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Body mass index, waist circumference and fasting blood glucose in patients undergoing hemodialysis

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Abstract

Background: The aim of study was to observe the patterns of fasting blood glucose (FBG), body mass index (BMI) and waist circumference (WC) in patients on hemodialysis and assess possible associated factors.

Methods: This was a cross-sectional study conducted on 204 patients undergoing hemodialysis. Disease characteristics, lifestyle factors, FBG, BMI, and WC were collected. The sampling method was convenient. Multivariable linear regression models were built after employment of stepwise backward elimination to explore the relationship between FBG/BMI/WC and possible risk factors. The models were adjusted for demographics diet, sleep, mood, lifestyle factors, and disease characteristics. *P* values < 0.05 were considered significant.

Results: The majority (58%) of patients were males. The mean (SD) age of study population was 55 (14) years. The prevalence of overweight and obesity were 32% and 19%, respectively. A significant association was observed between BMI and five variables: sleep quality (β=0.08, 95%CI, 0.006 to 0.15, *P*=0.03), night sleep duration on weekdays (β=-1.82, 95%CI, -3.64 to -0.007, *P*=0.049), plasma phosphorus level (β=0.76, 95%CI, 0.17 to 1.35, *P*=0.01), age (β=0.12, 95%CI, 0.05 to 0.18, *P*=0.001), and sex (β=2.01, 95%CI, 0.10 to 3.92, *P*=0.04). The prevalence of abdominal obesity was 38%. Two variables had a significant association with WC: sleep quality (β=0.20, 95%CI, 0.05 to 0.36, *P*=0.01), and age (β=0.28, 95%CI, 0.11 to 0.45, *P*=0.001). The prevalence of prediabetes and diabetes were 23% and 32%, respectively. Three variables were found to be associated with FBG: Fibromyalgia Impact Questionnaire score (β=1.28, 95%CI, 0.19 to 2.37, *P*=0.02), diet (β=-2.32, 95%CI, -4.33 to -0.31, *P*=0.02), and mood (β=-1.65, 95%CI, -2.94 to -0.36, *P*=0.01).

Conclusion: Sleep, age and fibromyalgia were the most significant and consistent factors associated with BMI/WC/FBG in patients with hemodialysis.

Keywords: hemodialysis, fasting blood glucose, body mass index, waist circumference, sleep, lifestyle

Introduction

Dialysis is a lifesaving treatment for individuals whose kidneys no longer work well enough to support their bodies. Dialysis treatment is being extensively used to treat End-Stage Renal Disease (ESRD), a medical condition in which the kidneys have stopped functioning permanently and thus requires treatment either in the form of dialysis or a kidney transplant [1]. Generally, there are two main types of dialysis, hemodialysis and peritoneal dialysis. Hemodialysis requires a machine to filter the blood externally, versus peritoneal dialysis uses the abdominal lining to filter the blood. Choices between hemodialysis and peritoneal dialysis are to be made based on patient preferences and physician opinion [2,3] . While the definitive treatment for ESRD is kidney transplant, hemodialysis is required for maintenance until transplantation due to the lengthy and difficult process of finding a suitable kidney (proportionate to patient's conditions [4,5].

One of the most significant issues regarding patients undergoing hemodialysis is quality of life. It has been shown that the quality of life of hemodialysis patients is significantly lower than healthy people and even than kidney transplant patients [6]. Balaban et al. demonstrated that psychiatric comorbidities and sexual dysfunction were significantly higher in ESRD patients undergoing hemodialysis than in controls [7]. Moreover, due to their strict treatment regimen and guidelines, patients undergoing hemodialysis face limitations in their social and physical activities [8].

Studies have shown that the prevalence of obesity in long-term hemodialysis patients is significantly increasing [9]. Interestingly the relationship between obesity and mortality in hemodialysis patients has been shown to contradict the accepted findings among the general population; in hemodialysis patients, higher BMI is associated with lower mortality rates [10]. However, other studies contradict this finding; Hoogeveen et al. found that very high or very low BMI increases risk of mortality in younger dialysis patients [11]. Considering the discrepancies in the literature, the relationship between BMI and mortality is an area that requires more investigation.

Because BMI has never been a reliable indicator of obesity as it is not possible to differentiate subcutaneous, visceral, or muscle fat using BMI(11), criteria for central or abdominal obesity, defined by waist circumference (WC) and waist-to-hip ratio, are used as the most important predictors of mortality, cardiovascular complications, and any significant complications [12]. Based on the many different studies that have been performed on patients with ESRD in the past, the WC has been identified as a direct and potent predictor of mortality and cardiovascular complications, even if BMI and other risk factors are adjusted [13].

In addition, significant results have been published according to studies on serum blood glucose levels in hemodialysis patients. In general, although proper control of blood sugar without hypoglycemia is required during the treatment of diabetes, the presence of chronic renal failure simultaneously complicates this mechanism and in patients undergoing hemodialysis [14], the risk of hemodialysis-induced abnormalities increases significantly [15]. Since dialysis contains 100 to 150 mg/dL of glucose, blood glucose levels drop rapidly. In contrast, plasma insulin is removed during the hemodialysis session, uptaked into the dialysis membrane. At the same time, lowering blood glucose stimulates the secretion of various hormones, such as glucagon, which consequently increases blood glucose levels [15]. The literature has also suggested that fasting blood glucose (FBG) levels in hemodialysis patients are significantly higher than other patient categories [16]. Therefore, the observation of increased blood glucose in hemodialysis patients is considered a common finding [17]. Importantly, both hyper and hypoglycemia are associated with poor outcomes in patients on hemodialysis [15].

Considering the demonstrated association and potential mechanism by which hemodialysis complicates blood glucose management and the potential negative influence this has on outcomes in these vulnerable patients, it is necessary to investigate what additional factors may be at play. Additionally, as mentioned previously, BMI is becoming more and more prevalent in dialytic patients, and to date little research has been done to clarify the factors driving this increase in this patient population. Similarly, the circumstances that are associated with WC must be identified, considering its demonstrated association with increased mortality. While these patient characteristics are rising, the research on specific risk factors within the dialysis patient population is lacking. Therefore, the main purpose of the present study is to analyze FBG patterns, BMI, and WC among hemodialysis patients as well as analyzing other relevant risk factors.

Methods

Population

This cross-sectional study was carried out in a medical university affiliated clinic during the summertime. The study protocol was approved by the university Committee of Ethics, and the methods were carried out in accordance with relevant guidelines and regulations. Written consent forms were signed by all participants prior to enrollment. Patients undergoing hemodialysis were consecutively enrolled (convenience sampling method). Demographics, smoking, mood status, social activity, sleep duration, sleep quality, physical activity, diet, disease duration and symptoms were inquired and recorded. Physical examination and laboratory data were conducted and recorded. Sleep quality was evaluated by the Mini-Sleep Questionnaire, a ten question survey [18] . Extra questions were devoted to measure all aspects of sleep quality and quantity (Table 1). Mood was assessed according to Gallup Well-being Index (Table 1) [19]. Fibromyalgia was evaluated through Fibromyalgia Impact Questionnaire. Diet status was assessed using modified Gallup Diet Questionnaire. Physical activity (Table 1) was inquired based on a modified question from the Brunel lifestyle physical activity questionnaire [20]. Smoking pattern was assessed as well FBG was defined as prediabetes when it was between 100 and 125 mg/dL. FBG was defined as diabetes when it was >125 mg/dL. BMI was defined as normal, overweight, and obesity when it was 18.5-24.9, 25.0-29.9, and ≥30.0 kg/m^2, respectively. Abdominal obesity was defined as WC greater than 88 cm in females and 102 cm in males.

Data Analysis

Descriptive analyses were used to determine the frequency distributions of demographics, lifestyle factors, symptoms and signs, and laboratory data. T-test was applied to compare the continuous variables. Model assumptions were assessed by investigating the normality of residuals, homoscedasticity, and residual symmetry. Univariable associations of outcome variables and other variables were carried out through linear and nonlinear regression analyses. FBG, BMI and WC were treated as outcome variables, independently. In case of finding no nonlinear association, multivariable linear regression model with backward elimination was executed to determine the linear associations of potential predictors and the outcomes. All models were adjusted for confounders including age, sex, diet, mood, sleep, physical activity, social activity, smoking, disease characteristics and medications. Data analyses were conducted using R software (Foundation for Statistical Computing, Vienna, Austria). A *P* value of <0.05 was considered significant.

Results

The sample size included 85 females and 119 male patients. The age range of the patients was 21-86 years. The mean (SD) age was 55 (14) years. The mean (SD) FBG was 128 (77) mg/dl which was in the diabetes defined range. Characteristics of patients were stratified according to three categories of FBG (normal FBG vs. prediabetes vs. diabetes) are presented in Table 2. There were no significant differences among the three groups in terms of sex, diet, mood, physical activity, social activity, smoking, most disease characteristics, and laboratory findings Age, disease duration, WC, and BMI were significantly different among the three groups. As FBG increased the mean age, the mean WC, and the mean BMI in each category increased as well. The diabetes cohort had the shortest disease duration, followed by the normal FBG, and individuals with prediabetes, who had the longest disease duration on average (Table 2).

The mean (SD) BMI was 26,0 (7,0) kg/m^2. Characteristics of patients stratified according to four categories of BMI (low BMI vs. normal BMI vs. overweight BMI vs. obesity) are presented in Table 3. The 51% of patients were classified as overweight or obesity. There were no significant differences among the four groups in terms of sex, diet, mood, physical activity, social activity, smoking, most disease characteristics, and laboratory findings (Table 3). Age, disease duration, WC, and FBG were significantly different among the four groups. Mean age and WC increased as BMI increased. Disease duration, on the other hand, decreased as BMI increased. The mean (SD) WC was 94,0 (16,0) cm. Abdominal obesity (WC>88 cm in females and >102 cm in males) was observed in 38% of patients. Mean FBG was highest for the low BMI cohort, but then climbed from normal BMI to obese BMI (Table 3).

Using generalized additive model, no significant nonlinear associations between FBG/BMI/WC and continuous variables were observed. Then, multivariable linear regression model along with backward elimination was applied to find the most significant factors associated with FBG/BMI/WC. The findings are presented in Table 4. There was one variable that was left in all three final multivariable linear regression models for FBG/BMI/WC: sleep quality

(Table 4). The higher the score of sleep quality (the worse the sleep quality), the higher the FBG/BMI/WC. Age also showed significant direct linear association with BMI/WC (Table 4). Fibromyalgia Impact Questionnaire score remained in two final multivariable linear regression models: FBG/WC (Table 4). Sleep duration, sex, and plasma phosphorus levels were associated with BMI in the final model whereas diet, mood, and physical activity were lifestyle factors that remained in the final model for FBG (Table 4).

Discussion

The prevalence of ESRD has been increasing for some time and its burden is projected to continue to increase in the United States through 2030 (McCullough et al. 2019). ESRD is known as the last stage of chronic kidney disease, indicating that chronic kidney disease is increasing in prevalence as well [21,22]. According to epidemiologic studies around 8-16% of the population worldwide have been diagnosed with ESRD and its prevalence is increasing on an annual basis [23,24]. As discussed previously, hemodialysis is an essential treatment for ESRD patients [25].

More than half of the patients studied here had a serum FBG within the prediabetic or diabetic ranges (¿100) (Table 2). The relationship between diabetes and ESRD is worrying, as diabetes has been shown to be the leading cause of CKD and ESRD [26]. As discussed previously, hemodialysis can induce high fasting blood sugar as well. Therefore, there may be a bidirectional relationship that exists here between high blood sugar and renal disease. Importantly, there is an additional association between both WC and BMI with FBG [27,28]. More than 50% of the patients studied here were overweight or with obesity according to their BMIs (Table 3). Obesity is an independent risk factor of CKD [29]. Among patients undergoing hemodialysis, worrying high levels of FBG, WC, and BMI are common, and the implications these findings have on dialysis outcomes have yet to be fully elucidated. However, here we have identified a number of significant risk factors influencing these trends.

First, we looked into how trends in different lifestyle factors and lab values correlated with different categories of WC, BMI, and FBG. There was a significant difference among all four study groups in terms of age, duration of the disease, WC, and FBG, such that the older the patients and the shorter the duration of their illness, the higher the BMI. Moreover, the WC of male subjects was higher than the WC of female subjects, which is corroborated by Sanches et al. which found a positive correlation between WC and male gender [30]. Both Sanches and He argued that there is a positive significant correlation between WC and BMI of CKD patients, such that the higher the BMI, the higher their WC would be [30,31]. Our findings agree with this assumption, as BMI increased the average WC increased as well (Table 3).

Our study found no significant correlation between laboratory results and BMI among hemodialysis patients, which is in contradiction with Kalantarzadeh et al., which found a positive significant correlation between laboratory results (especially inflammatory criteria) and BMI value [32]. More investigation into the relationship between laboratory values and BMI within hemodialysis patients is warranted.

Sleep Quality as a Risk Factor for Increased BMI, WC, and FBG

Here, we demonstrated that sleep quality was a significant risk factor for FBG, BMI, and WC; it was the only variable that was found to be significant for all outcomes (Table 4). Importantly, there are multiple studies demonstrating insufficient sleep as one of the most prevalent side effects among those undergoing hemodialysis treatment [24]. It is estimated the prevalence of sleep disorders within hemodialysis patients may be as high as 80% [33].

The presence of sleep disorders is one of the many ways in which the quality of life of dialysis patients is decreased [34].

It is possible that insufficient sleep is contributing to abnormal BMI, WC, and FBG through its effects on hormones, specifically leptin and ghrelin. The relationship between sleep insufficiency and weight gain is well document within the literature; sleep insufficiency has been shown to significantly increase the risk of obesity and diabetes [35]. Leptin, the appetite suppressing hormone, and ghrelin, the appetite promoting hormone, have been shown to be affected by sleep loss. In sleep deprived subjects, higher levels of ghrelin and lower levels of leptin have been seen, which likely promotes increased hunger [36,37]. Therefore, through this potential mechanism and the high prevalence of disordered sleep within hemodialysis patients, it is possible that by altering hormone levels poor quality sleep is influencing BMI, WC, and FBG.

Fibromyalgia Impact as a Risk Factor for WC and FBG

Fibromyalgia syndrome is one of the most prevalent rheumatologic diseases and its main characteristic is diffused pain, rigidity, fatigue, and low pain threshold in sensitive areas of the body. It involves musculoskeletal and various systemic symptoms including paresthesia, anxiety, sleep disorder, and headache. Importantly, one of the most significant side effects associated with CKD is musculoskeletal dysfunctions, which is associated to lower life quality; in one study, more than 75% of hemodialysis patients, reported musculoskeletal dysfunctions, and pain was the most frequent symptom [38]. While musculoskeletal dysfunction and associated pain are extremely common in the hemodialysis patient population, the prevalence of fibromyalgia appears to be similar to that found within the general population [39].

Fibromyalgia is associated with significantly reduced quality of life, especially because it is related to increased incidence of mental health disorders including depression and anxiety as well as increased incidence of disordered sleep [40]. It is thought that pain is one of the main reasons why fibromyalgia patients struggle to get sufficient sleep. Among hemodialysis patients, a group already vulnerable to sleep health struggles, additional pain that could interfere with sleep would only worsen an already existing problem. Perhaps by contributing to poorer sleep quality, fibromyalgia impact among hemodialysis patients would influence the same hormonal changes to leptin and ghrelin levels, increasing hunger and thus becoming a risk factor for WC.

It has also been shown that individuals with fibromyalgia score significantly lower than those without it in terms of physical performance and functional ability [41,42]. Patients undergoing hemodialysis are already more likely to engage in less physical activity than healthy controls [43]. Therefore, hemodialysis patients suffering the effects of fibromyalgia may struggle even more with getting physical activity due to their pain and treatment regimen. This is relevant because exercise has been demonstrated to be a mechanism by which individuals can improve their fasting blood glucose [44]. It is possible that presence of fibromyalgia within hemodialysis patients causes a reduction in physical activity, therefore increasing the risk of abnormal fasting blood glucose levels. Additionally, spending less time engaged in physical activity will contribute to an increase in adiposity and thus WC [45]. We suggest implementing physical activity guidelines into hemodialysis treatment to encourage patients to stay active in order to help manage their blood glucose levels. Investigations into how physically active dialysis patients may have improved blood glucose levels are suggested.

Here our results indicated that female sex is a significant risk factor for high BMI. Importantly, the mean (SD) BMI in men and women were 24.6 (4.7) and 27.8 (8.7), respectively (P = 0.001). It is well documented that the female gender is more associated with being overweight or obese. In fact, the female gender has been shown to have twice the risk of obesity [46]. Some of the factors that are considered to be affecting this disparity are the role of birth control pills, menopause, pregnancy, etc. It is important to further investigate this sexually dimorphic findings in dialysis patients specifically to help physicians proactively manage female patients.

Increasing Age as Risk Factor for WC and BMI

Here we found that age was a risk factor for both WC and BMI in hemodialysis patients. Interestingly, among older dialysis patients, BMI appears to act as a predictor of long-term survival [47]. WC, on the other hand, seemed to show the opposite relationship, acting as a risk factor for mortality [28]. This contradictory relationship between BMI and WC with mortality and survival seems to indicate that it is abdominal obesity, which is represented by WC, that is detrimental to the prognoses of dialysis patients. BMI, representing overall body volume, is associated with survival. It may be possible that increasing age is associated with increased BMI because those with higher BMI were more likely to survive on dialysis treatment longer. However, this would not explain the relationship we found between age and WC. Therefore, we recommend more research focused on the relationships between BMI, WC, and mortality; as well as how age affects this picture.

Phosphorus Level as a Risk Factor for BMI

Our results indicate that phosphorus levels are significantly and directly associated with BMI in dialytic patients. This is in contrast with what some of the existing literature shows. Billington et al. demonstrated an indirect relationship between serum phosphate and adiposity in both men and women [48]. Low serum phosphate was also associated with insulin resistance and were lower in children with obesity [49]. Fibroblast Growth Factor

(FGF)-23 is believed to be a potential mechanism mediating this relationship [48]. More results into serum phosphorus levels and its relationship with BMI are warranted considering conflicting findings.

Diet, Mood, and Physical Activity as a Risk Factors for FBG

Maintaining a specific diet is an important aspect of the hemodialysis regimen as many ESRD patients are prone to mineral imbalances and thus controlling one's diet is a mechanism by which patients can try to manage this balance. Importantly, the more time patients spend undergoing hemodialysis the lower their intake of protein [50]. Diabetes research has shown that high protein diets can help to reduce blood glucose levels [51]. However, evidence also suggests that too much protein can be damaging to the kidneys, which would be especially worrying in dialysis patients [52]. Therefore, we recommend more studies investigate what the ideal level of protein intake is for maintaining ideal blood sugar levels while also protecting renal health in dialysis patients. Additionally, working with a nutritionist may be one way for dialysis patients to improve their diets and ensure they are following nutritional recommendations. As mentioned, hemodialysis is a treatment with a strict regimen to follow, and diet is one area where it can become easy to sway from the recommendations, however it is essential to try to maintain a balanced diet, especially as we have now demonstrated the association between diet and high FBG.

As mentioned previously, hemodialysis patients are already more sedentary than their healthy counterparts [43]. It has been demonstrated that exercise is an ideal way to manage blood sugar levels [44]. Research has demonstrated that exercise during hemodialysis through the use of a stationary bike helps to improve health promoting behaviors [53]. We recommend including exercise professionals as providers at dialysis centers, and looking into how to help hemodialysis patients find accessible ways to engage in physical activity.

In terms of mood, a relationship between mood and glucose levels has been demonstrated in patients with diabetes, but in the opposite direction. High blood glucose levels were shown to negatively impact mood in patients with type I diabetes [54]. The research into the reverse relationship, where mood is a risk factor for increased blood sugar levels has not been investigated thoroughly, and we recommend more studies considering the bidirectionality that may exist between mood and blood sugar levels.

Conclusion

Here we demonstrated that the most significant and consistent risk factors affecting BMI, WC, and FBG in hemodialysis patients are sleep quality, age, and fibromyalgia. **Practical Application** Using the results here, physicians can proactively work to identify and manage dialysis patients that are higher risk for developing unhealthy BMI, WC, and FBG. This may help to reduce the CVD risk of this vulnerable patient population.

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Author Contributions: conceptualization, A.S. and Z.M..; methodology, A.S. and Z.M.; formal analysis, A.S.; investigation, M.S., M.B.B., M.M., F.S.R. and S.A.M.; writing—original draft preparation, B.B., M.S. and A.S.; writing—review and editing, all authors; supervision, Z.M.

Ethics: The study protocol was approved by the university Committee of Ethics and the methods were carried out in accordance with relevant guidelines and regulations. Written consent forms were signed by all participants prior to enrollment.

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Table 1. Lifestyle Questionnaire and the Calculating Method of Corresponding Scores.

Lifestyle Factors	Question	Time or Days per Week
Quantity of Sleep	What time did you usually go to bed on weekdays?	
	How long did it take to fall asleep?	
	What time did you usually go to bed on weekends?	
	What time did you usually get out of bed on weekdays?	
	What time did you usually get out of bed on weekends?	
	How many hours did you sleep every night on weekdays?	
	How many hours did you sleep every night on weekends?	
	How many hours did you get a nap on weekdays?	
	How many hours did you get a nap on weekends?	
Sleep Quality	How many days per week do you have difficulties falling asleep?	**/7**
	How many days per week do you wake up too early?	**/7**
	How many days per week do you use Hypnotic medications (sleep aids)?	**/7**
	How many days per week do you fall asleep during the day?	**/7**
	How many days per week do you feel tired upon waking up in the morning?	**/7**
	How many days per week do you snore?	**/7**
	How many days per week do you experience mid-sleep awakenings?	**/7**
	How many days per week do you experience headaches on awakening?	**/7**
	How many days per week do you experience excessive daytime sleepiness?	**/7**
	How many days per week do you experience excessive movement during sleep?	**/7**
Total Score of Sleep Quality out of 70		**/70**
Mood	How many days per week do you experience no energy to get things done?	**/7**
	How many days per week do you experience sadness?	**/7**
	How many days per week do you experience worry?	**/7**
	How many days per week do you experience anger?	**/7**
	How many days per week do you experience physical pain?	**/7**
Total Score of Mood Status out of 35		**/35**
Diet	How many days per week do you eat fast food?	**/7**
	How many days per week did you eat red meat?	**/7**
	How many days per week do you eat fish/omega 3?	**/7**
	How many days per week do you eat 4-5 servings of fruits/vegetables?	**/7**
	How many days per week did you take vitamin D tablet?	**/7**
	How many days per week did you take Magnesium tablet?	**/7**
Total Score of Diet out of 42		**/42**
Physical Activity	How many days per week in a normal week do you engage in at least 30-minute pre-planned physical activity?	**/7**
Social Activity	How many days per week did you participate in a social, cultural, or support group that you belong to?	**/7**
Smoking Behavior	Do you smoke?	
	If yes, how many cigarettes do you smoke per day?	
Self-rated Wellness & Health	How much do you rate your wellness and health out of 10; 10 being the healthiest and 0 being the unhealthiest?	**/10**

Table 2. Comparison of the patients' characteristics stratified by FBG.

Participants' Characteristics	**Fasting Blood Glucose**						***P* value**
	Normal *n*=91		**Prediabetes** n=46		**Diabetes** *n=66*		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Age, Years, Mean (SD)	50.04	14.21	57.35	14.41	60.29	11.85	**0.0001**
Sleep Duration, Weekdays, Hours, Mean (SD)	7.32	1.83	7.17	2.18	7.17	2.26	0.9
Sleep Duration, Weekends, Hours, Mean (SD)	7.32	1.80	7.65	2.40	7.19	2.30	0.5
Time to Bed, Weekdays, PM	23.79	1.56	23.54	1.60	23.65	1.85	0.7
Time to Bed, Weekends, PM	23.81	1.55	23.54	1.60	23.7	1.83	0.7
Time to Fall Asleep, Minutes, Mean (SD)	46.32	51.8	46.63	59.09	40.23	40.43	0.7
Time to Get Out of Bed, Weekdays, AM	7.11	2.20	6.71	2.26	6.79	2.19	0.5
Time to Get Out of Bed, Weekends, AM	7.13	2.22	7.19	2.65	6.88	2.24	0.7
Nap Duration, Weekdays, Minutes, Mean (SD)	0.84	1.07	0.99	1.21	0.9	1.08	0.8
Nap Duration, Weekends, Minutes, Mean (SD)	0.90	1.06	1.011	1.20	0.87	1.07	0.8
Sleep Quality Score, Mean (SD)	18.54	13.51	22.48	13.96	21.86	13.64	0.2
Mood Score, Mean (SD)	11.91	9.86	12.24	9.30	14.11	12.29	0.4
Diet Score, Mean (SD)	19.52	5.65	18.55	5.03	18.38	5.07	0.4
No Pre-planned Physical Activity, Days per Week, Mean (SD)	5.55	2.50	5.74	2.47	6.42	1.75	0.056
Sociocultural Activity, Mean (SD)	0.12	0.84	0	0	0.18	1.05	0.5
Smoking, Pack-Year, Mean (SD)	3.51	13.00	3.043	11.85	2.01	14.77	0.8
Diastolic Blood Pressure, mmHg, Mean (SD)	80.60	9.304	80.43	9.87	80.75	9.65	0.9
Systolic Blood Pressure, mmHg, Mean (SD)	129.67	19.17	128.48	18.13	131.97	20.47	0.6
Waist Circumference, cm, Mean (SD)	88.45	13.87	95.2	14.71	101.85	16.98	**0.0001**
Body Mass Index, kg/m2, Mean (SD)	24.14	4.57	26.47	5.58	28.08	9.29	**0.001**
Disease Duration, Years, Mean (SD)	5.85	5.08	7.54	6.49	4.08	3.19	**0.001**
Laboratory Findings							
Fasting Blood Glucose, mg/dL, Mean (SD)	81.14	12	113.13	7.17	203.17	95.94	**0.0001**
High Density Lipoprotein, mg/dL, Mean (SD)	33.87	14.45	32.85	12.19	31.8	14.23	0.7
Triglyceride, mg/dL, Mean (SD)	132.58	81.27	138	75.73	154.71	92.71	0.3
Hemoglobin, mg/dl	11.19	1.65	11.68	1.55	11.53	1.53	0.2
White Blood Cells, cells/L	6.244	2.54	15.11	59.10	6.63	1.82	0.2
Lymphocytes, cell/L	31.83	10.80	31.02	11.51	29.12	9.69	0.3
C-Reactive Protein, mg/L	2.94	4.64	2.73	8.12	4.50	11.71	0.4
Serum Albumin	4.59	4.61	4.14	0.30	4.01	0.27	0.5
Blood Urea Nitrogen before Dialysis, mg/dl	135.05	44.06	125.87	43.70	129.62	39.5	0.5
Blood Urea Nitrogen after Dialysis, mg/dl	42.23	16.02	45.02	15.78	42.76	13.87	0.6
Parathyroid Hormone	433.88	323.06	465.55	514.28	344.78	277.05	0.2
Serum Phosphorus, mg/dl	5.45	1.58	5.64	1.33	5.18	1.64	0.3
Serum Vitamin D, IU/L	58.27	42.56	58.59	40.99	82.83	191.22	0.4
Serum Calcium, mg/dl	8.39	0.81	8.64	0.76	8.59	0.65	0.1

Table 3. Comparison of the patients' characteristics stratified by BMI.

Participants' Characteristics	**Body Mass Index, kg/m^2**				***P* value**
	<18.5 *n*=11 (%6)	**18.5-24.9** *n*=86 (%43)	**25.0-29.9** *n=64 (%32)*	**≥30.0** *n=38 (%19)*	

	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age, Years, Mean (SD)	45.36	19.75	51.6	14.18	57.73	13.87	60.08	9.67	**0.0001**
Sleep Duration, Weekdays, Hours, Mean (SD)	7.72	2.49	7.14	1.94	7.25	2.16	7.15	1.99	0.9
Sleep Duration, Weekends, Hours, Mean (SD)	7.81	2.52	7.25	2.04	7.39	2.18	7.31	2.02	0.5
Time to Bed, Weekdays, PM	23.91	2.58	23.93	1.36	23.48	1.84	23.47	1.70	0.7
Time to Bed, Weekends, PM	23.91	2.58	23.94	1.34	23.52	1.84	23.5	1.69	0.7
Time to Fall Asleep, Minutes, Mean (SD)	54.55	43.61	41.16	56.55	42.89	45.03	51.71	46.09	0.7
Time to Get Out of Bed, Weekdays, AM	7.63	3.80	7.07	2.03	6.70	2.37	6.63	1.71	0.5
Time to Get Out of Bed, Weekends, AM	7.72	3.77	7.19	2.18	6.90	2.51	6.81	1.91	0.7
Nap Duration, Weekdays, Minutes, Mean (SD)	0.95	1.79	1	1.13	0.86	1.08	0.70	0.86	0.8
Nap Duration, Weekends, Minutes, Mean (SD)	1.13	1.73	1.04	1.13	0.85	1.05	0.75	0.87	0.8
Sleep Quality Score, Mean (SD)	18	13.72	16.19	13.45	22.64	12.41	26.21	14.00	0.2
Mood Score, Mean (SD)	6.91	7.59	10.69	9.71	14	11.79	16.45	9.77	0.4
Diet Score, Mean (SD)	18.27	5.78	18.85	5.31	19.18	5.92	18.90	4.50	0.4
No Pre-planned Physical Activity, Days per Week, Mean (SD)	6.54	1.21	5.30	2.73	6.25	1.92	6.44	1.73	0.056
Sociocultural Activity, Mean (SD)	0	0	0.16	1.06	0.06	0.5	0.13	0.81	0.5
Smoking, Pack-Year, Mean (SD)	0	0	5.21	19.38	1.56	5.65	1.18	5.38	0.8
Diastolic Blood Pressure, mmHg, Mean (SD)	81.81	8.73	81.74	9.22	79.92	10.40	79.73	8.85	0.9
Systolic Blood Pressure, mmHg, Mean (SD)	133.64	19.63	133.49	20.16	128.59	20.61	125.79	13.28	0.6
Waist Circumference, cm, Mean (SD)	77.82	13.18	85.49	10.59	99.72	12.22	111.71	14.57	**0.0001**
Body Mass Index, kg/m2, Mean (SD)	16.17	2.02	22.15	1.86	27.16	1.42	35.36	9.06	**0.001**
Disease Duration, Years, Mean (SD)	7.11	6.05	6.35	5.98	5.29	4.36	3.93	2.53	**0.001**
Laboratory Findings									
Fasting Blood Glucose, mg/dL, Mean (SD)	189	203.965	108.49	45.97	135.8	74.44	139.92	67.41	**0.0001**
High Density Lipoprotein, mg/dL, Mean (SD)	41.64	14.74	31.85	13.44	32.92	12.41	32.95	15.7	0.7
Triglyceride, mg/dL, Mean (SD)	102.91	55.17	125.81	67.39	142.44	82.78	180.63	110.20	0.3
Hemoglobin, mg/dl	10.82	2.21	11.35	1.71	11.56	1.33	11.39	1.62	0.2
White Blood Cells, cells/L	6.04	2.11	6.14	2.48	12.52	50.13	7.28	1.93	0.2
Lymphocytes, cell/L	26.4	13.00	32.05	11.03	30.97	10.66	29.25	9.09	0.3
C-Reactive Protein, mg/L	4.045	4.57	2.55	5.19	3.87	10.61	2.87	6.73	0.4
Serum Albumin	4.1	0.25	4.63	4.74	4.03	0.30	4.1	0.37	0.5
Blood Urea Nitrogen before Dialysis, mg/dl	127.91	37.86	133.17	47.62	136.56	40.92	120.45	34.82	0.5
Blood Urea Nitrogen after Dialysis, mg/dl	37.90	8.75	41.88	15.64	45	15.79	43.98	15.02	0.6
Parathyroid Hormone	318.09	228.35	427.98	340.34	396.20	267.64	460.91	555.91	0.2
Serum Phosphorus, mg/dl	4.94	1.69	5.5	1.57	5.39	1.61	5.42	1.44	0.3
Serum Vitamin D, IU/L	56.81	40.80	79.63	169.21	58.58	37.54	55.33	32.12	0.4
Serum Calcium, mg/dl	8.59	0.70	8.46	0.75	8.53	0.79	8.58	0.78	0.1

Table 4. Association of waist circumference/body mass index/fasting blood and independent variables measured by the multivariable linear regression models (R^2=0.21, 0.28 and 0.14, respectively).

Predictors	Multivariable Linear Regression Models built for:					
	Waist Circumference		Body Mass Index		Fasting Blood Glucose	
	β (95% CI)	*P*	β (95% CI)	*P*	β (95% CI)	*P*
Age, years	0.28 (0.11, 0.45)	**0.001**	0.12 (0.05, 0.18)	**0.001**	Removed Via Stepwise Backward Elimination	
Sleep Quality Score	0.20 (0.05, 0.36)	**0.01**	0.08 (0.006, 0.15)	**0.03**	0.88 (-0.05, 1.82)	0.06
Fibromyalgia Impact Questionnaire Score	0.19 (-0.03, 0.42)	0.08	Removed Via Stepwise Backward Elimination		1.28 (0.19, 2.37)	**0.02**
Female Sex	Removed Via Stepwise Backward Elimination		2.01 (0.10, 3.92)	**0.04**	Removed Via Stepwise Backward Elimination	
Night Sleep Duration on weekdays			-1.82 (-3.64, -0.007)	**0.049**		
Night Sleep Duration on weekends			1.65 (-0.13, 3.43)	0.07		
Phosphorus Level			0.76 (0.17, 1.35)	**0.01**		
Diet Score			Removed Via Stepwise Backward Elimination		-2.32 (-4.33, -0.31)	**0.02**
Mood Score					-1.65 (-2.94, -0.36)	**0.01**
Physical Activity					4.38 (-0.56, 9.33)	0.08
Time to fall asleep, Minutes					Removed Via Stepwise Backward Elimination	
Time to go to bed on weekdays						
Wake-up Time on weekdays						
Nap Duration on weekdays, Minutes						
Nap Duration on weekends, Minutes						
Time to go to bed on weekends						
Wake-up Time on weekends						
Social Activity						
Marital Status						
Smoking, Pack-Years						
Hemoglobin level						
Vitamin D						
Albumin level						
Blood Urea Nitrogen before Dialysis						