ORIGINAL RESEARCH

Effect of a Nutritional Intervention, Based on Transtheoretical Model, on Metabolic Markers and Food Consumption of Individuals Undergoing Hemodialysis

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Objective: This study aimed to evaluate the effect of a nutritional intervention, based on the transtheoretical model, on the metabolic markers and dietary intake of individuals undergoing hemodialysis (HD).

Methods: Intervention study at a nephrology clinic includes 83 individuals undergoing HD, over a period of 4 months. The nutritional intervention based on the transtheoretical model was composed of two group meetings and three individual ones, with delivery of personalized food plans and nutritional education activities. Anthropometry, dietary intake, metabolic markers, and stage of behavior change were evaluated before and after nutritional intervention.

Results: There was a significant change from the stage of contemplation to the stage of action, after the intervention ($P < .001$). There was a significant reduction in serum concentrations of creatinine and predialysis and postdialysis urea ($P < .001$). Hyperphosphataemia and hyperkalemia in the group were also significantly reduced as were markers related to bone metabolism ($P < .001$). The markers of iron metabolism ($P < .001$), protein ($P = .042$), and globulin ($P < .001$) showed a significant increase. Regarding food consumption, the caloric intakes ($P = .034$), cholesterol ($P = .034$), protein, and lipid as well as intake of iron, phosphorus, potassium, copper, and vitamin C ($P < .001$) were significantly higher after intervention.

Conclusions: The nutritional intervention based on the transtheoretical model promoted a change in the behavior of individuals undergoing HD, with an important improvement in their metabolic control. This can be explained by the significant change in the intake of calories, macronutrients, and micronutrients, as well as adequate use of phosphorus binders, indicating the crucial role of nutrition in this group.

Introduction

END-STAGE KIDNEY DISEASE (ESKD) is a major global public health problem, due to the significant increase in prevalence rates and incidence.[1] Individuals with ESKD treated with hemodialysis (HD) have metabolic disorders directly because of renal dysfunction. The frequent metabolic and hormonal complications include protein-energy wasting (PEW), inflammation, acidosis, hyperkalemia, chronic kidney disease–mineral and bone disorder (CKD-MBD), anemia, and uremic symptoms, which have a significant impact on the morbidity and mortality of these individuals.[2-4]

Thus, nutritional care plays a fundamental role in the treatment of ESKD. Dietary therapy in HD mainly involves controlling the consumption of food sources of protein, sodium, potassium, and phosphorus, as well as maintaining adequate nutritional and metabolic status of the patient, enabling the control of nutritional status and hydroelectrolytic and mineral disorders, and reduced production of nitrogen slags and uremic symptoms.[5-7] However, adherence to nutritional therapy in ESKD is a major challenge for the patient and their families, as it involves a wide dietary and behavioral change.[7] Studies have identified many nutritional transgressions and low adherence to a new eating

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pattern in individuals undergoing HD, which imply complications associated with the disease, such as edema, dyspnea, and bone pain, among others.[8,9]

In this context, the behavioral change stage model, also known as transtheoretical model, is an important method of investigating behavior.[10] The premise of the model is that behavior change is a process rather than an event, and that to change, a certain level of motivation or preparation should be provided. People at different points in this process can benefit from different interventions that are in line with their current stage.[11] The use of these stages of behavior change in nutritional interventions allows directing the intervention to each of the stages, which can be used as indicators of the effects of an intervention, represented by the advancement of the individual's classification in the stages of behavior change.[12] However, there are not many reports in the literature concerning the use of the transtheoretical model to change eating behavior in individuals undergoing HD.[13-16]

Overall, this study aimed to evaluate the effect of a nutritional intervention, based on the transtheoretical model, on the metabolic markers and dietary intake of individuals undergoing HD.

Methods

Subjects

This was an intervention study with nonprobabilistic convenience sampling performed at a nephrology clinic during the 4-month period. A total of 83 individuals undergoing HD participated in the study.

The study was carried out with individuals undergoing HD older than 18 years, who are regularly attended at the nephrology clinic. Individuals who did not show interest in participating in the study, with a treatment time of less than 1 month, hearing loss, newly implanted catheters, and hemodynamic instability evaluated by the physician were not included.

The study was approved by the Human Research Ethics Committee of the Universidade Federal de Viçosa (protocol number: 27364314.8.0000.5153) and by the staff of the Nephrology area. All participants read and signed the informed consent form.

Nutritional Intervention Based on the Transtheoretical Model

The nutritional intervention with individuals undergoing HD was composed of five meetings (2 groups and 3 individuals) for a period of 4 months. At the end of the intervention, a conversation wheel was performed with family members and companions (Figure 1).

Behavior Change Stage

Eating behavior was evaluated before and after the intervention period through interviews. For that, an algorithm was used for the stages of change of behavior to classify the participants between the stages. Stages of change were classified into five groups: precontemplation, contemplation, preparation, action, and maintenance, according to Prochaska et al.[11] The algorithm used consisted of questions to the participants, which allowed to classify the participants into: (1) precontemplation stage, individuals who did not follow the orientations and did not think about changing this behavior, (2) stage of contemplation, those who had intention to change in a period of up to 6 months, (3) stage of preparation, those who showed the intention to change the behavior in the next month, (4) stage of action, individuals who followed the orientations in a period less than 6 months, and (5) maintenance stage, those who followed the orientations in a period of 6 months or more.

From the identification of the stage that the patient was in, it was possible to establish individualized goals and strategies to assist in the progression to another stage (Figure 2). For analyzes in this study, the stages were grouped into two categories: active (action and maintenance) and inactive (precontemplation, contemplation, and preparation).[10]

Individual Meetings: Personalized Food Plan and Orientations

A trained dietitian developed a personalized food plan, and daily energy requirement of each individual was calculated as per the recommendation proposed by National Kidney Foundation - Kidney Disease Outcomes Quality Initiative.[17]

To calculate the protein requirement, we adopted 1.1 to 1.2 g/kg adjusted weight/day.[17] Lipid recommendation for individuals with hyperlipidemia was used.[18] Total fibers and micronutrients were prescribed as per Fouque's recommendations.[19] The macronutrient and micronutrient recommendations used to calculate dietary prescriptions are listed in Table S1. Diet plans were calculated using DietPro software, version 5.8.

During the first consultation, individuals received personalized diet plans, according to eating habits, behaviors, and metabolic and anthropometric markers. They were also instructed on the control of sodium, potassium, phosphorus, and liquids, as well as were provided with a printed form containing these orientations. Participants also received a food replacement list, specific for patients with renal disease in which fruits and vegetables were separated according to the potassium content.[20]

In the subsequent individual consultations, necessary adjustments were made in the food plan, according to the stage of change, and a record of the evolution of each patient was performed, according to testimonials. The individuals were followed up and supervised for four months by the same dietitian who developed the diet plans.

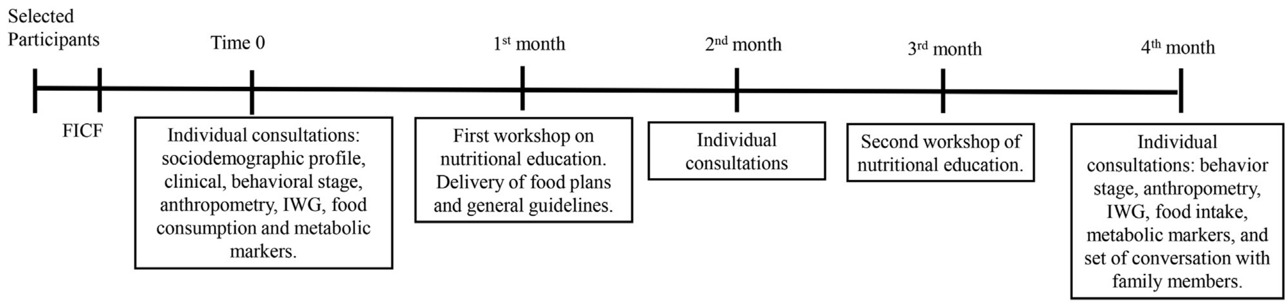

Figure 1. Study design. FICF, free informed consent from; IWG, interdialytic weight gain.

Group Meetings: Phosphorus, Potassium, and Sodium Workshops

To increase knowledge and stimulate the adoption of healthy dietary practices for patients with renal disease, two nutritional education workshops were carried out according to the stage of change. As most participants (42.2%) were in the contemplation stage for food behavior, specific materials were used for this stage, to obtain more satisfactory results, as previously reported.[21]

The nutritional education activities were carried out during the HD sessions by trained dietitians, collectively in groups of four to six participants and it was divided into two meetings: the first was on phosphorus and consisted of three stages. In the first stage, a trained dietitian applied the semistructured questionnaire for the evaluation of knowledge. The questionnaire consisted of four questions about the definition of phosphorus, consequences of hyperphosphatemia, phosphorus-rich foods, definition and proper use of phosphorus binders, and measures to reduce serum phosphorus concentrations (Table S1); the second stage was a lecture on the definition of phosphorus, the consequences of hyperphosphatemia, foods rich in phosphorus, the definition and proper use of phosphorus binders, and measures to reduce serum phosphorus concentrations. In the third stage, the semistructured knowledge assessment questionnaire was applied again. The knowledge assessment questionnaire applied before and after the activity had a total score of 4.8 points, with each question being equivalent to 1.2 points.

The second meeting consisted of two stages. The first stage addressed aspects on the influence of potassium on ESKD and, initially, a problem situation was presented, which contained the foods with low, medium, and high content of this mineral, the consequences of hyperkalemia and techniques to reduce potassium in food. Then, an activity was performed using the nutritional advices in accordance with the traffic light system in which foods were categorized as green (low potassium concentration), yellow

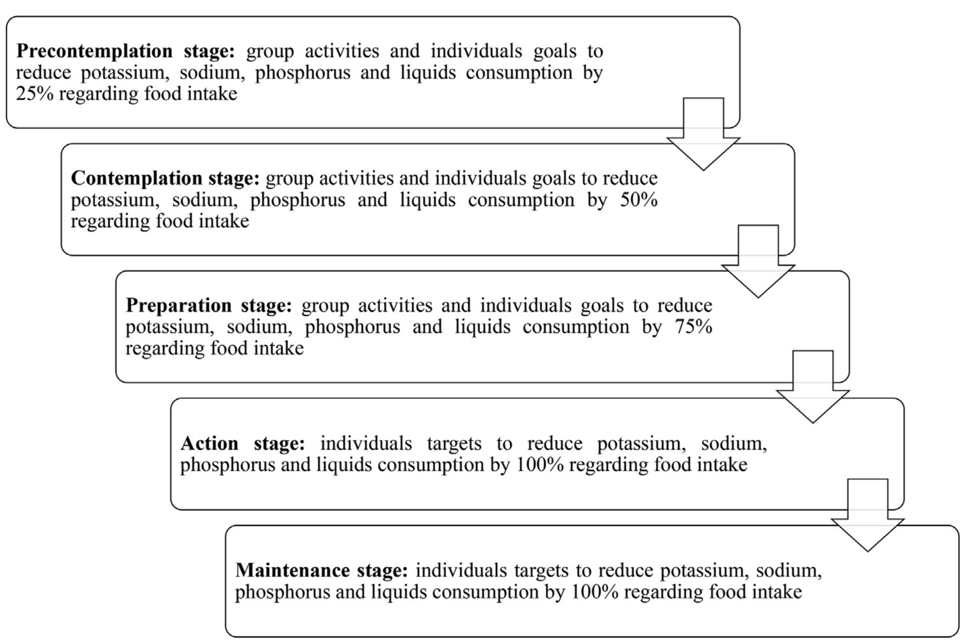

Figure 2. Behavior stage change algorithm.

Table 1. Sociodemographic, Clinical, and Metabolic Characteristics of the Sample Studied at the Baseline, According to Behavior Change Stage (n = 83)

Variables	Active (*n* = 22)	Inactive (*n* = 61)	*P*
Age (Years)	63.64 ± 16.31	60.10 ± 14.34	.342
HD time (months)	69.45 ± 55.90	71.05 ± 55.86	.909
Male (%)	23.6	76.4	.282
Dry Weight (kg)	59.43 ± 12.11	62.43 ± 10.58	.277
BMI (kg/m^2)	22.77 ± 2.89	23.96 ± 3.95	.199
IDWG (kg)	1.82 ± 0.74	2.39 ± 0.96	.014*
nPNA (g/kg/d)	0.66 ± 0.15	0.65 ± 0.17	.831
DM (%)	21.4	78.6	.318
SAH (%)	21.9	78.1	.311
Use of phosphorus binders (%)	26.6	73.4	.715
Nutritional supplement (%)	20.0	80.0	.474
Calcium (mg/dL)	8.54 ± 0.88	8.39 ± 0.77	.468
Creatinine (mg/dL)	8.54 ± 2.59	9.38 ± 2.86	.234
Phosphorus (mg/dL)	5.29 ± 1.06	5.19 ± 1.49	.774
Glucose (mg/dL)	188.50 ± 61.50	161.04 ± 89.46	.484
Red blood cells (millions/mm^3)	3.63 ± 0.73	3.60 ± 0.69	.844
Hemoglobin (g/dL)	11.24 ± 1.87	10.79 ± 1.94	.342
Hematocrit (%)	33.41 ± 5.35	32.27 ± 5.91	.427
Leukocyte (thousand/mm^3)	7254.5 ± 2643.0	6677.0 ± 2068.1	.301
Serum potassium (mEq/L)	5.43 ± 0.81	5.72 ± 1.00	.217
Predialysis urea (mg/dL)	117.86 ± 21.33	116.48 ± 27.27	.830
Postdialysis urea (mg/dL)	36.54 ± 12.32	38.00 ± 12.72	.644
Iron (μg/dL)	68.22 ± 31.89	69.74 ± 36.91	.865
Ferritin (ng/mL)	764.80 ± 586.44	650.02 ± 384.85	.304
Albumin (g/dL)	3.97 ± 0.29	4.00 ± 0.30	.728
Kt/V	1.53 ± 0.40	1.45 ± 0.31	.399
Calcium–phosphorus product (mg^2/dL^2)	45.02 ± 9.54	43.40 ± 13.57	.610
Alkaline phosphatase (U/l)	211.6 ± 237.9	163.8 ± 148.9	.278
Protein (g/dL)	7.06 ± 0.44	7.06 ± 0.45	.944
Globulin (mg/dL)	3.12 ± 0.29	3.09 ± 0.32	.681
Saturation of transferrin (U/l)	22.64 ± 9.28	23.09 ± 8.04	.833
Hyperphosphatemia (%)	27.7	72.3	.494
Hyperkalemia (%)	32.4	67.6	.419

BMI, body mass index; IDWG, interdialytic weight gain; nPNA, normalized protein nitrogen appearance; DM, diabetes mellitus; SAH, systemic arterial hypertension; HD, hemodialysis.

P, Mann–Whitney test or Student's t-test and chi-square or Fisher's exact test.

Data presented in mean ± standard deviation and relative frequency.

*It presented a statistically significant difference ($P < .05$).

(medium potassium concentration), and red (high potassium concentration) foods. The second stage was on sodium, and a lecture was given on the definition, consequences of excess sodium, sodium-rich foods, and how to reduce this mineral in food. Subsequently, a practical demonstration of the amount of sodium in food was performed. For this educational activity, we have used glasses with the amounts of sodium present in the following foods: seasonings, instant noodles, sausages, and ready-to-eat products. At the end of the nutritional intervention, an activity was organized in the form of a set of conversation, intended for the relatives and companions of the participants.

Data Collection

The individuals were subjected to a semistructured interview, with the application of a sociodemographic and health questionnaire. Anthropometry, dietary intake, interdialytic weight gain (IDWG), metabolic markers, and stage of behavior change were evaluated before (time 0) and after the nutritional intervention (4th month) (Figure 1). Body mass index was calculated and classified.[22,23] The IDWG was also collected from the medical records, being considered as the adequate increase of 2.0% to 4.5% in relation to the dry weight.[17] The average of the monthly IDWG was performed.

The metabolic markers were collected from the medical records of the nephrology clinic: serum concentrations of calcium, creatinine, phosphorus, glucose, red blood cells, hemoglobin, hematocrit, leukocytes, potassium, predialysis and postdialysis urea, iron, ferritin, albumin, phosphatase alkaline, protein, globulin, transferrin saturation, calcium–phosphorus product, and Kt/V values. For hyperphosphatemia and hyperkalemia,

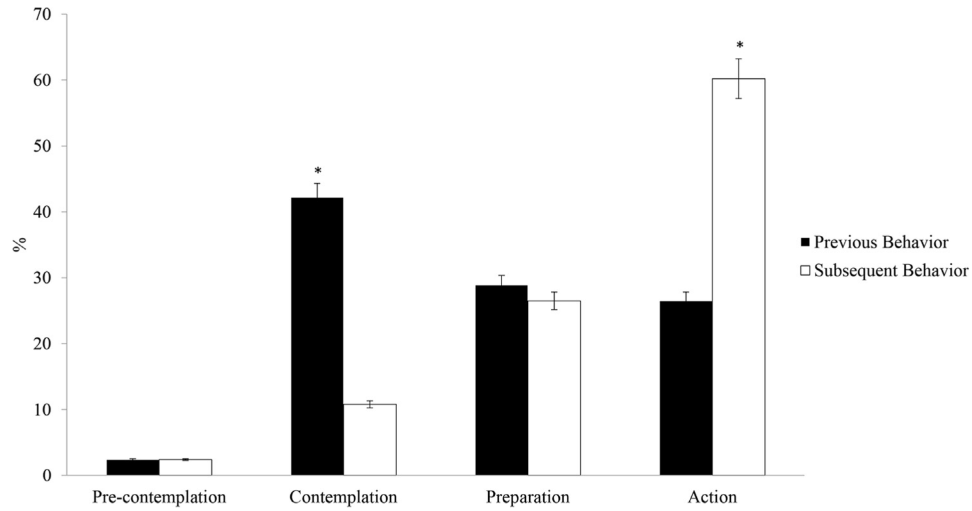

Figure 3. Stage of change in eating behavior of hemodialysis subjects before and after nutritional intervention (n = 83).*$P < .001$ by the McNemar test.

phosphorus and potassium serum concentrations above 5.5 mg/dL and 5.5 mEq/L, respectively,[24,25] were considered.

To assess dietary intake, three dietary recalls (2 days a week, 1 day on dialysis and 1 day without dialysis, and 1 weekend) were applied by interviewing a dietitian before and after the 4-month intervention. For some elderly individuals, the interview was performed with the help of the family member or caregiver. Participants were also asked about the use of additional oil, additional sugar, energy supplements, and calcium supplementation. Portion size was determined with the help of a food photo album. Thus, food intake was then converted to grams, and nutrients were analyzed using DietPro software, version 5.8. Protein intake was also estimated by the calculation of the normalized protein nitrogen appearance (g/kg/day),[5] considering adequate protein intake for values above 1.2 g/kg/day.[17,19]

Table 2. Metabolic Markers of the Studied Sample Before and After 4-Month Nutritional Intervention ($n = 83$)

Variables	Pre-intervention	Post-intervention	*P*
Calcium (mg/dL)	8.4 ± 0.8	8.3 ± 0.7	.026*
Creatinine (mg/dL)	9.2 ± 2.8	7.0 ± 2.3	<.001*
Phosphorus (mg/dL)	5.2 ± 1.4	4.3 ± 1.1	<.001*
Glucose (mg/dL)	166.2 ± 84.8	130.2 ± 64.4	.891
Hemoglobin (g/dL)	10.9 ± 1.9	11.7 ± 1.9	<.001*
Hematocrit (%)	32.6 ± 5.8	36.1 ± 6.0	<.001*
Leukocyte (thousand/mm^3)	6830.1 ± 2232.6	6060.2 ± 1874.1	<.001*
Potassium (mEq/L)	5.7 ± 1.0	5.0 ± 1.0	<.001*
Predialysis urea (mg/dL)	116.8 ± 25.7	97.6 ± 28.9	<.001*
Postdialysis urea (mg/dL)	37.6 ± 12.6	31.8 ± 10.9	<.001*
Iron (μg/dL)	69.3 ± 35.5	72.1 ± 35.5	.152
Ferritin (ng/mL)	680.4 ± 446.1	737.4 ± 476.7	.057
Albumin (g/dL)	4.0 ± 0.3	3.7 ± 0.4	<.001*
Kt/V	1.5 ± 0.3	1.4 ± 0.3	.195
Calcium–phosphorus product (mg^2/dL^2)	43.8 ± 12.6	35.9 ± 9.5	<.001*
Alkaline phosphatase (U/l)	176.5 ± 176.5	142.3 ± 136.1	<.001*
Protein (g/dL)	7.0 ± 0.4	7.2 ± 0.6	.042*
Globulin (mg/dL)	3.1 ± 0.3	3.5 ± 0.6	<.001*
Saturation of transferrin (U/l)	23.0 ± 8.3	33.0 ± 17.0	<.001*
Hyperphosphatemia (%)	41.0	10.8	<.001*
Hyperkalemia (%)	56.6	28.9	<.001*

P, Paired *t*-test or Wilcoxon. McNemar for proportion.
Data presented in mean ± standard deviation and relative frequency.
*It presented a statistically significant difference ($P < .05$).

Statistical Analyses

Results are presented as mean (standard deviation) or median (interquartile range), according to the distribution of variables, determined by the Shapiro–Wilk test. Qualitative variables were described by relative frequency (%).

The main characteristics of individuals undergoing HD in the baseline, according to age, were evaluated using the Mann–Whitney test or Student's t-test and chi-square or Fisher's exact test. The change in metabolic control and food intake variables after the intervention was evaluated by the paired t-test or the Wilcoxon test. All the nutrients evaluated in this study were adjusted by daily caloric intake by residual method[26] before the analyses were performed.

Data on behavior change stages collected before and after the intervention were compared by the McNemar test. The data were processed and analyzed in SPSS software, version 20.0, adopting the significance level α <5%.

Results

Among the 83 subjects included in the study, the majority was men (66.3%). The mean age was 61 ± 15 years. The most frequent etiology of ESKD was hypertensive nephrosclerosis (38.6%). Regarding weight status, most of the individuals were of normal weight (50.6%), followed by underweight (26.5%) and overweight (22.9%).

When compared with eating behavior at the baseline, the inactive individuals presented higher IDWG than the active ones (Table 1). Data on dietary behavior for the control of phosphorus, potassium, sodium, and liquids show that there was a statistically significant ($P < .001$) movement of the contemplation stage, observed in the preintervention, to the action stage, after 4 months of intervention (Figure 3).

When applying the semistructured questionnaire to evaluate the knowledge about phosphorus (containing 4 questions worth 1.2 points each), the average score of the questionnaire after the educational activity was statistically higher, compared with the questionnaire applied before (4.1 vs. 1.6 points, respectively, $P < .001$). The proportion of correct answers was 33.6% before the educational activity and 85.9% after the educational activity. The questions that presented the greatest number of errors and correct answers before the educational activity were the use of binders (mean of errors of 95.1%) and consequences of hyperphosphatemia (average of 50% correct answers), respectively. After the educational activity, the questions with the greatest number of hits were those related to meals in which the binders should be taken (94.6%), followed by foods rich in phosphorus (94.1%). When compared between the sexes, the women had more correct answers than the men (3.10 vs. 2.10 points, $P = .021$). Individuals with HD time <5 years had a greater number of hits compared with individuals undergoing HD time ≥5 years (2.69 vs. 1.95 points, $P = .02$).

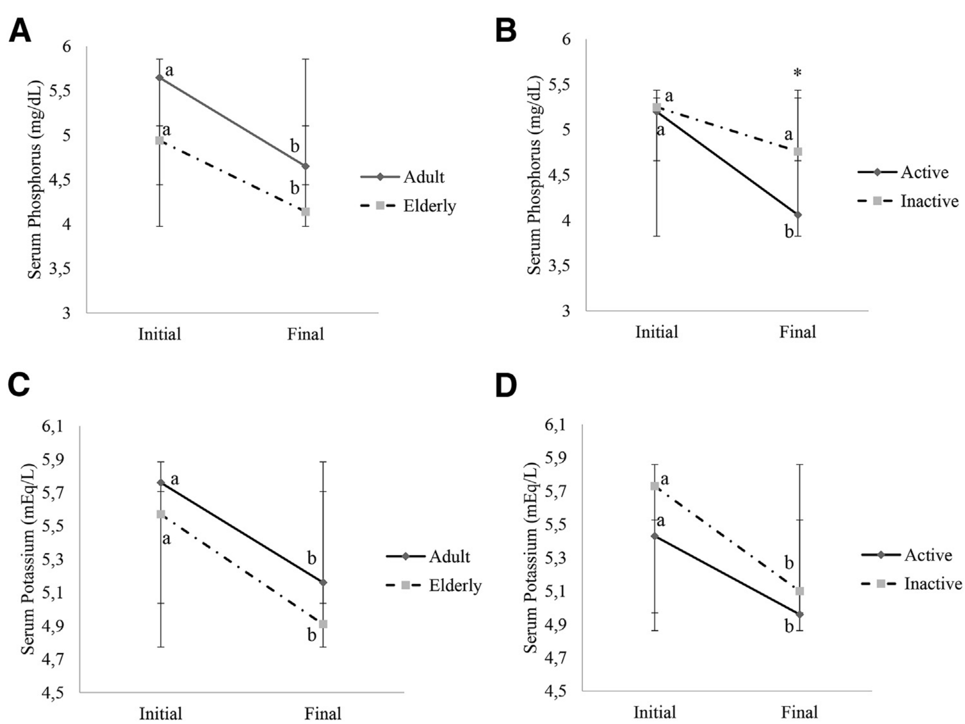

Figure 4. Serum phosphorus (A and B) and potassium (C and D) of hemodialysis subjects before and after the nutritional intervention (4 months) according to age and behavioral stage. Different letters are to indicate significant difference ($P < .05$) by the Wilcoxon test (*$P < .05$) by the Mann-Whitney test.

Table 3. Daily Food Consumption of Hemodialysis Subjects Before and After Nutritional Intervention (n = 83)

Variables	Pre-intervention	Post-intervention	*P*
Energy (Kcal/kg/day)	22.7 (17.5-32.3)	24.7 (21.3-31.5)	.034*
Carbohydrate (% EI)	55.6 (48.8-62.1)	45.5 (39.5-52.5)	<.001*
Protein (g/kg of dry weight)	0.88 (0.73-1.04)	1.05 (0.85-1.23)	<.001*
Lipids (% EI)	32.8 (26.2-39.7)	39.7 (34.4-43.8)	<.001*
Monounsaturated fat (% EI)	9.3 (7.4-11.1)	12.1 (10.5-14.4)	<.001*
Polyunsaturated fat (% EI)	14.1 (9.5-17.6)	13.4 (10.0-16.0)	<.001*
Saturated fat (% EI)	9.0 (6.9-10.5)	10.0 (8.6-11.7)	<.001*
Alfa-linolenic acid (g/day)	2.0672 ± 0.77	2.22 ± 0.76	.077
Linolenic acid (g/day)	17.67 ± 7.62	19.67 ± 6.95	.015*
Cholesterol (mg/day)	95.6 (48.9-143.1)	137.1 (85.7-210.0)	.004*
Fiber (g/day)	19.5 (13.8-27.9)	20.1 (13.6-27.6)	.942
Calcium (mg/day)	362.7 (269.1-539.2)	418.1 (296.0-615.3)	.253
Iron (mg/day)	5.2 (3.9-6.3)	7.0 (5.3-9.0)	<.001*
Phosphorus (mg/day)	698.9 (580.7-801.0)	782.6 (617.5-902.5)	<.001*
Potassium (mg/day)	1784.3 (1493.4-2117.2)	2032.3 (1752.0-2548.3)	<.001*
Copper (mg/day)	0.6 (0.4-0.7)	0.7 (0.5-0.9)	.045*
Magnesium (mg/day)	162.0 (133.7-192.7)	181.9 (154.2-230.3)	.310
Sodium(mg/day)	1142.7 (823.1-1480.7)	1106.7 (791.7-1550.2)	.813
Zinc (mg/day)	7.1 (4.6-8.8)	6.3 (4.6-11.5)	<.001*
Vitamin C (mg/day)	34.7 (13.0-89.4)	52.1 (13.3-124.5)	<.001*

EI, energy intake.
P, Paired t-test or Wilcoxon. Adjusted by energy.
Data presented in mean ± standard deviation or median and interquartile range (P25-P75).
*It presented a statistical significant difference ($P < .05$).

Regarding the metabolic markers, serum concentrations of calcium, creatinine, phosphorus, potassium, predialysis and postdialysis urea, albumin, calcium–phosphorus product, alkaline phosphatase, and leukocyte count (within the recommended range) were significantly reduced after 4 months of intervention. In turn, hemoglobin, hematocrit, transferrin saturation, protein, and globulin showed a significant increase after the nutritional intervention (Table 2). Interestingly, the individuals classified as active in relation to the behavioral stage had a reduction in the phosphorus concentration after the intervention, whereas in the inactive individuals, the reduction was not verified (Figure 4). The reduction in serum concentrations of creatinine, predialysis and postdialysis urea, phosphorus, and potassium were also evaluated according to age (adults vs. elderly), sex, and behavior change (active vs. inactive), but there was no statistical difference in the comparison between groups for these variables.

Regarding food consumption, caloric intake, of proteins, lipids (monounsaturated and saturated fats and linoleic acid), and cholesterol were high after nutritional intervention, whereas consumption of carbohydrates, polyunsaturated fat, and zinc was low. Among the micronutrients, the intake of iron, phosphorus, potassium, copper, and vitamin C showed a significant increase after the intervention (Table 3).

Discussion

This study aimed to evaluate the effect of a nutritional intervention, based on the transtheoretical model, on the metabolic markers and food consumption of individuals undergoing HD. The first relevant result of this study was the change in behavioral stages, from the contemplation stage to the action stage, which indicates the most beneficial behavior after a nutritional intervention.

Previous studies have also shown the effectiveness of nutritional education programs in the stages of behavior change in young adults,[16,27] adult women,[28] and individuals with type 2 diabetes mellitus.[29] Furthermore, the adoption of healthy eating habits is essential in the treatment of individuals undergoing HD, especially in the control of phosphorus, potassium, sodium, and fluids. Thus, the transtheoretical model of behavior change can be a promising tool to help understand the behavioral change related to food and health.[30]

In a multicenter cross-sectional study (n = 172), the efficacy regarding fluid control was greater when individuals were characterized as actives.[14] Karavetian et al.[15] also observed a significant improvement in both knowledge and serum phosphorus [concentration] related to behavior change (stage of preparation for action) after 6 months of intensive education for individuals undergoing HD.[15] Our outcomes are similars in which individuals considered active after the intervention presented lower IDWG then inactive individuals, suggesting a better control of fluid in HD. Moreover, serum phosphorus concentration was significantly reduced in the active group but not among inactive participants.

In addition, we observed reductions in markers of nitrogen status (predialysis and postdialysis urea and creatinine) and serum potassium. Because the reduction of uremic toxicity and hypercalcemia is one of most important purposes of nutritional management in HD, this study showed promising metabolic outcomes using transtheoretical model. Casas et al.[7] also observed a significant reduction in serum potassium after a specific nutritional education program developed for patients undergoing HD.[7]

In relation to bone metabolism, plasma phosphorus concentrations are commonly increased in ESKD, resulting in hyperphosphatemia. In fact, lower vitamin D3 activation and subsequent reduction in intestinal calcium absorption, concomitant with hyperparathyroidism, and hyperphosphatemia, characterize a picture of metabolic bone disorder, which can result in osteodystrophy, neuropathy, bone marrow suppression, and soft tissue mineralization.[31,32] Given the great clinical challenge of controlling this disorder in HD,[33,34] the data of this study are very favorable because there was a significant decrease in the serum concentration of phosphorus, calcium-phosphorus product, and alkaline phosphatase and significant reduction of hyperphosphatemia from 41.0 to 10.8%.

Treatment of hyperphosphataemia is based on phosphorus feed restriction and inhibition of intestinal phosphorus absorption by medication.[35] In diet, the recommendation of this mineral is up to 800 mg/day.[24] As the recommended diet for these patients is high in protein, it becomes difficult to achieve restriction of phosphorus levels to a greater extent. Therefore, it is necessary to combine dietary restriction with the proper use of phosphorus binders.[36] In this study, a better understanding of the correct use of phosphorus binders was observed after the intervention, which may have influenced the reduction of metabolic markers (serum concentrations of phosphorus, alkaline phosphatase, and calcium-phosphorus product). In this context, dietary counseling should be routinely given to educate patients about food sources of phosphorus, the consequences of high phosphorus concentrations, and the correct use of phosphorus binders. Some studies have obtained results similar to those found in relation to the benefits of educational counseling in the management of hyperphosphatemia in patients undergoing HD.[15,37-39]

Regarding iron metabolism, serum concentrations of hemoglobin and hematocrit increased after the intervention. A possible explanation would be that metabolic disorders associated with uremia may affect the production and survival of red blood cells (for example, uremic toxins, parathyroid hormone, and PEW).[40] Because individuals had a reduction in uremic toxins, this metabolic change may have affected, consequently, these parameters. Transferrin saturation also increased after the intervention, probably because of increased iron intake.

In this study, there was a reduction in relation to serum albumin, although the frequency of low levels of albumin (<3.0 g/L) remained. Because there was no evidence of an extreme reduction in protein consumption, evidence indicates that serum albumin concentration is much more affected by nondietary factors, such as inflammatory and catabolic processes, advanced age, comorbidities, hypervolemia, urinary losses, and losses through the dialytic process.[41] For the total proteins and globulins, there was an increase after the nutritional intervention.

Regarding food consumption, energy intake was higher after the intervention, although it had not yet reached the recommendation.[17] Protein intake also increased after the intervention, without reaching the recommendation of 1.1 to 1.2 g/kg adjusted weight/day.[17] Our results are in agreement with the results of the study by Luis et al.[42] who observed that 77% and 50% of participants did not consume the recommended amount of energy and protein, respectively. Similar data were also found by Khoueiry et al[43] In fact, PEW, so prevalent among individuals subjected to HD, contributes to multiple complications, such as increased morbidity, mortality, and impairment of quality of life,[44] and low protein intake may be related to the most restrictive nutritional counseling in the interest to improve bone and mineral disease in HD.[45] However, our results were superior to those found by Khoueiry et al[43] and Therrien et al[46] in relation to protein intake.

We also emphasize an increase in the intake of phosphorus and iron, probably caused as consequence of the increase in protein intake. Despite the increase of iron, this micronutrient did not reach the recommendation. However, phosphorus values remained within the recommended range,[19] without affecting the significant improvement in the related metabolic markers. In this sense, Khoueiry et al[43] also observed that the patient's phosphorus intake in HD was within the recommended range. Contrary to what was observed in this study, Luis et al[42] found excessive consumption of phosphorus, calcium, sodium, and potassium.

In this study, there was also an increase in the daily intake of total lipids, saturated fat, monounsaturated fat, linoleic acid, and cholesterol. However, total lipids, polyunsaturated fat, and saturated fat presented values above the recommendation.[18] The polyunsaturated fat reduced after the intervention but not enough to reach the recommendation. These results agree with a recent report from the United States on women undergoing dialysis.[46] In the study by Luis et al[42] was also found an excess of fat consumption, mainly saturated fat (92%).[42] These findings may be related to the higher consumption of proteins because the protein sources (dairy products and meats) also have significant amounts of fats.

In addition, our study patients showed higher intakes of potassium and vitamin C after the intervention, probably because of the increase in the consumption of fruits and vegetables. However, potassium values remained within the recommended range,[19] not affecting the positive results in the control of hyperkalemia. Vitamin C did not reach the recommendation,[19] as demonstrated also in the study by Luis et al.[42]

It is important to highlight that we believe that the change in caloric, macronutrients, and micronutrients intake had a direct effect on the metabolic improvements achieved. Thus, nutritional intervention is an important instrument for metabolic control because this increase of knowledge combined with behavior change will impact on the reduction of complications associated with the disease and improve the quality of life of these individuals. As our sample presented features common to those described in studies with patients undergoing HD, majority men and elderly,[47,48] low income,[49] and low schooling,[36,49] our methodology could be replicable in other centers as promising as ours.

Despite the positive impact of the stages of food behavior change for the control of phosphorus, potassium, sodium, and fluids, this study has the limitation of not having a control group because of ethical issues imposed by the nephrology area. As we know the importance of nutritional interventions for metabolic control, we could not leave individuals on HD without receiving this treatment. In addition, we could not underestimate food composition tables of the amount of phosphorus in processed foods (phosphorus additives). The application of the methodology in the long term, as well as the evaluation of the maintenance of the knowledge acquired and changes achieved are still necessary.

Conclusion

In conclusion, the 4-month nutritional intervention, based on the transtheoretical model, promoted the movement of individuals undergoing HD from the contemplation stage to the action stage, improving metabolic control related to uremic toxins, bone metabolism, iron metabolism, and hyperkalemia, which are relevant in ESKD. A better understanding about nutrition in chronic kidney disease, change in food consumption, and adequate use of phosphorus binders may have a direct effect on the metabolic control achieved.

Practical Application

This study will contribute effectively to improving the metabolic markers of individuals undergoing hemodialysis and consequently improving the quality of life. The nutritional intervention based on the transtheoretical model promoted a change in the behavior of individuals undergoing HD, with an important improvement in their metabolic control.

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Supplementary Data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1053/j.jrn.2019.12.004.

References

1. Sesso RC, Lopes AA, Thomé FS, Lugon JR, Martins CT. Inquérito Brasileiro de Diálise Crônica 2014. *J Bras Nefrol*. 2016;38:54-61.
2. Cibulka R, Racek J. Metabolic disorders in patients with chronic kidney failure. *Physiol Res*. 2007;56:697-705.
3. Elias SG, Bucharles, Varela AM, Henrique S, Barberato Pecoits-Filho R. Assessment and management of cardiovascular disease in patients with chronic kidney disease. *J Bras Nefrol*. 2010;32:120-127.
4. Sociedade brasileira de nefrologia. *1º Censo do Estado Nutricional de Pacientes em Hemodiálise 2010*. São Paulo: Sociedade Brasileira de Nefrologia. 2010.
5. Nerbass FB, Cuppari L. Hemodiálise. In: *Nutrição na Doença Renal Crônica*. São Paulo: Manole; 2013:247-269.
6. Steiber AL. Chronic kidney disease. *J Parenter Enter Nutr*. 2014;38:418-426.
7. Casas J, Rodrigues CIS, D'avila R. Nutritional education for chronic renal failure patients in hemodialysis program. *Nutrire*. 2015;40:36-44.
8. Kugler C, Vlaminck H, Haverich A, Maes B. Nonadherence with diet and fluid restrictions among adults having hemodialysis. *J Nurs Scholarsh*. 2005;37:25-29.
9. De Las Heras Mayoral MT, Rincon CM. Conocimiento y percepción nutricional en diálisis: Su influencia en la transgresión y adherencia; estudio inicial. *Nutr Hosp*. 2015;31:1366-1375.
10. Madureira AS, Corseuil HX, Pelegrini A, Petroski EL. Associação entre estágios de mudança de comportamento relacionados à atividade física e estado nutricional em universitários. *Cad Saude Publica*. 2009;25:2139-2146.
11. Prochaska JO, DiClemente CCNJ. In search of how people change: applications to addictive behaviors. *Am Psychol*. 1992;47:1102-1114.
12. Horwath CC, Nigg CR, Motl RW, Wong KT, Dishman RK. Investigating fruit and vegetable consumption using the transtheoretical model. *Am J Heal Promot*. 2010;24:324-333.
13. Welch JL. Hemodialysis patient beliefs by stage of fluid adherence. *Res Nurs Heal*. 2001;24:105-112.
14. Ghaddar S, Shamseddeen W, Elzein H. Behavioral modeling to guide adherence to fluid control in hemodialysis patients. *J Ren Nutr*. 2009;19:153-160.
15. Karavetian M, de Vries N, Elzein H, Rizk R, Bechwaty F. Effect of behavioral stage-based nutrition education on management of osteodystrophy among hemodialysis patients, Lebanon. *Patient Educ Couns*. 2015;98:1116-1122.
16. Martins CTB, Biavo BMM, Uezima CBB, et al. EPIC Trial: education programme impact on serum phosphorous control in CKD 5D patients on hemodialysis. *J Bras Nefrol*. 2017;39:398-405.
17. Group. KDOQI. KDOQI clinical practice guidelines for nutrition in chronic renal failure. *Am J Kidney Dis*. 2000;35:1-141.
18. Kidney Disease Outcomes Quality Initiative (K/DOQI) Group. K/DOQI clinical practice guidelines for management of dyslipidemias in patients with kidney disease. *Am J Kidney Dis*. 2003;41:S11-S21.
19. Fouque D, Vennegoor M, Ter Wee P, et al. EBPG guideline on nutrition. *Nephrol Dial Transpl*. 2007;22(Suppl 2):ii45-ii87.
20. Riella MC, Martins C. *Nutrição e o Rim*. 1ª ed. Paraná: Guanabara Koogan; 2001:416.
21. Toral N. *A alimentação saudável na ótica dos adolescentes e o impacto de uma intervenção nutricional com materiais educativos baseado no Modelo Transteórico entre escolares de Brasília-DF*. São Paulo: Universidade de São Paulo; 2010.
22. World Health Organization. *Obesity : preventing and managing the global epidemic Report of a. Obesity: preventing and managing the global epidemic*. Geneva: World Health Organization 2000.
23. Lipschitz D. Screening for nutritional status in the elderly. *Prim Care*. 1994;21:55-67.
24. National Kidney Foundation. Clinical practice guidelines for bone metabolism and disease in chronic kidney disease. *Am J Kidney Dis*. 2003;42:1-201.
25. Kovesdy CP, Regidor DL, Mehrotra R, et al. Serum and dialysate potassium concentrations and survival in hemodialysis patients. *Clin J Am Soc Nephrol*. 2007;2:999-1007.

26. Willett WC, Stampfer M. Implications of total energy intake for epidemiologic analyses. In: *Nutritional Epidemiology.* New York: Oxford University Press; 1998:272-301.

27. Nitzke S, Kritsch K, Boeckner L, et al. A stage-tailored multi-modal intervention increases fruit and vegetable intakes of low-income young adults. *Am J Heal Promot.* 2007;22:6-14.

28. Helitzer DL, Peterson AB, Sanders MTJ. Relationship of stages of change to attendance in diabetes prevention program. *Am J Heal Promot.* 2007;21:517-520.

29. Natali CM, Oliveira MCF, Alfenas RCG, et al. Impactos dos estágios de mudança de comportamentos alimentar e de atividade física nos perfis bioquímico e antropométrico de portadores de Diabetes mellitus tipo 2. *J Braz Soc Food Nutr.* 2012;37:322-334.

30. Prochaska JO, Di Clemente C. Transtheoretical therapy: toward a more integrative model of change. *Psychotherapy.* 1992;19:276-288.

31. Mehrotra S, Rishishwar P, Sharma RK. Malnutrition and hyperphosphatemia in dialysis patients. *Clin Queries Nephrol.* 2015;4:25-27.

32. Moe SM, Drüeke T, Lameire N, Eknoyan G. Chronic kidney disease-mineral-bone disorder: a new Paradigm. *Adv Chronic Kidney Dis.* 2007;14:3-12.

33. Peres LAB, Pércio PPV. Mineral and bone disorder and vascular calcification in patients with chronic kidney disease. *J Bras Nefrol.* 2014;36:201-207.

34. Shaman AM, Kowalski SR. Hyperphosphatemia management in patients with chronic kidney disease. *Saudi Pharm J.* 2016;24:494-505.

35. Kuhlmann MK. Management of hyperphosphatemia. *Hemodial Int.* 2006;10:338-345.

36. Nerbass FB, Morais JG, dos Santos RG, Kruger TS, Koene TT, Filho HA da L. Adesão e conhecimento sobre o tratamento da hiperfos- fatemia de pacientes hiperfosfatêmicos em hemodiálise. *J Bras Nefrol.* 2010;32:149-155.

37. Ford JC, Pope JF, Hunt AE, Gerald B. The effect of diet education on the laboratory values and knowledge of hemodialysis patients with hyperphosphatemia. *J Ren Nutr.* 2004;14:36-44.

38. Nerbass FB, Cuppari L, Avesani CM, Alexandre H. Diminuição do Fósforo Sérico Após Intervenção nutricional em pacientes hiperfosfatêmicos em hemodiálise decrease in serum phosphorus after nutricional intervention in hyperphosphatemic patients on hemodialysis. *J Bras Nefrol.* 2008;30:288-293.

39. Caldeira D, Amaral T, David C, Sampaio C. Educational strategies to reduce serum phosphorus in hyperphosphatemic patients with chronic kidney disease: Systematic Review with Meta-analysis. *J Ren Nutr.* 2011;21:285-294.

40. Golper TA, Goral S, Becker BN, Langman CB. -Carnitine treatment of anemia. *Am J Kidney Dis.* 2003;41:27-34.

41. Santos NS, Draibe SA, Kamimura MA, et al. Is serum albumin a marker of nutritional status in hemodialysis patients without evidence of inflammation? *Artif Organs.* 2003;27:681-686.

42. Luis D, Zlatkis K, Comenge B, et al. Dietary quality and adherence to dietary recommendations in patients undergoing hemodialysis. *J Ren Nutr.* 2016;26:190-195.

43. Khoueiry G, Waked A, Goldman M, et al. Dietary intake in hemodialysis patients does not reflect a heart healthy diet. *J Ren Nutr.* 2011;21:438-447.

44. Carrero JJ, Stenvinkel P, Cuppari L, et al. Etiology of the protein-energy wasting syndrome in chronic kidney disease: a consensus statement from the International Society of Renal Nutrition and Metabolism (ISRNM). *J Ren Nutr.* 2013;23:77-90.

45. Elliott JO, Ortman C, Almaani S, Lee YH, Jordan K. Understanding the associations between modifying factors, individual health beliefs, and hemodialysis patients' adherence to a low-phosphorus diet. *J Ren Nutr.* 2015;25:111-120.

46. Therrien M, Byham-Gray L, Denmark R, Beto J. Comparison of dietary intake among women on maintenance dialysis to a women's health initiative cohort: results from the NKF-CRN second National Research Question Collaborative Study. *J Ren Nutr.* 2014;24:72-80.

47. Chen J, Peng H, Yuan Z, et al. Combination with anthropometric measurements and MQSGA to assess nutritional status in Chinese Hemodialysis Population. *Int J Med Sci.* 2013;10:974-980.

48. As'habi A, Tabibi H, Nozary-Heshmati B, Mahdavi-Mazdeh M, Hedayati M. Comparison of various scoring methods for the diagnosis of protein–energy wasting in hemodialysis patients. *Int Urol Nephrol.* 2014;46:999-1004.

49. de Oliveira CMC, Kubrusly M, Mota RS, da Silva CAB, Oliveira VN. Desnutrição na insuficiência renal crônica: qual o melhor método diagnóstico na prática clínica? *J Bras Nefrol.* 2010;32:57-70.