



Examining the relationship between nutrition, quality of life, and depression in hemodialysis patients

Shawona C. Daniel¹ · Andres Azuero¹ · Orlando M. Gutierrez² · Karen Heaton¹

Accepted: 17 October 2020 / Published online: 27 October 2020
© Springer Nature Switzerland AG 2020

Abstract

Purpose Lifestyle changes associated with end-stage renal disease may be a factor in depression and quality of life (QOL) for patients receiving hemodialysis. This cross-sectional study examined the relationship between nutritional status, QOL, and depression in 124 hemodialysis patients.

Methods Nutritional markers included serum albumin, normalized protein catabolic rate (nPCR), body mass index (BMI), body fat percentage, and daily protein intake. Physical and Mental dimension scores of the Kidney Disease QOL-Short Form (KDQOL-SF), and the Center for Epidemiological Studies of Depression (CESD) survey were used to measure QOL and depression, respectively. Data were analyzed using regression analyses. Measures of effect size were used for interpretation.

Results Nutritional status indicators explained a moderate amount of the variability of the Physical dimension of QOL (crude $R^2 = .14$, covariate-adjusted $\Delta R^2 = .06$) but had weak explanatory ability for the Mental dimension of QOL (crude $R^2 = .05$, covariate-adjusted $\Delta R^2 = .02$) and CESD (crude $R^2 = .02$, covariate-adjusted $\Delta R^2 = .005$). Additional findings suggested the presence of non-linear relationships between protein intake and both the Physical and Mental QOL dimension scores. Longer dialysis vintage was also correlated with lower psychosocial patient outcomes.

Conclusion While nutritional status is an important element in predicting hemodialysis patient outcomes, its relationship to depression and QOL, in this sample, demonstrated only moderate explanatory ability. However, dialysis vintage and level of education had a significant relationship with depression and QOL. These findings suggest that patients with longer dialysis vintage and limited health literacy require unique plans of care. Future studies aimed at understanding the interrelationships between non-modifiable patient characteristics and psychosocial outcomes are imperative.

Keywords Hemodialysis · Nutrition · Quality of life · Depression

An estimated 30 million American adults have chronic kidney disease with a large number being treated for end-stage renal disease, ESRD [1]. Approximately 700,000 were treated for ESRD in the United States in 2015 and accounts

for an increase of 80% since 2000 [1]. In 2017, more than 70% of these individuals received a hemodialysis or peritoneal dialysis modality, while the remaining affected persons were sustained by renal transplantation [2]. Although the implementation of evidence-based medical guidelines and use of innovative technological advances have improved the life expectancy of dialysis patients, the incidence of morbidity and mortality remains higher than other chronic illnesses in the general population [2]. Exploring the contribution of psychosocial well-being and clinical factors, such as nutritional status, to existing disparities is important to close the gap.

A vital component of psychosocial well-being is how a person perceives his or her health and the effect of an illness on his or her personal life. Quality of life is a broad multidimensional concept that includes subjective evaluations of both positive and negative aspects of life,

✉ Shawona C. Daniel
shawona@uab.edu

Andres Azuero
andreo@uab.edu

Orlando M. Gutierrez
ogutierrez@uabmc.edu

Karen Heaton
kharnp@uab.edu

¹ University of Alabama at Birmingham-School of Nursing, Birmingham, AL, USA

² University of Alabama at Birmingham-School of Medicine, Birmingham, USA

including perceptions of life quality, value, and/or worth in terms of personal satisfaction (or dissatisfaction) with cultural or intellectual conditions under which a person lives [3]. Chronic illnesses such as ESRD are conditions of long duration and slow progression and are rarely curable. A diagnosis of ESRD requires ongoing adjustment to all aspects of daily life and can include physical suffering, functional impairments, losses, worry, and grief, which pose threats to quality of life [4]. Hemodialysis patients have a significantly reduced quality of life compared with the general population and those who rely on other treatment modalities including peritoneal dialysis and renal transplant [5, 6]. Hemodialysis patients have poorer health-related quality of life in several aspects of their environment and their social relationships [7]. Moreover, spirituality and overall psychosocial adjustment significantly influence quality of life in patients with kidney disease [8]. While studies have revealed several contributing factors to poor quality of life in ESRD patients including fatigue, lack of autonomy, and confounding co-morbidities [9–11], nutritional well-being as a contributor to this phenomenon is not well understood. Several predictive factors including co-morbid chronic conditions (i.e., diabetes, hepatitis C), low serum albumin, and higher BMI have also been associated with quality of life outcomes [12, 13].

Evidence suggests that body composition contributes to psychosocial health. Obese hemodialysis patients and those with higher body fat percentages have demonstrated lower quality of life than normal weight or underweight patients [14, 15]. Additionally, lean body mass is associated with increased depression and anxiety [16]. Body mass index (BMI) has also been shown to have a negative correlation with quality of life depicting an inverse relationship between BMI and quality of life [17]. Further evidence suggests that poor quality of life is preceded by lower albumin levels [15, 18]. Patients who achieved target albumin goals had higher quality of life scores on the Mental and Physical Components of the standard SF-36 [19]. Quality of life in this population further declines in the presence of depression and anxiety [20].

Depression is another independent dynamic that has a negative impact on patient outcomes including quality of life, treatment compliance, and mortality [21, 22]. The prevalence of depressive effect in hemodialysis patients is higher than the general population [23, 24]. The estimated rates of clinical depression in hemodialysis patients range from 20 to 30%, with as many as 42% showing some form of depressive affect [25–27]. Depression in this population is associated with increased age, female gender, lower educational level, poor socioeconomic status, and increased co-morbidities and mortality [28, 29]. The association between nutritional markers and the incidence of depression in this population has not been adequately investigated [30].

Patients on hemodialysis suffer a diminished quality of life and malnutrition is a major concern. There is a substantial need to investigate the role of nutrition and other psychosocial factors in decreased quality of life of hemodialysis patients. When targeting modifiable factors and their role in quality of life and depression, it is reasonable to believe that amendable behaviors and circumstances may have a profound effect on dialysis patient outcomes. However, there is limited research that examines the association between modifiable behaviors and quality of life or depression in the hemodialysis population. Therefore, the purpose of this investigation was to explore the relationship between nutritional status (measured by serum albumin, normalized protein catabolic rate (nPCR), BMI, percent body fat, and self-report dietary protein intake), health-related quality of life, and depression in patients with ESRD receiving maintenance hemodialysis.

Methodology

Design

A cross-sectional correlational design was used for the examination of relationships between nutrition and health-related outcomes in hemodialysis patients.

Sample and setting

The study was conducted in central Alabama, a Southeastern state located in the Deep South. Alabama ranks 5th in the nation for kidney disease occurrence [31]. Following University of Alabama at Birmingham (UAB) Institutional Review Board approval and approval from the dialysis provider's review board, 124 participants were recruited from four, for-profit, in-center hemodialysis facilities in the tri-county area of Montgomery, Alabama. From a collective pool of approximately 200 patients, roughly 140 patients who met eligibility criteria were approached to participate in the study. Those who declined had varying reasons ranging from disinterest to plans of relocation. The sample size was estimated based on the number of potential participants who were available for recruitment, who could potentially meet the inclusion criteria, and within the proposed time frame for the study. The sample consisted of individuals with ESRD who received in-center hemodialysis as the primary modality of treatment in one of the four selected facilities.

Inclusion and exclusion criteria

Patients from any racial/ethnic group or gender were eligible to participate in the study. Inclusion criteria included (1) confirmed diagnosis of ESRD, (2) receiving active, in-center

maintenance hemodialysis, (3) at least 19 years of age or older, (4) able to speak and understand English, and (5) hemodialysis ‘vintage’ (length of time on dialysis) of at least 90 days. Individuals with a dialysis vintage less than 90 days were excluded due to the risk of higher acuity and unstable biophysical status at the initiation of dialysis. Anyone who verbally confirmed experiencing suicidal thoughts and those with bilateral lower extremity amputations, preventing accurate height assessment for calculating BMI, were also excluded. Approximately 60 potential participants were excluded due to inability to provide consent, had a dialysis vintage less than 90 days, and/or had bilateral lower limb amputations.

Data collection and measures

Data were collected on the day of the month that coincided with each facilities’ scheduled monthly lab specimen collection. If a participant did not receive treatment in the facility on the expected date of collection, weekly communication was maintained with the treatment facility and data were collected when the participant returned for treatment. After obtaining informed consent from the participant, the Center for Epidemiological Studies of Depression (CESD) survey was administered to assess the participant’s level of depression and eligibility to continue in the study. The CESD is a 20-item self-report survey used to estimate severity of depression [32], and has an α reliability of 0.90 [33]. Each item has four response options ranging from 0 to 3 with 0 indicating rare occurrence of depressive symptoms and 3 indicating depressive symptoms most of the time. The composite score ranges from 0 to 60 with scores greater than 16 suggesting a clinically significant level of psychological distress. If a participant scored greater than 16 on the CESD, indicating a probable depressive episode or major depressive episode, they were assessed for suicidal ideations, requiring removal from the study and referral according to facility protocol. No participants met this criteria for removal from the study.

Demographic and clinical data including age, race, gender, education, vascular access type, vintage, alcohol/tobacco use, and co-morbidities were obtained via self-report and/or medical records. Participants completed the Kidney Disease Quality of Life-Short Form (KDQOL-SF) v. 1.3 survey within the first 60 min of their dialysis treatment. The KDQOL is an 81-item self-report survey comprised of 8 independent scales, 2 main dimensions (mental and physical functioning), and 8 disease targeted subscales that concentrate on the health-related concerns of individuals with kidney disease who are receiving dialysis. This instrument has demonstrated an α reliability of 0.90 [34]. The two main dimension scores, mental composite score (MCS) and physical composite score (PCS), were used in this study.

Nutritional status is measured by five clinical parameters that are used to assess nutritional well-being in hemodialysis patients: (1) serum albumin, (2) nPCR, (3) BMI, (4) body fat percentage, and (5) daily protein intake (g/day). Serum albumin, body composition, and protein intake are fundamental to the nutritional assessment of ESRD patients [35]. Collected nutritional data included albumin, nPCR, 24-h dietary recall, BMI, and percent body fat. Blood samples to assess serum albumin levels and nPCR values were collected on the same day as survey data with subsequent results retrieved from the medical record when they became available. A 24-h dietary recall and diet diary was administered by the investigator and reviewed with participants. The diet diary was recorded 24 h prior to treatment and data collection on a non-dialysis day and reviewed with the participant during the hemodialysis treatment. Food and beverage items and accompanying portion sizes were entered into an online software program, the Automated Self-Administered 24-h Recall (ASA24), provided by the National Cancer Institute [36]. The ASA24 is a software program used to collect recalled dietary data, and manage and analyze input for obtaining specific nutrient intake within a 24-h period [36]. The ASA24 is based upon the USDA Automated Multiple-Pass Method (AMPM), which has been validated and shown to accurately estimate mean total energy and protein intake compared to recovery biomarkers [37, 38]. The ASA24 is comparable to the AMPM in the ability to reflect true protein intake [39].

BMI and body fat mass were measured following the dialysis treatment. The participants’ post treatment weight, in kilograms, was recorded to calculate BMI. The participant was escorted to a private room away from the treatment area to assess body fat percentage using near-infrared interactance following the hemodialysis treatment. Body fat measurements were obtained using the Bod-e Comm2 Near-Infrared Body Composition Analyzer by Futrex, Inc. Near-infrared interactance (NIR) is independent of fluid status, which proves to be the optimal tool for fat analysis in dialysis patients [40]. Further, NIR (using Futrex 6100) estimates body fat percentage similar to estimates obtained using hydrostatic weighing and skinfold [41]. NIR is a non-invasive, painless procedure that involves the passage of near-infrared light through the bicep of the participant’s dominant arm. A wand attached to a base device is held to the participant’s arm which allows for absorption and reflection of light to determine percent body fat.

Data analysis

Study variables were examined using descriptive statistics such as means, standard deviations, frequencies, and percentages. Descriptive statistics were also used to screen data for missing and out-of-range data points. The analytical dataset consisted

of 2356 data points (19 variables from 124 participants) of which nine (0.38%) were missing [education, $n=2$; protein intake, $n=1$; CESD, $n=5$; and KDQOL mental score (MCS), $n=1$]. Non-parametric imputation [42] using a Random Forest approach was used to estimate plausible values for the missing data points. A single imputation was used due to the very small amount of missing data. The purpose of the main analysis was to estimate the crude association and covariate-adjusted association between the nutritional status indicators and the psychosocial patient outcomes. Covariates included demographic (age, gender, race, education, alcohol use, and smoking status) and clinical variables (vintage, co-morbidities, and vascular access type). To this end, the analytical approach proceeded as follows: (1) collinearity analyses among the nutritional indicators, and among the covariates, using bivariate correlations and variance inflation factors (VIF); (2) estimation of the crude or unadjusted relationships between nutritional indicators (explanatory variables) and psychosocial patient outcomes (dependent variables) using multiple regression models; (3) estimation of the relationships between covariates and psychosocial patient outcomes; and (4) estimation of covariate-adjusted relationships between nutritional indicators and psychosocial patient outcomes. To maintain a ratio of at least $n=10$ cases per estimated coefficient [43] in each fitted model, for the covariate-adjusted models, the covariates were selected in a stepwise manner using the Akaike Information Criterion (AIC) in an effort to include only the most relevant covariates based on the sample. Measures of effect size [44] were computed to aid in interpretation of the models: R^2 (proportion of an outcome variance explained by a model), ΔR^2 (proportion of outcome variance explained by a subset of predictors in a model), and partial η^2 (proportion of outcome variance explained by individual predictors after partialling out the effects of others in the same model). A False Discovery Rate (FDR) approach [45] was used to adjust significance tests for 54 inferences (18 per outcome) conducted on the same body of data. A 10% FDR threshold was used to indicate study-wise parameters whose magnitude was inconsistent with a null hypothesis of no association, given the sample size and the number of inferences conducted. Additionally, curvilinear models with spline effects [46] (generalized additive models with the smoothness of the splines estimated via restricted maximum likelihood) were used to explore non-linear relationships between the nutritional indicators and psychosocial patient outcomes. Analyses were implemented in SPSS v20 and R v3.5.1 software packages.

Results

Descriptive characteristics of the sample, including CESD and KDQOL scores, and nutritional markers, are noted in Table 1. The average length of dialysis duration in this

sample was roughly 4 years. Approximately 30% of the sample reported achievement of a high school diploma; however, 29% of the sample had some college education, a bachelor's degree or higher. More than 50% of the sample had a diagnosis of diabetes and 97% had a diagnosis of hypertension. Due to the low variation in hypertension status, this characteristic was not used in subsequent analyses.

36% ($n=45$) of the participants had depressive symptoms as evidenced by a CESD score ≥ 16 . The mean PCS score was 50 and the mean MCS score was 65. All participants had

Table 1 Descriptive characteristics of sample ($n=124$)

Characteristic	Sample estimate
Age (years), $M \pm SD$ (range)	57.91 \pm 14.32 (22–89)
Vintage (months), $M \pm SD$ (range)	52.68 \pm 46.20 (3–282)
Gender, n (%)	
Male	60 (48.4)
Female	64 (51.6)
Ethnicity, n (%)	
Caucasian	27 (21.8)
African-American	97 (78.2)
Education, n (%)	
< High School	38 (31.1)
High School Graduate	36 (29.5)
Some College/AD	34 (27.9)
BA/BS or higher	14 (11.5)
Use alcohol, n (%)	28 (22.6)
Smoker, n (%)	15 (12.1)
Co-morbidities, n (%)	
DM	66 (53.2)
HTN	120 (96.8)
CVD	49 (39.5)
Vascular access type, n (%)	
AVG	48 (38.7)
AVF	63 (50.8)
CVC	13 (10.5)
Psychosocial outcomes, $M \pm SD$ (range)	
CESD	14.19 \pm 11.18 (0–55)
KDQOL PCS	50.09 \pm 21.66 (13–96)
KDQOL MCS	65.32 \pm 21.95 (4–99)
Nutritional markers, $M \pm SD$ (range)	
Albumin (g/dL)	3.99 \pm .36 (3–4.9)
nPCR (g/kg/day)	.92 \pm .22 (.37–1.5)
Body fat percentage	30.89 \pm 13.48 (3–60.5)
BMI	30.29 \pm 8.56 (16.9–60.93)
Protein intake (g/day)	68.25 \pm 37.73 (1.2–219.2)

AD Associate Degree, BA Bachelor of Arts Degree, BS Bachelor of Science Degree. DM diabetes mellitus, HTN hypertension, CVD cardiovascular disease, AVG arteriovenous graft, AVF arteriovenous fistula, CVC central venous catheter, PCS physical composite score, MCS mental composite score, nPCR normalized protein catabolic rate, BMI body mass index

an albumin greater than 3.0 g/dL and an average nPCR of 0.92 g/kg/day. The average BMI was 30 kg/m² and the average body fat composition was approximately 31%. Protein intake within a 24-h period varied greatly ranging from 1.2 to 219 g/day as derived from patient reported intake.

Collinearity analysis

Among the nutritional indicators, percent body fat and BMI were highly correlated ($r=0.81$), which resulted in a high VIF (> 3.27) for both variables when considering all nutritional indicators simultaneously as predictors. Therefore, BMI was not included in all subsequent analyses. Albumin was moderately correlated with nPCR ($r=0.27$) and with % body fat ($r= -0.24$), and nPCR was moderately correlated with % body fat ($r= -0.3$); however, after exclusion of BMI, the VIFs for the remaining nutritional markers were < 1.23 indicating that the subset of nutritional variables could be used simultaneously as predictors. Among the covariates considered (age, vintage, gender, race, education, alcohol use, smoking, diabetes, cardiovascular disease, and vascular access type), the VIFs < 1.33 indicated no relevant collinearity issues.

Nutritional status and psychosocial outcomes

Table 2 presents crude and covariate-adjusted modeling results for each outcome. The nutritional status markers explained a small amount of the variability of the KDQOL PCS (crude $R^2=0.14$, covariate-adjusted $\Delta R^2= 0.06$) but had very small explanatory ability for the KDQOL MCS (crude $R^2=0.05$, covariate-adjusted $\Delta R^2=0.02$) and CESD (crude $R^2= 0.02$, covariate-adjusted $\Delta R^2=0.005$). As per the estimates of partial η^2 , the data suggested that nPCR and protein intake were the strongest correlates of the KDQOL PCS. However, no strong inferential statements could be made about any of these relationships since none of the tests P values crossed the 10% FDR threshold estimated at $P < 0.01$. Exploratory curvilinear models (unadjusted for covariates) suggested non-linear relationships between protein intake and both the Physical and Mental QOL dimension scores as shown in Fig. 1. The inclusion of curvilinear effects for the nutritional indicators substantially improved the unadjusted model fit for both KDQOL MCS ($R^2=0.12$) and KDQOL PCS ($R^2=0.22$). However, due to the sample size, the addition of the curvilinear terms utilized the maximum number of parameter to be estimated per model and precluded a covariate-adjusted analysis.

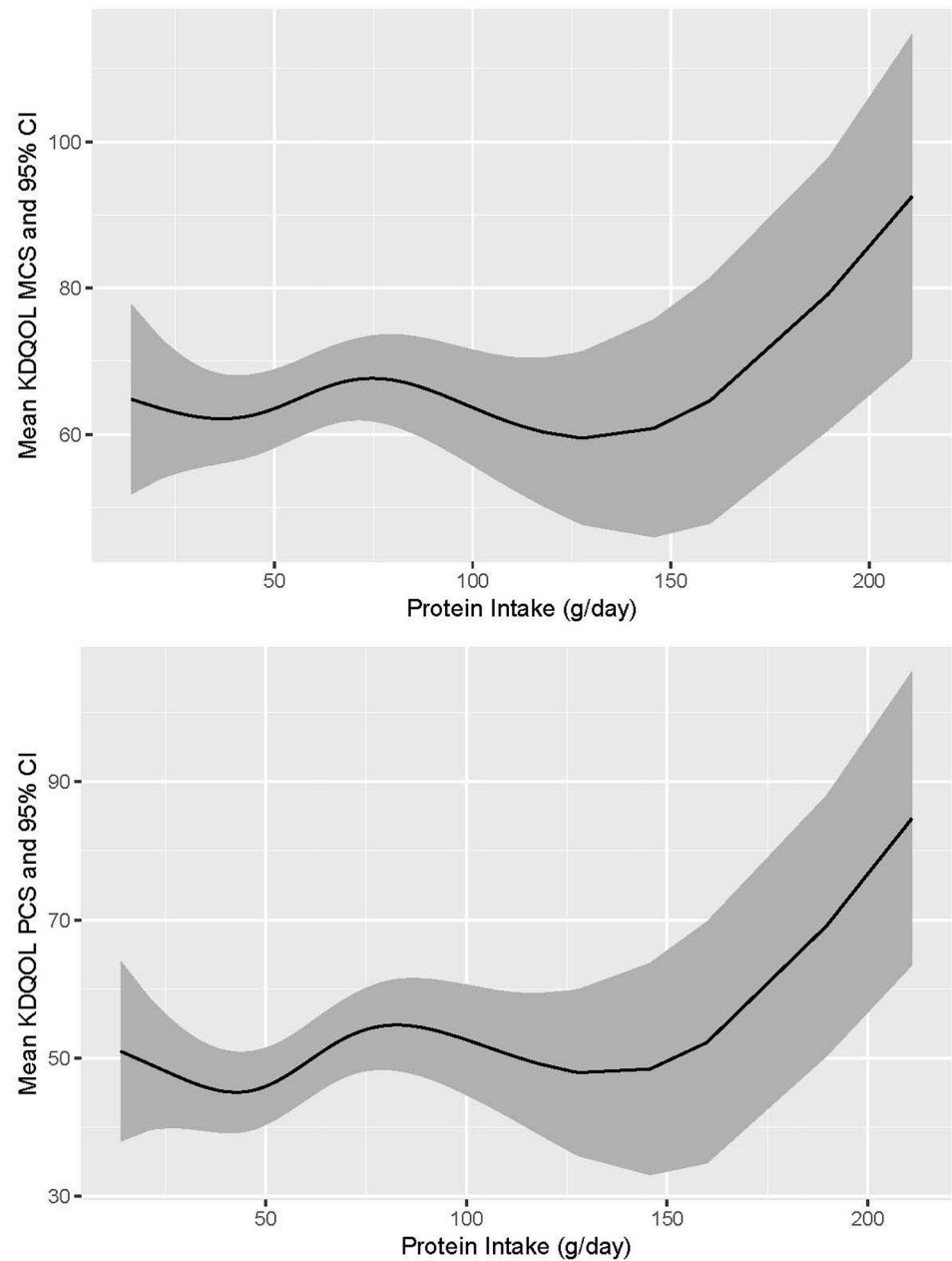
Table 2 Linear modeling results for psychosocial outcomes using nutritional markers as predictors

Model coefficients	Unadjusted model			Covariate-adjusted model		
	Estimate (SE)	P value	Partial η^2	Estimate (SE)	P value	Partial η^2
CESD						
Albumin	1.08 (2.91)	0.711	< .01	-0.57 (3)	0.851	< .01
nPCR	-4.17 (4.91)	0.397	< .01	-1.21 (4.54)	0.79	< .01
% Body fat	0.02 (0.08)	0.787	< .01	0.06 (0.09)	0.502	< .01
Protein intake	-0.03 (0.03)	0.233	0.01	0.01 (0.03)	0.842	< .01
Model R^2 or ΔR^2	0.02			0.005		
KDQOL MCS						
Albumin	-7.97 (5.67)	0.162	0.02	-5.56 (5.48)	0.312	0.01
nPCR	11.47 (9.54)	0.232	0.01	9.73 (9.14)	0.289	0.01
% Body fat	-0.1 (0.16)	0.517	< .01	-0.01 (0.15)	0.925	< .01
Protein intake	0.08 (0.05)	0.132	0.02	0.02 (0.05)	0.643	< .01
Model R^2 or ΔR^2	0.05			0.02		
KDQOL PCS						
Albumin	5.55 (5.33)	0.3	0.01	-0.06 (5.92)	0.992	< .01
nPCR	21.8 (8.98)	0.017	0.05	19.3 (8.97)	0.034	0.04
% Body fat	-0.01 (0.15)	0.948	< .01	0.12 (0.18)	0.522	< .01
Protein intake	0.13 (0.05)	0.01	0.05	0.09 (0.05)	0.099	0.02
Model R^2 or ΔR^2	0.14			0.06		

P values < .01 are considered significant at the 10% false discovery rate

PCS physical composite score, MCS mental composite score, R^2 proportion of outcome variance explained by nutritional markers unadjusted for covariates, ΔR^2 proportion of outcome variance explained by nutritional markers after covariate adjustment

Fig. 1 Exploratory curvilinear model of relationship between protein intake and the physical and mental QOL dimension scores



Covariates and psychosocial outcomes

Table 3 shows modeling results for each outcome using the considered covariates. The covariates explained a relevant amount of the variability of each outcome. As per the estimates of partial η^2 , the most important predictors of CESD scores were vintage, smoking status, and education. Longer vintage, smoking, and lower levels of education were associated with higher CESD scores. The tests of coefficient estimates for vintage and smoking status crossed the 10% FDR level threshold. The stepwise AIC selection algorithm resulted in the selection of the aforementioned three covariates in addition to age, gender, and

alcohol intake as the most relevant predictors of CESD scores. The most important predictors of KDQOL MCS were vintage and diabetes status, and the test of coefficient estimates for these two covariates crossed the 10% FDR level. Longer vintage and having diabetes were associated with lower MCS. The stepwise AIC algorithm selected only these two covariates. The most important predictors of KDQOL PCS were vintage, education, and alcohol intake. Longer vintage, higher education, and no alcohol intake were associated with lower PCS. The stepwise AIC algorithm selected these three covariates in addition to age, gender, smoking status, and diabetes status as the stronger predictors of PCS.

Table 3 Linear modeling results for psychosocial outcomes using covariates as predictors

Model coefficients	CESD			KDQOL MCS			KDQOL PCS		
	Estimate (SE)	<i>P</i> value	Partial η^2	Estimate (SE)	<i>P</i> value	Partial η^2	Estimate (SE)	<i>P</i> value	Partial η^2
Age (years)	−0.13 (0.07)	0.062	0.03	−0.04 (0.14)	0.771	<.01	−0.28 (0.14)	0.046	0.04
Vintage (months)	0.08 (0.02)	<.001	0.10	−0.18 (0.05)	<.001	0.11	−0.11 (0.05)	0.014	0.05
Male	−3.72 (2.04)	0.071	0.03	3.03 (4.29)	0.481	<.01	8.58 (4.29)	0.041	0.04
White	0.99 (2.35)	0.674	0.00	0.97 (4.94)	0.844	<.01	1.29 (4.94)	0.787	<.01
Education			0.05			<.01			0.07
<High school	Ref.			Ref.			Ref.		
High school graduate	0.29 (2.43)	0.905		0.27 (5.11)	0.958		0.61 (5.11)	0.902	
Some college/AD	−3.74 (2.6)	0.154		−2.34 (5.46)	0.669		−10.77 (5.46)	0.043	
BA/BS or higher	−5.72 (3.43)	0.098		5.03 (7.19)	0.486		−12.09 (7.19)	0.085	
Uses alcohol	−3.11 (2.35)	0.188	0.02	7.38 (4.93)	0.137	0.02	10.73 (4.93)	0.026	0.04
Smokes	8.07 (3.01)	0.009	0.06	−3.3 (6.32)	0.602	<.01	−9.7 (6.32)	0.115	0.02
With DM	1.08 (2.02)	0.595	0.00	−11.29 (4.24)	0.009	0.06	−6.49 (4.24)	0.116	0.02
With CVD	−1.8 (1.99)	0.366	<.01	2.62 (4.16)	0.530	<.01	−2.35 (4.16)	0.561	<.01
Vascular access type			<.01			0.03			0.01
AVG	0.02 (2.16)	0.994		7.7 (4.53)	0.092		3.65 (4.53)	0.406	
CVC	−2.72 (3.28)	0.409		4.02 (6.89)	0.561		7.31 (6.89)	0.274	
AVF	Ref.			Ref.			Ref.		
Model R^2	0.28			0.19			0.22		

P values <.01 are considered significant at the 10% false discovery rate

PCS physical composite score, MCS mental composite score, R^2 proportion of outcome variance explained by model

Discussion

While percentage of body fat and BMI correlated highly with each another ($r=0.81$) as expected [47], the relationship between nutritional parameters, quality of life, and depression in this sample, after adjusting for relevant covariates, did not reveal associations of large magnitude. This was similar to related studies that have shown moderate correlations between depression, hypoalbuminemia, and decreased body fat, nPCR, and protein intake [18, 48–51]. The lack of strong relationships between nutritional parameters, quality of life, and depression in this sample may be directly related to study limitations including small sample size, extreme response set bias linked to the length of the KDQOL, the acuity of each participant (independent of vintage), singular use of near-infrared interactance for body fat measurement, and self-reporting of dietary intake. In addition, the dietary recall only captured one day of dietary intake which can be variable due to appetite, activity, and altered eating behaviors on non-dialysis days compared to treatment days. It is also possible that the nutritional indicator levels and study outcome scores are reflections of a common unobserved causal factor, such as overall health status. Adjusting for indicators of overall health status such as vintage provides an estimate of the causal effect of the nutritional indicators on study outcomes, which, if this reasoning holds, would be a small effect as observed. The exploratory curvilinear

analysis, which was unadjusted due to sample size limitations, may provide some support for this reasoning. Higher average levels of protein intake may be an indication of better overall health status not a cause of it, thus the observed increasing average KDQOL trend only among participants with higher protein intake (> 125 g/day).

Further, the curvilinear analysis suggests that these relationships might not be linear which has at least two implications. First, linear models may be an oversimplification when studying these relationships. Second, if in fact, protein intake (or other nutritional variable) were to influence quality of life, the curvilinear analysis suggests that this is only within a certain group of patients—those with protein intake > 125 g/day. Therefore, the question should not be whether nutrient-related variables matter, but under what conditions nutrient-related variables matter. This question warrants further research in larger samples. It might be possible to implement nutrition-related interventions for certain patient profiles in order to improve their perceived quality of life.

The study did reveal that personal characteristics of the patient combined with hemodialysis specific characteristics may have a direct impact on health-related outcomes. For example, vintage has been shown to confound nutritional and health-related outcomes [52] and has a direct impact on the patients' experience of depression [53]. In the current study, vintage correlates significantly with increased

depressive symptomatology and poorer quality of life in the areas of mental and physical functioning. However, factors that influence this phenomenon remain unclear. In a longitudinal study conducted by Bossola et al. [54], depressive symptoms worsened over time in hemodialysis patients and worsening was associated with lower Mini Mental Status Examination scores suggesting a significant relationship between depression and cognitive decline. Previous studies have provided evidence that depression and poor cognitive performance are interrelated in hemodialysis patients and implementation of measures to improve depression has resulted in improved cognition [55, 56]. However, depression often goes undetected and untreated or undertreated in hemodialysis patients [57]. Understanding the profound psychological effects of long-term maintenance hemodialysis and its contribution to poor quality of life outcomes highlights the imperative need for early and aggressive treatment of depression in hemodialysis patients.

It is equally important for providers and caregivers to be empathetic to the role of formal education on patients' quality of life. There is very little information in the literature related to the impact of level of formal education on the hemodialysis patient's experience of depression or quality of life perspective. In the current study, lower levels of education were associated with more depressive symptoms; however, higher educational fairing was related to poorer quality of life. Some studies have shown that dialysis patients with higher levels of formal education, specifically those who completed the 12th grade, perceive better health-related quality of life [58, 59]. The ability to engage in treatment decisions and adhere to treatment regimens plays a key role in quality of life and depression [60]. Health literacy may be an important element to consider because poor health literacy is prevalent in the hemodialysis population with many having a literary scope less than the ninth grade reading level [61]. Those with higher health literacy scores have demonstrated a better perceived quality of life [62]. While prior educational attainment is not modifiable, consideration of the patient's current knowledge and ability to understand instructions and imposed dietary restrictions are important when providing health education for the hemodialysis patient. Routine health literacy screening for all patients and tailoring educational interventions to meet their literacy needs may be a viable option for overcoming the existing disparity between level of education and psychological outcomes [63].

In summary, this study serves as the initial step to (1) acquire a broader understanding of the relationships between quality of life, nutritional status, and depression in patients receiving hemodialysis; and (2) explore the potential to improve quality of life and improve psychosocial outcomes among hemodialysis patients. Based on the findings in this study, future research will include

examining the interrelationships between patient specific characteristics, such as vintage and level of education, and clinical and psychosocial outcomes. These findings also suggest a need for tailoring treatment plans to meet patient needs and optimize outcomes by considering non-modifiable patient characteristics.

Acknowledgements The late Dr. Karen Meneses provided content and formatting guidance at the inception of this work.

Disclosure The contents of this manuscript, in whole or in part, have not been previously reported, and are not under consideration for publication elsewhere, nor will be, until a decision is made by the Quality of Life Research Editor.

Funding This research did not receive any specific grant funding from agencies in the public, commercial, or not-for-profit sectors.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The Institutional Review Board at the University of Alabama at Birmingham and the Dialysis Provider's Review Board approved this research.

Informed consent The Institutional Review Board at the University of Alabama at Birmingham and the Dialysis Provider's Review Board approved this research.

References

1. USRDS. (2017). *The USRDS end-stage renal disease incident and prevalent quarterly update*. www.usrds.org/adr.htm.
2. USRDS. (2018). *The USRDS end-stage renal disease incident and prevalent quarterly update*. www.usrds.org/adr.htm.
3. Center for Disease Control and Prevention. (2016). *Health-Related Quality of Life (HRQOL)* (cited 2016 November 3, 2016). <https://www.cdc.gov/hrqol/>.
4. Klein, D. M., Turvey, C. L., & Pies, C. J. (2007). Relationship of coping styles with quality of life and depressive symptoms in older heart failure patients. *Journal of Aging and Health, 19*(1), 22–38.
5. Ginieri-Coccosis, M., et al. (2008). Quality of life, mental health and health beliefs in haemodialysis and peritoneal dialysis patients: Investigating differences in early and later years of current treatment. *BMC Nephrology, 9*, 14.
6. Sapkota, A., Sedhain, A., & Rai, M. K. (2013). Quality of life of adult clients on renal replacement therapies in Nepal. *J Renal Care, 39*(4), 228–235.
7. Theofilou, P. (2011). Quality of life in patients undergoing hemodialysis or peritoneal dialysis treatment. *Journal of Clinical Medicine Research, 3*(3), 132–138.
8. Davison, S. N., & Jhangri, G. S. (2012). The relationship between spirituality, psychosocial adjustment to illness, and health-related quality of life in patients with advanced chronic kidney disease. *Journal of Pain and Symptom Management, 45*(2), 170–178.

9. Chen, M. F., et al. (2017). Effects of perceived autonomy support and basic need satisfaction on quality of life in hemodialysis patients. *Quality of Life Research*, 27, 765–773.
10. Giannaki, C. D., et al. (2017). Restless legs syndrome is contributing to fatigue and low quality of life levels in hemodialysis patients. *World Journal of Nephrology*, 6(5), 236–242.
11. Rhee, C. M., et al. (2017). Thyroid status, quality of life, and mental health in patients on hemodialysis. *Clinical Journal of American Society of Nephrologists*, 12(8), 1274–1283.
12. Jong, I. C., et al. (2017). Close correlation between the ankle-brachial index and symptoms of depression in hemodialysis patients. *International Urology and Nephrology*, 49(8), 1463–1470.
13. Norozi Firoz, M., et al. (2017). Relationship of hemodialysis shift with sleep quality and depression in hemodialysis patients. *Clinical Nursing Research*. <https://doi.org/10.1177/1054773817731852>
14. Bossola, M., et al. (2009). Body mass index, comorbid conditions and quality of life in hemodialysis patients. *Journal of Nephrology*, 22(4), 508–514.
15. Feroze, U., et al. (2011). Quality-of-life and mortality in hemodialysis patients: Roles of race and nutritional status. *Clinical Journal of the American Society of Nephrology*, 6(5), 1100–1111.
16. Alston, H., Burns, A., & Davenport, A. (2017). Loss of Appendicular muscle mass in haemodialysis patients is associated with increased self-reported depression, anxiety and lower general health scores. *Nephrology (Carlton)*, 23(6), 546–551.
17. Hsieh, R. L., et al. (2007). Quality of life and its correlates in ambulatory hemodialysis patients. *Journal of Nephrology*, 20(6), 731–738.
18. Hung, K. C., et al. (2011). Serum IL-6, albumin and co-morbidities are closely correlated with symptoms of depression in patients on maintenance haemodialysis. *Nephrology, Dialysis, Transplantation*, 26(2), 658–664.
19. Lacson, E., Jr., et al. (2009). Associates of mortality and hospitalization in hemodialysis: Potentially actionable laboratory variables and vascular access. *American Journal of Kidney Diseases*, 53(1), 79–90.
20. Li, Y. N., et al. (2016). Association between quality of life and anxiety, depression, physical activity and physical performance in maintenance hemodialysis patients. *Chronic Diseases and Translational Medicine*, 2(2), 110–119.
21. Chilcot, J., et al. (2017). Depression symptoms in haemodialysis patients predict all-cause mortality but not kidney transplantation: A cause-specific outcome analysis. *Annals of Behavioral Medicine*. <https://doi.org/10.1007/s12160-017-9918-9>
22. Kauric-Klein, Z. (2017). Depression and medication adherence in patients on hemodialysis. *Current Hypertension Reviews*, 13(2), 138–143.
23. Cwiek, A., et al. (2017). Association between depression and hemodialysis in patients with chronic kidney disease. *Psychiatria Danubina*, 29(Suppl 3), 499–503.
24. McDougall, K. A., et al. (2018). Depressive affect in incident hemodialysis patients. *Clinical Kidney Journal*, 11(1), 123–129.
25. Conde, S. A., et al. (2010). Cognitive decline, depression and quality of life in patients at different stages of chronic kidney disease. *Jornal brasileiro de nefrologia*, 32(3), 242–248.
26. Hedayati, S. S., et al. (2008). Death or hospitalization of patients on chronic hemodialysis is associated with a physician-based diagnosis of depression. *Kidney International*, 74(7), 930–936.
27. Riezebos, R. K., et al. (2010). The association of depressive symptoms with survival in a Dutch cohort of patients with end-stage renal disease. *Nephrology, Dialysis, Transplantation*, 25(1), 231–236.
28. Gerogianni, G., et al. (2017). The role of socio-demographic factors in depression and anxiety of patients on hemodialysis: An observational cross-sectional study. *International Urology and Nephrology*, 50(1), 143–154.
29. Fan, L., et al. (2014). Depression and all-cause mortality in hemodialysis patients. *American Journal of Nephrology*, 40(1), 12–18.
30. Oliveira, C. M., et al. (2012). Depression in dialysis patients and its association with nutritional markers and quality of life. *Journal of Nephrology*, 25(6), 954–961.
31. Alabama Kidney Foundation. (2018). *Kidney facts* (May 7, 2018). <https://alkidney.org/kidney-facts/>.
32. Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied Psychological Measurement*, 1(3), 385–401.
33. Nunnally, J. C. (1967). *Psychometric theory*. McGraw-Hill series in psychology. New York: McGraw-Hill.
34. Hays, R., et al. (1997). *Kidney Disease Quality of Life Short Form (KDQOL-SF), Version 1.3: A manual for use and scoring*. Santa Monica, CA: RAND.
35. Fouque, D., et al. (2008). A proposed nomenclature and diagnostic criteria for protein-energy wasting in acute and chronic kidney disease. *Kidney International*, 73(4), 391–398.
36. National Cancer Institute. (2011). *Risk factor monitor and managing: Automated self-administered 24-hour recall* (January 22, 2012). <https://riskfactor.cancer.gov/tools/instruments/asa24/>.
37. Kipnis, V., et al. (2003). Structure of dietary measurement error: Results of the OPEN biomarker study. *American Journal of Epidemiology*, 158(1), 14–21; discussion 22–26.
38. Moshfegh, A. J., et al. (2008). The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. *American Journal of Clinical Nutrition*, 88(2), 324–332.
39. Kirkpatrick, S. I., et al. (2014). Performance of the Automated Self-Administered 24-hour Recall relative to a measure of true intakes and to an interviewer-administered 24-h recall. *American Journal of Clinical Nutrition*, 100(1), 233–240.
40. Kalantar-Zadeh, K., et al. (2001). Near infra-red interactance for longitudinal assessment of nutrition in dialysis patients. *Journal of Renal Nutrition*, 11(1), 23–31.
41. Fukuda, D. H., et al. (2017). Validity of near-infrared interactance (FUTREX 6100/XL) for estimating body fat percentage in elite rowers. *Clinical Physiology and Functional Imaging*, 37(4), 456–458.
42. van Buuren, S., & Groothuis-Oudshoorn, K. (2011). mice: Multivariate imputation by chained equations. *R. Journal of Statistical Software*, 1(3).
43. Harrell, F. E. (2015). *Regression modeling strategies: With applications to linear models, logistic regression, and survival analysis*. Springer series in statistics (2nd ed.). New York: Springer.
44. Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
45. Glickman, M. E., Rao, S. R., & Schultz, M. R. (2014). False discovery rate control is a recommended alternative to Bonferroni-type adjustments in health studies. *Journal of Clinical Epidemiology*, 67(8), 850–857.
46. Wood, S. N. (2006). *Generalized additive models: An introduction with R*. Texts in statistical science. Boca Raton, FL: Chapman and Hall/CRC.
47. Barros, A., et al. (2011). Nutritional status evaluated by multi-frequency bioimpedance is not associated with quality of life or depressive symptoms in hemodialysis patients. *Therapeutic Apheresis and Dialysis*, 15(1), 58–65.
48. Araujo, S. M., et al. (2012). Risk factors for depressive symptoms in a large population on chronic hemodialysis. *International Urology and Nephrology*, 44(4), 1229–1235.
49. Huang, T. L., & Lee, C. T. (2007). Low serum albumin and high ferritin levels in chronic hemodialysis patients with major depression. *Psychiatry Research*, 152(2–3), 277–280.

50. Kalender, B., et al. (2007). Quality of life in chronic kidney disease: Effects of treatment modality, depression, malnutrition and inflammation. *International Journal of Clinical Practice*, 61(4), 569–576.
51. Wang, L. J., et al. (2012). The relationship between psychological factors, inflammation, and nutrition in patients with chronic renal failure undergoing hemodialysis. *International Journal of Psychiatry in Medicine*, 44(2), 105–118.
52. Wasse, H., et al. (2007). Association of initial hemodialysis vascular access with patient-reported health status and quality of life. *Clinical Journal of American Society of Nephrologists*, 2(4), 708–714.
53. Vettath, R. E., et al. (2012). A multicenter cross-sectional study of mental and physical health depression in MHD patients. *Indian Journal of Nephrology*, 22(4), 251–256.
54. Bossola, M., et al. (2012). Symptoms of depression and anxiety over time in chronic hemodialysis patients. *Journal of Nephrology*, 25(5), 689–698.
55. Kielstein, J. T., & Bernstein, H. G. (2014). The reversible part of cognitive impairment in chronic kidney disease: Can mice help men break the TEMPOLimit? *Nephrology, Dialysis, Transplantation*, 29(3), 476–478.
56. Agganis, B. T., et al. (2010). Depression and cognitive function in maintenance hemodialysis patients. *American Journal of Kidney Diseases*, 56(4), 704–712.
57. Hedayati, S. S., Yalamanchili, V., & Finkelstein, F. O. (2012). A practical approach to the treatment of depression in patients with chronic kidney disease and end-stage renal disease. *Kidney International*, 81(3), 247–255.
58. Germin-Petrovic, D., et al. (2011). Health-related quality of life in the patients on maintenance hemodialysis: The analysis of demographic and clinical factors. *Collegium Antropologicum*, 35(3), 687–693.
59. Manns, B., et al. (2003). Quality of life in patients treated with hemodialysis or peritoneal dialysis: What are the important determinants? *Clinical Nephrology*, 60(5), 341–351.
60. Purnell, T. S., et al. (2013). Comparison of life participation activities among adults treated by hemodialysis, peritoneal dialysis, and kidney transplantation: A systematic review. *American Journal of Kidney Diseases*, 62(5), 953–973.
61. Cavanaugh, K. L., et al. (2010). Low health literacy associates with increased mortality in ESRD. *Journal of American Society of Nephrologists*, 21(11), 1979–1985.
62. Dodson, S., et al. (2016). Multifaceted assessment of health literacy in people receiving dialysis: Associations with psychological stress and quality of life. *Journal of Health Communication*, 21(sup2), 91–98.
63. Jain, D., & Green, J. A. (2016). Health literacy in kidney disease: Review of the literature and implications for clinical practice. *World Journal of Nephrology*, 5(2), 147–151.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.