Anthropometric, biochemical and clinical characteristics of renal patients undergoing hemodialysis, in West *Bahia*, 2018-2019.

Variables	Mean	±SD	Amplitude P25; P75
Anthropometric variables			
Body mass index (Kg/m²)	23.83	±5.51	20.1; 27.3
Arm circumference (cm)	29.51	±5.73	25; 35
Waist circumference (cm)	87.08	±13.67	77; 95
Neck circumference (cm)	36.11	±4.28	33; 38
Lean mass (Kg)	48.41	±12.61	40; 55.8
Body fat (%)	26.08	±11.04	17.99; 33.10
Triceps skin fold (mm)	14.70	±8.67	9; 20
Subscapular skinfold (mm)	15.92	±8.29	10; 20
Handgrip strength (kg f^{-1})	28.21	±17.51	15; 40
Biochemical variables			
Serum albumin concentration (mg/dL)	3.55	±0.53	3.25; 3.91
Serum hemoglobin concentration (mg/dL)	9.39	±1.99	8.00; 10.50
Serum leukocyte concentration (mg/dL)	5.91	±3.99	4.20; 6.50
Serum iron (mg/dL)	73.18	±47.24	43.00; 90.50
Clinical variables			
Hemodialysis time (months)	36.18	±42.60	9.00; 47.00
Systolic blood pressure (mmHg)	133.86	±19.91	120.00; 150.00
Diastolic blood pressure (mmHg)	78.75	±17.03	80.00; 80.00
Mean arterial pressure (mmHg)	90.11	±28.87	90.00; 100.33

Note: SD: Standard Deviation.

Table 2 – Correlation between dietary total antioxidant capacitywith anthropometric, biochemical and clinical variables of renal patients undergoing hemodialysis, in West *Bahia*, 2018-2019.

Anthropometric variables	Dietary total antioxidant capacity R (*p*-value)
Body mass index (Kg/m²)	-0.310 (0.04)*
Arm circumference (cm)	-0.079 (0.472)*
Waist circumference (cm)	-0.270 (0.013)*
Neck circumference (cm)	-0.164 (0.137)*
Lean mass (Kg)	-0.076 (0.491)*
Body fat (%)	-0.299 (0.005)*
Triceps skin fold (mm)	-0.229 (0.035)**
Subscapular skinfold (mm)	-0.325 (0.002)**
Handgrip strength (kg f^{-1})	0.196 (0.075)**
Biochemical variables	
Serum albumin concentration (mg/dL)	0.183 (0.07)**
Serum hemoglobin concentration (mg/dL)	0.213 (0.039)**
Serum leukocyte concentration (mg/dL)	-0.368 (<0.001)**
Serum iron (mg/dL)	0.101 (0.34)**
Clinical variables	
Hemodialysis time (meses)	0.166 (0.112**
Systolic blood pressure (mmHg)	0.06 (0.54)*
Diastolic blood pressure (mmHg)	0.08 (0.44)*
Mean arterial pressure (mmHg)	0.11 (0.24)**

Note: *Pearson correlatin; **Spearman correlation.

Table 3 shows the association between independent variables and TAC. A negative association was found between TAC and BMI (p=0.008) after adjusting for sex, education level and socioeconomic level; that is, the higher the BMI, the lower the intake of dietary antioxidants. Handgrip strength (p=0.037) and serum albumin concentration (p=0.047) were positively associated with TAC.

Table 3 – Univariate and multivariate analysis of factors associated with the dietary total antioxidant capacity in renal patients undergoing hemodialysis, in West *Bahia*, 2018-2019.

Anthropometric variables	β	CI95%	*p*	βAj	CI95%	*p*
Body mass index (Kg/m²)	-0.094	-0.159; -0.030	0.004	-0.089	-0.155; -0.023	0.008
Arm circumference (cm)	-0.023	-0.087; 0.040	0.473			
Waist circumference (cm)	-0.033	-0.059; -0.007	0.013			
Neck circumference (cm)	-0.064	-0.150; 0.021	0.138			
Lean mass (Kg)	-0.010	-0.039; 0.019	0.491			
Body fat (%)	-0.045	-0.077; -0.013	0.006			
Triceps skin fold (mm)	-0.047	-0.088; -0.005	0.026			
Subscapular skinfold (mm)	-0.070	-0.112; -0.029	0.001			
Handgrip strength (kg f^{-1})	0.018	-0.001; 0.039	0.076	0.025	0.001; 0.048	0.037
Biochemical variables						
Serum albumin concentration (mg/dL)	0.627	0.002; 1.254	0.050	0.668	0.005; 1.343	0.047
Serum hemoglobin concentration (mg/dL)	0.162	-0.005; 0.331	0.058			
Serum leukocyte concentration (mg/dL)	-0.104	-0.193; -0.016	0.020			
Serum iron (mg/dL)	-0.001	-0.007; 0.008	0.970			
Clinical variables						
Hemodialysis time (months)	0.004	-0.003; 0.012	0.279			
Systolic blood pressure (mmHg)	0.005	-0.0121; 0.022	0.547			
Diastolic blood pressure (mmHg)	0.007	-0.012; 0.028	0.441			
Mean arterial pressure (mmHg)	0.011	-0.001; 0.0228	0.054			

Note: β: β value for simple linear regression; βAj: value of β adjusted to covariates; *p* value: multiple linear regression adopting significance for $p<0.05$; The variables were adjusted for sex, education and socioeconomic level for the final model.

DISCUSSION

To the best of our knowledge, this is the first study in Western *Bahia* to investigate the association between TAC and anthropometric, functional and biochemical factors in CKD patients on hemodialysis. The results showed that the high intake of dietary antioxidants was related to the lower BMI, the higher handgrip strength and the higher concentration of serum albumin in patients on renal dialysis.

It was also identified that the foods that most contributed to the increase in the antioxidant content of the diet were wine, grapes, mandarin, broccoli and papaya. Although the greatest contribution of antioxidants through fruit ingestion has been identified, it is observed that renal patients often have low consumption of these. The National Health Survey (Brazilian NHS) 2013, which involved the Brazilian adult (≥18 years) population and self-reported a medical diagnosis of chronic kidney disease (n=839), estimated the high proportion of the CKD individuals reported never consuming juice fruit and alcoholic beverages [28]. Patients on hemodialysis are often discouraged from consuming fruits and vegetables to prevent hyperkalaemia [29].

The negative association between BMI and CAT allows the assumption that a high intake of antioxidants would have a protective role in CKD. A longitudinal study carried out with Mexican adults showed that the increase in the consumption of antioxidants may have favorable effects on body composition [30]. Although no studies showing the relationship between high consumption of TAC and the reduction in BMI in renal patients have been identified, which may limit possible comparisons, it is known that both the high BMI and the reduced consumption of antioxidants are risk factors for chronic diseases [31-33].

As in this work, positive correlation between handgrip strength and dietary antioxidant intake was reported in a cross-sectional study with 62 cirrhotic patients by Lima [20]: individuals who consumed higher levels of antioxidants had higher handgrip strength ($p=0.029$). This finding is important for clinical practice, as it indicates that an antioxidant-rich diet might be associated with the control of reactive oxygen species in outpatients and can lead to improvements in muscle strength. Review published by Cesare *et al*. [34] presents epidemiological studies that have identified positive relationships between the intake of antioxidants in the diet and muscle strength.

Studies have shown that dietary antioxidants can protect the body against oxidative damage and reduce the risks of some clinical complications [20,35,36]. Sahni [37] compared the nutritional status of healthy subjects and CKD patients and observed that individuals with the poorest nutritional status had the lowest dietary antioxidant intake. In addition, intake was found to be directly proportional to antioxidant capacity [37]. This reinforces the importance of a balanced, high-quality diet composed of foods that help prevent oxidative damage. A previous study showed that the consumption of antioxidant nutrients is crucial for hemodialysis patients because of their impaired antioxidant defenses, accumulation of uremic retention solutes and oxidative imbalance triggered by intense production of reactive species [38].

The positive association between TAC and serum albumin concentrations allows inferring that consumption of antioxidant-rich foods decreases the risk of malnutrition in CKD patients under hemodialysis. Maraj *et al*. [39], in a study conducted with 97 hemodialysis patients, identified a positive correlation between TAC, measured by the ferric reducing antioxidant power assay, and serum albumin concentrations. Dantas *et al*. [40] cite that CKD patients are often exposed to oxidative stress, and, therefore, adequate nutritional therapy is essential to prevent the inflammatory state. Consumption of raw or minimally processed foods, which have higher antioxidant contents than processed foods, can contribute to improving the control of oxidative stress and the quality of life of CKD patients [41].

It is noteworthy that the hemodialysis treatment interferes with daily activities and homeostasis of CKD patients, leading to an increase in inflammatory mediators and, consequently, in the prevalence of chronic inflammation [42,44]. Thus, according to Novaes *et al*. [45], many complications associated with oxidative damage can be avoided by eating a healthy diet. Renal patients have weakened antioxidant defense mechanisms, due to the dietary restrictions of fruits and vegetables, resulting in reduced concentrations of vitamins C and E. In addition, during dialysis treatment, a large loss of vitamin C and selenium is observed [46].

Some limitations of the study must be considered. The method used to estimate daily food intake may have underestimated or overestimated food amounts and does not reliably reflect the patients' eating habits. It was sought to minimize this bias by applying three 24HR on non-consecutive days (every other day). It should be noted that 24h dietary recalls are inexpensive, do not promote changes in an individual's food intake and have been widely used to investigate the relationship between diet and health outcomes. Moreover, because of the cross-sectional nature of the present study, it is not possible to establish the directionality of associations, and the possibility of reverse causality cannot be excluded. A strong point of the present study includes its originality, as few studies have investigated the relationship between TAC and anthropometric, functional and biological parameters in patients with CKD on dialysis.

CONCLUSION

In conclusion, high TAC is associated with low BMI, high handgrip strength, and high serum albumin concentration in CKD patients undergoing hemodialysis. A high intake of dietary antioxidants may contribute to reducing oxidative stress. Future studies should investigate the relationship between consumption of antioxidant-rich foods and the morbidity and mortality of CKD patients.

A C K N O W L E D G M E N T S

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C O N T R I B U T O R S

DCG SILVA, TC SANTOS, JNM ALMEIDA and ES ALMEIDA contributed to the conception and design of the study, data collection and data analysis and interpretation. They wrote the article, revised and approved the final version of it. FG FERREIRA, contributed to the analysis and interpretation of data. He wrote the article, revised and approved the final version of it.

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