Progress in Nutrition 2020; Vol. 22, N. 1: 96-105 DOI: 10.23751/pn.v22i1.7944

Original article

Evaluation of nutritional status in patients with end-stage renal disease in hemodialysis using principal component analysis

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Summary. The evaluation of nutritional status in patients with end-stage renal disease in hemodialysis is composed of a large number of measurements that complicate their execution. Therefore, the objective of this study is to reduce the number of variables through the principal component analysis (PCA). For this, a PCA was performed with 10 variables of the nutritional diagnosis in patients with hemodialysis: Energy Intake, Protein Intake, IBM,% UBW,% SBW,% MUAC, cAMA,% TCF, HGS and TLC as well as the age of the patients. The results show that PCA matrix with orthogonal rotation Varimex yielded four main components of the evaluation of the nutritional status of renal disease in patients with end-stage hemodialysis, whose value was greater than 0 and explains the 79.91% of the total variance. The first factor was called body composition status, which is composed of cAMA (r = 0.9138), IBM (r = 0.8755),% MUAC (r = 0.8681) and% SBW (r = 0.6238). In the second factor called nutritional risk, a correlation was observed with energy intake (r = -0.8934), protein intake (r = -0.8752) and %TCF (0.5040). The third component called functional status risk is composed of age (r = 0.9022) and HGS (r = 0.8508). The fourth factor, called body composition stability, was correlated with %UBW (r = 0.7456) and %TCF (r = 0.5825). The results of this study will allow reducing the number of variables for the preparation of a nutritional diagnosis in hemodialysis patients. From many to one of the four main components: 1) body composition status, 2) nutritional risk, 3) functional status risk or 4) body composition stability.

Key words: evaluation of nutritional status, principal component analysis, hemodialysis patients, end-stage renal disease

List of abbreviations

%MUAC: Percent of Mid-Upper Arm Circumference
%SBW: Percent of Standard Body Weight
%TSF: Percent of Triceps Skinfold Thickness
%UBW: Percent of Usual Body Weight
Alb: Albumin
AND: Academy of Nutrition and Dietetics
AW: Actual Weight
BMI: Body Mass Index
cAMA: Corrected Arm Muscle Area
CKD: Chronic Kidney Disease
ESRD: End-Stage Renal Disease
HD: Hemodialysis
HGS: Hand-Grip Strenght
ISRNM: International Society of Renal Nutrition and Metabolism
KDOQUI: Kidney Disease Outcomes Quality Initiative
KMO: Kaiser-Meyer-Olkin
LYM%: Lymphocyte percentage
MUAC: Mid-Upper Arm Circumference
NCPM: The Nutrition Care Process and Model
NHANESS II: The second National Health and Nutrition Examination Survey
NKF: National Kidney Foundation
PCA: Principal Component Analysis

PEM: Protein-Energy Malnutrition
PEW: Protein-Energy Wasting
SAH: Systemic Arterial Hypertension
SEGG: Spanish Society of Geriatrics and Gerontology
SENPE: Spanish Society of Parenteral and Enteral Nutrition
T2DM: Type 2 Diabetes mellitus
TLD: Total Lymphocyte count
TSF: Triceps Skinfold
WBC: White Blood Cells
WHO: World Health Organization

Introduction

The Academy of Nutrition and Dietitians (AND) places the evaluation of nutritional status as the first step of the Nutritional Care Process Model (NCPM) and describes it as a systematic method of collecting, comparing and interpreting data and information from different sources that allow us to write a nutritional diagnosis (1-3). In turn, over the years, various authors have differed in the number of components that make up the evaluation of nutritional status in patients with end-stage renal disease in hemodialysis, but have agreed that it requires several components for its application. In addition, it has been sought to group all the components by categories, establishing that the evaluation of nutritional status is composed mainly of anthropometric, biochemical, clinical and dietary parameters, usually referred as the A, B, C, D of the evaluation of nutritional status. However, each proposed category is made up of a large number of components that, when collected and interpreted together, complicate the execution of the evaluation of nutritional status and the writing of nutritional diagnosis (1-14,20,22-23).

For this reason, the objective of this study is to determine the main components of the evaluation of nutritional status that allow formulating a nutritional diagnosis in patients with end-stage renal disease (ESRD) in hemodialysis (HD). In such a way that the clinical health and nutrition professional can select the minimum components of the evaluation of nutritional status that make up the nutritional diagnosis in a group of patients.

Materials and methods

Cross-sectional, observational, descriptive and correlational study, in which the principal component analysis method was applied and the main indicators of nutritional status in hemodialysis patients were correlated. We evaluated 31 outpatients diagnosed with chronic renal failure (CKD) between 21 and 84 years who were in a hemodialysis program. The study was conducted according to the Helsinki declaration and the informed consent of all the patients was obtained before enrollment.

The evaluation of the nutritional status of patients on hemodialysis was made up of the following components: 1) anthropometric parameters, 2) biochemical parameters, 3) dietary parameters and 4) functional parameters.

Anthropometric parameters

The anthropometric measurements were made by a specialist in clinical nutrition with 10 years of experience in Care Process Certification & Medical Therapy in Renal Disease. The anthropometric parameters evaluated were: current weight (AW), body mass index (BMI), percent of usual body weight (% UBW), percent of standard body weight (% SBW), percent of triceps skinfold (% TSF), the percentage of the mid-upper arm circumference (% MUAC), the corrected mid-upper arm muscle area (cAMA).

Next, the method used for its interpretation is described. The AW was considered post-hemodialysis weight or dry weight. The BMI was interpreted in subjects > 20 and < 65 years of age using the cut-off points proposed by the World Health Organization (WHO) of 2006. For subjects > 64 years of age, the interpretation proposed by the Spanish Society of Parenteral and Enteral Nutrition (SENPE) and the Spanish Society of Geriatrics and Gerontology (SEGG) of 2007 was used (15-16).

The % UBW was calculated by comparing the AW against the usual body weight (UBW) by the following formula: %UBW=[(UBW-AW)]/UBW x100, considering weight loss > 7.5% in three months as a serious weight loss. To calculate the % SBW, the bone structure of the patient was first determined and classified with the tables of the Metropolitan Life Insurance Company. Subsequently, the standard body weight (SBW) was obtained with the tables of the National Health and Nutrition Examination Survey (NHANESS II) and finally the variation between the patient›s AW with the SBW using the formula: %SBW=(AW/SBW)X100; being interpreted as malnutrition values < 95% and as excess weight at values > 115% (17-20).

To calculate and interpret the % TSF and the % MUAC, the TSF and the MUAC were first located in the Frisancho percentile tables and then the percentages of each were calculated with the following formulas: % TSF=[(TSF actual)/(TSF p50)]x100 y MUAC=[MUACactual/(MUAC p50)]x100. Finally, the TSF was interpreted as adipose tissue excess at values > 110% and deficit values <90%. Subsequently, the cAMA was calculated and according to the Frisancho percentile tables, the data located from p5 to p15 were interpreted as mild to moderate depletion of muscle tissue and the data <p5 as severe depletion of muscle tissue (17-20).

Height and current weight (AW) were taken in a single measurement. The triceps skinfold (TSF) and mid-upper arm circumference (MUAC) were performed in three measurements repeated by a single evaluator. Subsequently, we calculated the technical error (TEM) intra-evaluator of TSF and MUAC measurements for patients with end-stage renal disease in hemodialysis with the following equation: Absolute TEM=$\sqrt{(\sum D_i^2)/2n}$ and Relative TEM%=(Absolute TEM)/VAV*100. The relative TEM for intra-evaluator verification for TSF were 5.2% and for MUAC were 0.6%, this means that the human error for measurements in the study was acceptable. (21-22).

Biochemical parameters

The biochemical parameters analyzed for the evaluation of nutritional status were serum albumin (Alb) and total lymphocyte count (TLC). The TLC was calculated with the total leukocyte values (WBC) and the percentage of lymphocytes (LYM%) by the following formula: TLC=[LYM(%)*WBC(k/uL)]/100, considering as malnutrition the values ≤ 2000 lymphocytes / mL; and values ≤ 3.5 g/dL were interpreted as malnutrition by serum albumin. Serum phosphorus and potassium were also evaluated as metabolic markers related to the nutrition of patients on hemodialysis (11,23-25).

Dietary parameters

The energy and protein intake was evaluated by means of a 3-day food diary also called a food and beverage register. Prior to the delivery of the food diary, individual training was provided on the size of the portion in household measurements and grams by a specialist in clinical nutrition. In turn, the method of registering the food diary was taught and the patients were asked to record the consumption of two non-consecutive weekday days and one weekend day. Afterwards, the nutrient content of the ingested food and beverages of the three days was calculated in the Nutrimind© nutrition software and an average of the energy, protein, phosphorus, potassium, liquid and fiber intake of each patient was performed. Finally, the data obtained were compared with the values recommended by the KDOQUI Clinical Practice Guidelines for patients on hemodialysis. In the intake of phosphorus, potassium, liquids and fiber, an adjustment was made to be considered deficient intake at values lower than 90% compared to those recommended and an excessive intake at values higher than 110% compared to those recommended for each nutrient (4,7-9,24-26).

Functional parameters

The hand-grip strength (HGS) was evaluated by dynamometry, performing the measurement on the non-fistula side or hemodialysis catheter. The measurement was made before the hemodialysis session, with the arms in extension, parallel to the body and without support, indicating the patients to grasp the dynamometer with maximum force. The strength of the hand was measured three times with a recovery time of one minute, registering the maximum value with the muscle strength data. Values lower than the 10th percentile according to age and sex were interpreted as low muscular strength and values between the 10th percentile and the 25th percentile categorized as below average muscular strength (27).

Statistical analysis

A Principal Components Analysis (PCA) was performed using the Factor procedure in STATA (version 12.0). We use the 10 types of nutritional status assessment in our models. In nutritional epidemiology, the most used method to derive the nutritional diagnosis is ACP with varimax rotation; therefore, the factors were rotated by an orthogonal transformation (varimax rotation function) to improve the difference between the loads, which allowed an easier interpretation. The number of factors to be retained was determined using the own values diagram (the Scree graph) and the interpretability of the factors.

Results

Of the 31 patients evaluated nutritionally, 39% (n = 12) corresponded to the female sex and 61% (n = 19) to the male sex; with a minimum age of 21 years, a maximum of 84 years and a mean of 61.1 ± 16.9 years. In addition to the diagnosis of CDK, 87% (n = 27) had pathological personal history of systemic arterial hypertension (SAH), 68% (n = 21) of diabetes mellitus type 2 (T2DM), 6% (n = 2) of hyperuricemia, 6% (n = 2) of alcoholism and 3% (n = 1) of dyslipidemias (Table 1). The results obtained from the evaluation of nutritional status in hemodialysis patients are described below:

Anthropometric parameters

The sample of patients on hemodialysis had a minimum AW of 41 kg and a maximum of 117.4 kg, with a mean of 70.9 ± 17.9 kg. Regarding the evaluation of nutritional status, the results are shown in Table 1, with a higher prevalence of normal BMI (54.8%), followed by overweight (19.4%) and obesity I (19.4) and without any diagnosis of thinness by BMI. However, in the evaluation of nutritional status by %UBW it is shown that 26% of the population has presented a serious loss of weight, that is, they lost more than 5% of weight in a month. Likewise, a high prevalence of malnutrition was shown by %SBW (58%), a high prevalence of adipose tissue deficit (39%) and a greater prevalence of muscle mass depletion as measured by %MUAC (45.3%) and cAMA (54.9 %).

Biochemical parameters

A higher prevalence of malnutrition was shown when evaluating nutritional status by means of CTL than by Alb levels; we observed a frequency of 72.4% of the diagnosis of malnutrition by CTL, in contrast

Table 1. Anthropometric parameters of nutritional assessment

	n	**%**
BMI (kg/m^2)[1]		
-Severe thinness (<16 kg/m^2)	0	0
-Moderate thinness (16 to 16.99 kg/m^2)	0	0
-Mild thinness (17 to 18.49 kg/m^2)	0	0
-Normal range (18.5 to 24.99 kg/m^2)	17	**54.8**
-Overweight (25 to 29.99 kg/m^2)	6	19.4
-Obese class I (30 to 34.99 kg/m^2)	6	19.4
-Obese class II (35 to 39.99 kg/m^2)	1	3.2
-Obese class III (≥ 40 kg/m^2)	1	3.2
%UBW[1]		
-Severe weight loss (in 3 months a weight loss of 7.5%)	7	**23**
%SBW[1]		
-Severe malnutrition (<70%)	2	**6**
-Moderate malnutrition (70 to 85%)	8	**26**
-Mild malnutrition (85.1 to 95%)	8	**26**
-Normal (95 to 115%)	8	26
-Overweight (115.1 to 130%)	5	16
-Moderate obese (131 to 150%)	0	0
-Severe obese (>150%)	0	0
%TSF[1]		
-Severe deficit of adipose tissue (<70%)	8	**26**
-Moderate deficit of adipose tissue (70 to 80%)	1	**3**
-Mild deficit of adipose tissue (80 to 90%)	3	**10**
-Average adipose tissue (90 to 110%)	8	26
-Excess of adipose tissue (>110%)	11	35
%MUAC[1]		
-Severe muscle tissue deficit (<70%)	2	**6.5**
-Moderate muscle tissue deficit (70 to 80%)	6	**19.4**
-Mild muscle tissue deficit (80 to 90%)	6	**19.4**
-Average muscle tissue (90 to 110%)	15	48.4
-Excess of muscle tissue (>110%)	2	6.5
cAMA[1]		
-Severe depletion of muscle mass (<p5)	11	**35.5**
-Moderate depletion of muscle mass (p5 to p15)	6	**19.4**
-Average muscle mass (>p15)	14	45.2

[1]BMI: Body mass index; %USW: Percent usual body weight; %SBW: Percent standard body; %TSF: Percent triceps skinfold thickness; %MUAC: Percent mid-upper arm circumference; cAMA: Corrected arm muscle area

Table 2. Evaluation of nutritional biochemical parameters

	n	%
Alb[1] (n=23)		
-Severe malnutrition (<2.5 g/dL)	0	0
-Moderate malnutrition (2.5 - 2.9 g/dL)	1	4
-Mild malnutrition (3 - 3.49 g/dL)	2	9
-Normal (3.5 - 4.5 g/dL)	20	**87**
TLC[1] (n=29)		
-Severe malnutrition (<800 lymphocytes/mL)	4	**13.8**
-Moderate malnutrition (800-1999 lymphocytes/mL)	4	**13.8**
-Mild malnutrition (1200-1599 lymphocytes/mL)	13	**44.8**
-Normal (>1600 lymphocytes/mL)	8	27.6
Serum phosphorus levels (n=25)		
-Normal values (2.5 - 5 mg/dL)	12	48
-High (>5 mg/dL)	11	**44**
-Below (<2.5 mg/dL)	2	8
Serum potassium levels (n=28)		
-Normal values (3.5 - 5 meq/L)	8	29
-High (> 5 meq/L)	20	**71**

[1]Alb: Albumin; TLC: Total lymphocyte count

Table 3. Dietary parameters of nutritional assessment

	n	%
Energy intake		
-Inadequate energy intake	30	**97**
>60 years: <30 cal/kg		
<60 years: <35 cal/kg		
-Adequate energy intake	0	0
>60 years: 30-35 cal/kg		
<60 years: 35 cal/kg		
-Excessive energy intake	1	3
>60 years: >35 cal/kg		
<60 years: >35 cal/kg		
Protein intake		
-Inadequate protein intake (<1.1 g/kg)	26	**84**
-Adequate protein intake (1.1 - 1.2 g/kg)	3	10
-Excessive protein intake (>1.2 g/kg)	2	6
Phosphorus intake[1]		
-Inadequate phosphorus intake (<800 mg)	23	**74.2**
-Adequate phosphorus intake (800-1000 mg)	6	19.4
-Excessive phosphorus intake (>1000 mg)	2	6.5
Potassium intake[1]		
-Inadequate potassium intake (<40 mg/kg)	0	0
-Adequate potassium intake (40 mg/kg)	7	23
-Excessive potassium intake (>40 mg/kg)	24	**77**
Fluid intake[1]		
-Inadequate fluid intake (<1000 mL + diuresis)	21	**68**
-Adequate fluid intake (1000 mL + diuresis)	9	29
-Excessive fluid intake (>1000 mL + diuresis)	1	3
Fiber intake[1]		
-Inadequate fiber intake (<20 g)	23	**74**
-Adequate fiber intake (20 - 30 g)	8	26
-Excessive fiber intake (>30 g)	0	0

[1]Inadequate intake: <90% of recommended values; Excessive intake >110% of recommended values.

with 13% by Alb. On the other hand, the evaluation of the metabolic markers related to the nutrition of patients on hemodialysis showed high levels of serum phosphorus with a 44% prevalence and elevated levels of serum potassium in 71%.

Dietary parameters

The evaluation of nutritional status by dietary parameters showed that patients on hemodialysis have a deficient intake of energy (97%) and proteins (84%). In addition to a deficient intake of phosphorus (74.2%), liquids (68%) and fiber (74%); and an excessive intake of potassium (77%).

Functional parameters

There was a high prevalence of low muscular strength (92%, n = 24) measured by HGS in the hemodialysis patients evaluated. In addition, no patient showed average muscle strength levels for age and sex, and only 8% (n = 2) had below-average muscle strength levels.

Principal Component Analysis (PCA)

A PCA was performed with 10 variables of nutritional diagnosis in patients with hemodialysis: Energy Intake, Protein Intake, IBM, %UBW, %SBW, %MUAC, cAMA, %TCF, HGS and TLC as well as the age of the patients. First, we obtain a matrix of correlations between all the variables considered (r of Pearson). The basic assumption of factor analysis is that the correlation matrix expresses a pattern of relations between variables that can be deciphered. It can be seen in table 4, the significant correlation between the variables (p <0.005).

Table 4. Correlation matrix

Variable	Age	Energy Intake	Protein Intake	IBM	%UBW	%SBW	%MUAC	cAMA	%TCF	HGS	TLC
Age	1										
Energy Intake	0.8830	1									
Protein Intake	0.9060	**0.0000**	1								
IBM	0.6454	**0.0024**	**0.0004**	1							
%UBW	0.5772	**0.0150**	**0.0356**	0.0933	1						
%SBW	0.0913	**0.0005**	**0.0003**	**0.0000**	0.3235	1					
%MUAC	0.7449	**0.0325**	**0.0207**	**0.0000**	**0.0214**	**0.0366**	1				
cAMA	0.6931	**0.0011**	**0.0005**	**0.0000**	0.0625	**0.0000**	**0.000**	1			
%TCF	0.5315	0.0743	**0.0323**	**0.0190**	0.9663	**0.0136**	0.3589	0.0558	1		
HGS	**0.0006**	0.3787	0.4393	0.3970	0.5970	**0.0422**	0.6285	0.3284	0.5256	1	
TLC	0.4695	**0.0664**	0.1826	**0.0164**	**0.0397**	0.1163	0.0815	0.0531	0.6560	0.7862	1

Determinant of the correlation matrix P<0.005

With the generation of the correlation matrix, we obtain a series of statistical tests that indicated whether it is pertinent or not to carry out the factorial analysis with the available information. Then, it was found that for the Bartlett test, the variables are significantly correlated since a value of p-value = 0.0000 is obtained, so the adjustment of the variables by factor analysis is considered appropriate. In addition, for the Kaiser-Meyer-Olkin Coefficient (KMO) the value is greater than 0.6 (0.661), so it is considered an acceptable analysis (Table 5).

From the correlation of the main components (Table 6), four factors whose value is greater than 0 were determined and which explain 79.91% of the total variance. The first factor identified explains 43.85% of the variance, the second factor explains 59.74% of the variance, factor three the 70.69% of the variance and the last factor of 79.91% of the variance.

An orthogonal varimax rotation was performed, from which we obtain a matrix of rotated components that indicates the correlation between each of the variables and their corresponding factor. According to the matrix of analysis of principal components (PCA) with varimax orthogonal rotation, the first factor is made up of IBM, %SBW, %MUAC, cAMA. In such a way that IBM, %SBW, %MUAC, cAMA, present positive correlations indicating that an increase in IBM, %WBW, %MUAC involves an increase in cAMA. The second factor is formed by Energy Intake, Protein Intake and %TCF in such a way that when there is a decrease in energy and protein intake there is an increase in %TCF. The third factor is formed by age and HGS so that when age increases the measure of HGS decreases and the fourth factor is made up of %UBW and %TCF with a positive correlation (Table 7).

Table 5. Bartlett Test of Sphericity and Kaiser-Meyer-Olkin measure

Bartlett test	Chi-square	234.089
	Degrees of freedom	55
	p-value	**0.000**
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	KMO	**0.661**

Table 6. Correlation of principal components

Component	Eigenvalue	Difference	Proportion	Cumulative
Component 1	4.82299	3.0749	43.85%	43.85%
Component 2	1.74809	0.543774	15.89%	59.74%
Component 3	1.20431	0.190118	10.95%	70.69%
Component 4	1.0142	0.258623	9.22%	79.91%
Component 5	.755573	.171305	6.87%	86.77%
Component 6	.584268	.182416	5.31%	92.09%
Component 7	.401852	137625	3.65%	95.74%
Component 8	.264227	.158208	2.40%	98.14%
Component 9	.106019	.036534	0.96%	99.10%
Component 10	.0694851	.0404956	0.63%	99.74%
Component 11	.0289895	.	0.26%	100%

Chi2(45) = 243.27 and P= 0.0000

Table 7. Matrix rotation

Variable	Matrix rotation			
	Factor 1	Factor 2	Factor 3	Factor 4
Age	-0.0587	0.1150	0.9022	0.0968
Energy Intake	-0.2714	-0.8934	0.0251	0.1679
Protein Intake	-0.3253	-0.8752	-0.0216	0.0576
IBM	0.8755	0.3602	-0.1096	0.0475
%UBW	-0.2207	-0.3774	0.0800	0.7456
%SBW	0.6238	0.4977	-0.3870	0.1914
%MUAC	0.8681	0.0774	0.1517	-0.2425
cAMA	0.9138	0.2979	-0.0853	-0.0441
%TCF	0.2922	0.5040	0.0671	0.5825
DINAMOTRY	0.0153	0.1970	-0.8508	0.0572
TLC	0.3953	0.2437	0.1898	-0.4588

After the varimax rotation, the correlation between the set of variables that make up the factor 1 present 29.25% of the total variance. The correlation between the variables in factor 2 is 52.38%, factor 3 represents 68.55% of the total variance and factor 3 of 79.91% (Table 8).

Discussion

First, it is important to discern the nomenclature and the diagnostic criteria used so far to evaluate the nutritional status in patients with CDK. The International Society of Renal Nutrition and Metabolism (ISRNM) "review and develop standard terminology and definitions related to wasting, cachexia, malnutrition, and inflammation in CDK and recommends the term protein-energy wasting (PEW) for the loss of body protein mass and fuel reserves" that has specific criteria for clinical diagnosis (28). For its part, the National Kidney Foundation (NKF) developed the K/DOQUI guidelines which have a section entitled "Evaluation of Protein-Energy Nutritional Status" in patients with dialysis, concluding that the nutritional status should be evaluated with a combination of different components, since there is no single measure that provides a complete indication of the protein-energy status. It is recommended to evaluate energy and protein intake, visceral protein reserves, muscle mass, other dimensions of the body composition and functional status to evaluate protein-energy malnutrition (PEM) (24).

Therefore, it is important to point out that the purpose of the evaluation of nutritional status is to identify problems related to nutrition and the pathology of study, which allow to plan and implement evidence-based strategies and clinical practice guidelines designed to address the identified nutritional problems (1-11,24). The objective of this study is to simplify the process of evaluation of nutritional status through the PCA.

This study shows that patients with ESRD in HD have a high prevalence of PEM diagnosed nutritionally by a severe weight loss determined by %UBW (26%), malnutrition by %SBW (58%), adipose tissue deficit by %TSF (39%), depletion of muscle tissue by

Table 8. Analysis principal component factors

Principal component	Names	Location	Variance	Difference	Cumulative
Factor 1	Body composition status	IBM %SBW %MUAC cAMA	3.21	0.67356	29.25%
Factor 2	Nutritional risk	Energy Intake Protein Intake %TCF	2.54	0.76614	52.38%
Factor 3	Functional status risk	HGS Age	1.77	0.52851	68.55%
Factor 4	Body composition stability	%SBW %TCF	1.24	.	79.91%

Chi2(55) = 243.27 P= 0.0000

%MUAC (45.3%) and cAMA (54.9%), malnutrition by CTL (72.4%), deficient energy intake (97%), deficient protein intake (84%) and low HGS (92%). These results agree with cross-sectional analyzes performed in patients on HD who have found a prevalence of more than 60% of PEM and some authors have cited that the HD procedure is a general catabolic event *per se*, which decreases circulating amino acids and accelerates proteolysis rates muscle and body mass leading to PEM (29-32). It is also important to point out that in the sample studied, 68% (n = 21) of the patients with ESRD in HD had T2DM and it has been experimentally concluded that diabetes mellitus causes loss of muscle proteins by the activation of the ubiquitin-proteasome pathway with increased expression of the ubiquitin gene (33).

In addition to the above, it is relevant to note the high prevalence of low HGS (92%) present in patients with ESRD in HD and to contrast this fact with the results found by BMI and Alb; the BMI did not identify underweight (0%) as a nutritional problem that contributes to the nutritional diagnosis of PEM and a low prevalence of malnutrition (13%) was found by Alb. Some studies have found that low HGS is not influenced by dialysis variables and therefore can be used as a reliable nutritional marker in HD patients. A significant linear trend towards progressively lower values of HGS with the degree of malnutrition has also been shown (27,30). Therefore, we conclude that HGS can be considered an indicator of nutritional risk in patients with ESRD in HD independently of the results of anthropometric and biochemical parameters. Given that muscle strength is the first component of the evaluation of nutritional status that is affected, reflecting a decrease in functionality that will lead to a progressive loss of muscle mass that will affect the morbidity and mortality of this group of patients.

The objective of the analysis of main components was to reduce the number of variables used for the evaluation of nutritional status, losing as little information as possible. The results of this analysis showed that a nutritional diagnosis can be made in patients on hemodialysis by means of four main components of the evaluation of nutritional status. Also, the results obtained through the PCA show theoretical and practical logic that allowed us to assign names to the components. The first component was called the body composition status component, the second component was the nutritional risk component, the third component was functional status risk and the fourth component was body composition stability. In the rotation matrix (Table 7) the relation between the components and the indicators is observed, being in the first component called body composition status a correlation with cAMA (r = 0.9138), IBM (r = 0.8755), %MUAC (r) = 0.8681) and %SBW (r = 0.6238), that is, the higher the cAMA, IBM, %MUAC and %SBW, the greater or better body composition status. As previously mentioned, these results show theoretical and practical coherence, since the anthropometric parameters of weight and body mass are related to the body composition status (15-20) since several studies have shown that decreased levels in these parameters lead to a decrease in the quality of life and an increased risk of mortality related to PME (34-36).

In the second component called nutritional risk, a correlation was observed with energy intake (r = -0.8934), protein intake (r = -0.8752) and %TCF (0.5040), that is, the lower the energy and protein intake, the greater the nutritional risk, or in other words, the higher the energy and protein intake, the lower the nutritional risk. These results have already been demonstrated in several studies, recognizing as one of the main causes of malnutrition in patients on hemodialysis to deficient food intake. On the other hand, the correlation between the %TCF with this component shows that body fat is a nutritional risk factor, because it increases the risk of suffering cardiovascular disease (37-40).

In the third component called functional status risk, a correlation was found with age (r = 0.9022) and HGS (r = 0.8508), that is, higher values of HGS lower functional status risk, or said other way at lower values of HGS greater functional status risk. Likewise, the higher the age, the higher the functional status risk. These results agree with the information shown in other studies in patients on hemodialysis, in which, it has been found that a low HGS is related to a lower quality of life and nutritional status. Likewise, it has been pointed out that age is a risk factor for malnutrition and morbidity and mortality in patients on hemodialysis 30,41).

Finally, in the fourth component called body composition stability was correlated with the %UBW (r = 0.7456) and the %TCF (r = 0.5825), that is, the higher %USW and %TCF higher body composition stability. Concluding that the body composition stability is indispensable in patients with end-stage renal disease in hemodialysis.

To conclude: The number of variables used for the evaluation of nutritional status in the end-stage renal disease in hemodialysis was reduced by the PCA to four main components called: 1) body composition status, 2) nutritional risk, 3) functional status risk and 4) body composition stability.

Ultimately, this manuscript provides scientific evidence for health and nutrition professionals to make decisions about the selection and interpretation of the main minimum components for the assessment of nutritional status in the end-stage renal disease in hemodialysis. These conclusions facilitate the medical and nutritional care of greater efficiency and quality in this group of patients.

References

1. Lacey K, Pritchett E. Nutrition care process and model: ADA adopts road map to quality care and outcomes management. J Am Diet Assoc. 2003; 8:1061-72.
2. Writing Group of the Nutrition Care Process/Standardized Language Committee. Nutrition care process and model part I: the 2008 update. J Am Diet Assoc. 2008;108(7):1113-7.
3. Writing Group of the Nutrition Care Process/Standardized Language Committee. Nutrition care process part II: using the international dietetics and nutrition terminology to document the nutrition care process. J Am Diet Assoc. 2008;108(8):1287-93.
4. Pasticci F, Fantuzzi AL, Pegoraro M, McCann M, Bedogni G. Nutritional management of stage 5 chronic kidney disease. J Ren Care. 2012;38(1):50-8.
5. Moise C, Thomas LK. Nutrition Care Process: Screening and assessment. In: Thomas LK, Bohnstadt JO, editors. Nutrition therapy for chronic kidney disease. New York: CRC Press; 2012. p. 93-106.
6. DiBenedetto P, Brommage D. Nutrition assessment in chronic kidney disease. In: Byham-Gray L, Stover J, Wiesen K, editors. A clinical guide to nutrition care in kidney disease. 2nd Ed. US: Academy of Nutrition and Dietetics; 2013. p. 7-24.
7. Hutson B, Stuart N. Nutrition management of adult hemodialysis patient. In: Byham-Gray L, Stover J, Wiesen K, editors. A clinical guide to nutrition care in kidney disease. 2nd Ed. US: Academy of Nutrition and Dietetics; 2013. p. 53-68.
8. Beto JA, Ramirez WE, Bansal VK. Medical nutrition therapy in adults with chronic kidney disease: integrating evidence and consensus into practice for the generalist registered dietitian nutritionist. J Acad Nutr Diet. 2014;114(7):1077-87.
9. Moore L. Dietary Assessment in Kidney Disease. In: Byham-Gray LD, Burrowes JD, Glen MC, editors. Nutrition in Kidney disease. 2nd Ed. US: Humana Press; 2014. p. 25-48.
10. Dumbler F. Anthropometric assessment in kidney disease. In: Byham-Gray LD, Burrowes JD, Glen MC, editors. Nutrition in Kidney disease. 2nd Ed. US: Humana Press; 2014. p. 49-56.
11. Cockram D. Biochemical nutritional assessment in chronic kidney disease. In: Byham-Gray LD, Burrowes JD, Glen MC, editors. Nutrition in Kidney disease. 2nd Ed. US: Humana Press; 2014. p. 57-68.
12. Suverza A, Haua. El ABCD de la evaluación del estado de nutrición. México: Mc Graw Hill, 2010.
13. Gibson R. Principles of nutritional assessment. New York: Oxford University Press, 1990.
14. Gibson R. Principles of nutritional assessment. 2nd Ed. New York: Oxford University Press, 2005.
15. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser. 1995; 854:1-452.
16. Sociedad Española de Nutrición Parenteral y Enteral (SENPE), Sociedad Española de Geriatría y Gerontología (SEGG). Valoración nutricional en el anciano. Recomendaciones prácticas de los expertos en geriatría y nutrición. España: Galénitas-Nigra Trea, 2007.
17. Blackburn GL, Bistrian BR, Maini BS, Schlamm HT, Smith MF. Nutritional and metabolic assessment of the hospitalized patient. JPEN J Parenter Enteral Nutr. 1977; 1:11-22.
18. Frisancho AR. Anthropometric standards for the assessment of growth and nutritional status. Ann Arbor, Michigan: University of Michigan Press, 1990.
19. Frisancho AR. New standards of weight and body composition by frame and size and height for assessment of nutritional status of adults and the elderly. Am J Clin Nutr. 1984; 40(4): 808-19.
20. Osuna IA. Proceso del Cuidado Nutricional en la Enfermedad Renal Crónica. México: Manual Moderno, 2016.
21. Perini TA, Oliveira GL, Ornellas J, Oliveira FP. Technical error of measurement in anthropometry. Rev Bras Med Esporte. 2005; 11(1): 81-85.
22. Geeta A, Jamaiyah H, Safiza MN, Khor GL, Kee CC, Ahmad AZ, Suzana S, Rahmah R, Faudzi A. Reliability, technical error of measurements and validity of instruments for nutritional status assessment of adults in Malasyia. Singapore Med J. 2009; 50(10): 1013-8.
23. Ignacio de Ulíbarri J, González-Madroño A, de Villar NG, González P, González B, Mancha A, Rodríguez F, Fernández G. CONUT: a tool for controlling nutritional status. First validation in a hospital population. Nutr Hosp. 2005; 20:38-45.
24. National Kidney Foundation: K/DOQUI. Clinical practice guidelines for chronic kidney disease: Nutrition in chronic renal failure: adult guidelines. Am J Kidney Dis. 2000;35(6S2): S17-S104.

25. National Kidney Foundation: K/DOQUI. Clinical practice guidelines for bone metabolism and disease in chronic kidney disease. Am J Kidney Dis. 2003;42(4S3):S63-S64,S77-S78.
26. Nutrimind. Software de Nutrición. 2018. https://www.nutrimind.net
27. Leal VO, Stockler-Pinto MB, Farage NE, Aranha LN, Fouque D, Anjos LA, Mafra D. Handgrip strength and its dialysis determinants in hemodialysis patients. Nutrition. 2011; 27(11-12):1125-1129.
28. Fouque D, Kalantar-Zadeh K, Kopple J et al. A proposed nomenclature and diagnostic criteria for protein-energy wasting in acute and chronic kidney disease. Kidney Int. 2008;73(4):391-8.
29. Kalantar-Zadeh K. Protein-Energy Wasting. In: Byham-Gray LD, Burrowes JD, Glen MC, editors. Nutrition in Kidney disease. 2nd Ed. US: Humana Press; 2014. p. 219-230.
30. Qureshi AR, Alvestrand A, Danielsson A, Divino-Filho JC, Gutierrez A, Lindholm B, Bergström J. Factors predicting malnutrition in hemodialysis patients: a cross-sectional study. Kidney Int.1998;53(3):773–82.
31. Guiterrez A, Alvestrand A, Wahren J, Bergström, J. Effect of in vivo contact between blood and dialysis membranes on protein catabolism in humans. Kidney Int. 1990;38(3):487-94.
32. Ikizler TA, Pupim LB, Brouillette JR, Levenhagen DK, Farmer K, Hakim RM, Flakoll PJ. Hemodialysis stimulates muscle and whole-body protein loss and alters substrate oxidation. Am J Physiol Endocrinol Metab. 2002; 282: E107-16.
33. Price SR, Bailey JL, Wang X, Jurkovitz C, England BK, Ding X, Phillips LS, Mitch WE. Muscle wasting in insulinopenic rat's results from activation of the ATP-dependent, ubiquitin-proteasome proteolytic pathway by a mechanism including gene transcription. J Clin Invest. 1996;98(8):1703-08.
34. Allen KL, Miskulin D, Yang G, Dwyer JT, Frydrych A, Leung J, Poole D. Hemodialysis (HEMO) Study Group. Association of nutritional markers with physical and mental health status in prevalent hemodialysis patients from HEMO study. J Ren Nutr. 2002;12(3):160-9.
35. Chumlea WC, Dwyer J, Bergen C, Burkat J, Paranandi L, Frydrych A, Cockram DB, Kusek JW, McLeroy S. Hemodialysis Study Group. Nutritional status assessed from anthropometric measures in the HEMO study. J Ren Nutr. 2003;13(1):31-8.
36. Fung F, Sherrard DJ, Gillen DL, Wong C, Kestenbaum B, Seliger S, Ball A, Stehman-Breen C. Increased risk for cardiovascular mortality among malnourished end-stage renal disease patients. Am J Kidney Dis. 2002;40(2):307-14.
37. Dwyer JT, Cunniff PJ, Maroni BJ, Kopple JD, Burrowes JD, Powers SN, Cockram DB, Chumlea WC, Kusek JW, Makoff R, Goldstein DJ, Paranandi L. The hemodialysis pilot study: nutrition program and participant characteristics at baseline. The HEMO Study Group. J Ren Nutr. 1998;8(1):11-20.
38. Bossola M, Muscaritoli M, Tazza L, Panocchia N, Liberatori M, Giungi S, Tortorelli A, Rossi Fanelli F, Luciani G. Variables associated with reduced dietary intake in hemodialysis patients. J Ren Nutr. 2005;15(2):244-252.
39. Bergström J. Why are dialysis patients malnourished? Am J Kidney Dis. 1995;26(1):229-41.
40. González E, Díez JJ, Pérez Torres A, Bajo MA, Del Peso G, Sánchez-Villanueva R, Grande C, Rodríguez O, Coronado M, Gómez Candela C, Díaz-Almirón M, Iglesias P, Selgas R. Body composition analysis and adipocytokine concentrations in hemodialysis patients: abdominal fat gain as and additional cardiovascular risk factor. Nefrologia. 2017;37(2):138-148.
41. Chauveau P, Combe C, Laville M, Fouque D, Azar R, Cano N, Canaud B, Roth H, Leverve X, Aparicio M. French Study Group for Nutrition in Dialysis. Am J Kidney Dis. 2001;37(5):997-1003.

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