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Predictors of nutritional status and fluid balance among ESRD patients undergoing hemodialysis

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ABSTRACT

Introduction: Patients with End-Stage Renal Disease (ESRD) undergoing hemodialysis must adapt to strict nutritional and fluid restrictions to achieve optimal therapeutic outcomes. Nonadherence leads to complications and clinical deterioration. This study examined psychosocial (knowledge, illness perception, family support) and clinical factors (illness duration, comorbidities, and blood pressure) as predictors of nutritional status and fluid balance, measured by biochemical markers and interdialytic weight gain (IDWG), among hemodialysis patients in West Sumatra.

Methods: This cross-sectional correlational study included 245 ESRD patients from four hemodialysis units in West Sumatra. Knowledge, family support, and illness perception were measured using validated questionnaires. Biochemical parameters (urea, creatinine, albumin, sodium, potassium, and hemoglobin) and IDWG served as proxies for nutritional status and fluid balance. Data analysis was performed using Pearson's correlation and t-test ($\alpha = 0.05$).

Results: The mean age was 51.4±11.8 years, and 60% were male. Most patients had good knowledge (81.6%), strong family support (90.6%), and positive perceptions (82%). A significant correlation was found between illness duration and interdialytic weight gain (IDWG) ($r=0.153$, $p<0.05$). Notably, knowledge level was negatively correlated with urea level ($r = -0.127$, $p < 0.05$), indicating that higher knowledge was associated with better nutritional control. Family support was not significantly correlated with biochemical outcomes.

Conclusions: Patient knowledge emerged as an important predictor of biochemical indicators of nutritional status, whereas dialysis duration predicted fluid imbalance as reflected by IDWG. Family support, although prevalent, did not significantly influence the clinical outcomes related to nutrition and fluid control. Strengthening educational strategies may enhance adherence to treatment and improve clinical outcomes.

Keywords: adherence; end-stage renal disease (ESRD); fluid restriction; hemodialysis; nutritional management

Introduction

End-stage renal disease (ESRD) occurs when the kidneys fail to execute their essential functions and presents a profound global health challenge (Yadav *et al.*, 2025). ESRD, which is an end-stage chronic renal disease, is characterized by reduced renal function. Unless managed properly, this condition may result in severe health complications and could potentially increase the risk of mortality(Hansrivijit *et al.*, 2021). The international prevalence of ESRD has been rising at a rate with an estimated annual increase of 6–8%(Coresh, 2017; Hansrivijit *et al.*, 2021). The rising prevalence reflects the urgent need for best practices in treatment protocols and concurrent management strategies to improve patient outcomes and prevent mortality in ESRD. The prevalence of ESRD in Indonesia is 0.18% by 2023(Ministry of Health, 2023). Although relatively low, such prevalence is not only a critical issue for the health care system but also justifies the importance of examining the intricacies of treatment modalities and patient compliance in Indonesia.

Hemodialysis is a cornerstone therapy for ESRD as a renal replacement therapy to assume the role of failing kidneys(Webster *et al.*, 2017; Bello *et al.*, 2022). As a life-sustaining treatment, hemodialysis requires careful adherence to prescribed regimens to achieve intended therapeutic outcomes. Adhering to daily hemodialysis regimens, however, is problematic. Successful

hemodialysis relies on a multitude of factors, each of which must be strictly monitored if the therapy is to achieve optimal benefits(Ozen *et al.*, 2019). Adherence is both extensive and complicated, from faithful attendance at sessions to strict dietary and fluid restrictions(Başer and Mollaoğlu, 2019; Kustimah *et al.*, 2019). Among these determinants of adherence, diet management and fluid restriction are the most challenging due to the complexity of the dietary regimen and the high consistency required for its application(Durose *et al.*, 2004; Ohashi *et al.*, 2018; Beerappa and Chandrababu, 2019; Ozen *et al.*, 2019; Chen *et al.*, 2022).

Non-adherence can lead to complications that affect patients' clinical condition, including Interdialytic Weight Gain (IDWG) of more than 4%, malnutrition/protein Energy Wasting (PEW), and hyperkalemia(Miyata *et al.*, 2018; Alikari *et al.*, 2019; Dantas *et al.*, 2019). However, even though there is exceedingly clear evidence of the applicability of compliance, a staggering 50% of the patients were reported to have not complied with their treatment and therapy sessions(Kustimah *et al.*, 2019). Non-compliance not only nullifies the aim of hemodialysis but also jeopardizes attendant morbidity and mortality(Bello *et al.*, 2022).

Several factors influence the adherence of hemodialysis patients to hemodialysis regimens. Knowledge, illness perception, and family support are central and interrelated determinants. Knowledge of an illness and the rationale for diet and fluid limitations allows the patient to better understand their illness and form the basis of informed decision-making(Fernandes *et al.*, 2024; Snijders *et al.*, 2025; Zhou *et al.*, 2025). The cognitive and emotional representation of a disease, namely illness perception, influences patients' motivation and attitudes regarding the path of treatment adherence(Eshete *et al.*, 2023; Laradhi *et al.*, 2025). Family support, especially in communal and matrilineal societies, provides critical resources with an instrumental, informational, and emotional nature that may facilitate or hinder adherence(Goins *et al.*, 2022; Wulandari, Astuti and Udani, 2024; Laradhi *et al.*, 2025). These elements often appear separately, yet their combined, possibly interacting effects on adherence in some specific cultural contexts remain underexplored.

Most studies exploring the determinants of adherence among hemodialysis patients have targeted single-dimensional factors, such as knowledge or family support, and have mostly been conducted in urban settings(Naalweh *et al.*, 2017; Isa and Chan, 2020). Emphasis on single variables and only urban populations limits the applicability and generalizability of the results to diverse groups with specific sociodemographic and cultural characteristics. Therefore, there is an evident need for investigations with a multidimensional approach, taking into consideration the clinical, psychosocial, environmental, and health system determinants of nonadherence-particularly within the rural or underserved population.

West Sumatra provides a unique and important setting for such studies. In this region, the Minangkabau ethnic group and its well-known matrilineal kinship system, where family and family relations play a central role in everyday life and decision-making processes related to health, dominate(Yusefni *et al.*, 2022; Fatmariza, Febriani and Salleh, 2024). Such sociocultural characteristics are likely to influence health behaviors, including dietary and fluid adherence, among patients with ESRD. Despite their importance, the role of these cultural and familial structures in shaping adherence behaviors in West Sumatra remains unclear. Furthermore, the joint influence of knowledge, illness perception, and family support-three highly relevant variables within strong familial and communal bonds-has not been well examined within this region (Naalweh *et al.*, 2017; Isa and Chan, 2020).

Therefore, this study aimed to identify psychosocial factors (knowledge, illness perception, and family support) and clinical factors as predictors of nutritional status and fluid balance, as measured by routine biochemical parameters and interdialytic weight gain (IDWG), in patients with end-stage renal disease (ESRD) undergoing maintenance hemodialysis in West Sumatra, Indonesia. Conducting this research in a socioculturally unique setting not only fills a significant gap in the literature, but also provides evidence to inform the development of culturally sensitive interventions and policies to enhance patient adherence and clinical outcomes.

Materials and Methods

Study Design and Setting

This was a quantitative correlational study with a cross-sectional design. The study was conducted in four hemodialysis units across West Sumatra Province, Indonesia. These hospitals were selected based on regional representativeness, covering both urban (provincial capital) and suburban areas, to capture patients undergoing hemodialysis from various regions of West Sumatra.

Study Population and Sampling

The target study population included patients with ESRD who were undergoing hemodialysis therapy. Convenience sampling was employed with the following inclusion criteria: patients with ESRD who were willing to participate in the study, routine hemodialysis patients, those with good communication capacity, those cognitively intact, and those who had previously received nutrition and fluid education, according to the hospital's standard procedures.

Data Collection Instruments

Knowledge Questionnaire: This instrument has been adapted from the guidelines provided by Kidney Disease Outcomes Quality Initiative (KDOQI) 2020 and the Pernefri's consensus on nutrition(Pernefri, 2011). It consists of 23 statements divided into two sections: knowledge of nutrition management and fluid management in hemodialysis patients. The tool uses binary scoring, with one mark for correct responses and zero marks for incorrect responses. The highest possible score was 23. A high score indicated high knowledge. The tool's reliability was confirmed through Cronbach's alpha coefficient, which was 0.75, which was above the threshold of 0.7. The confidence level was 95% ($p < 0.05$).

Family Support Questionnaire: This 20-item questionnaire, adapted from the Family Support Scale (FSS)(Uddin, 2019), assesses various domains of family support, including instrumental, informational, emotional, and appraisal support. It employs an ordinal scale of 1 to 4, with scores ranging from 20 to 80. Validity was tested with this tool and produced a value of 0.851, which exceeded the critical point of 0.444. Thus, all the items in the questionnaire were consistent. In addition, the questionnaire also conformed to the value of the coefficient of 0.891, which was higher than the minimum of 0.444. That is, all the items in the questionnaire were consistent.

Perception Questionnaire: The Brief Illness Perception Questionnaire (B-IPQ) was used to measure the patients' illness beliefs. It contains nine items rated on a ratio scale from 0 to 10 and one further open question. The maximum possible B-IPQ score is 0–80 (Broadbent et al., 2006). The measurement validity was determined using Cronbach's alpha coefficient, which was 0.812, far higher than the suggested 0.7 point at the 95% confidence level ($p < 0.05$).

Observation Sheet: In study, nutritional status was operationalized by biochemical markers (urea, creatinine, albumin, potassium, and hemoglobin), while fluid balance was operationalized by IDWG calculated between dialysis sessions. It quantifies patients' fluid and nutritional status from the clinical laboratory results of pre-dialytic urea, pre-dialytic creatinine, pre-dialytic albumin, pre-dialytic sodium, pre-dialytic potassium, and IDWG. IDWG was calculated by dividing the pre-dialysis weight of the previous session by the post-dialysis weight, which indicates fluid intake between sessions(Maimani *et al.*, 2021).

Ethical Considerations

Before initiating the study, ethical approval was obtained from the ethics commission of Dr. M Djamil Hospital, Padang, with reference number LB.02.02/5.7/336/2023. All ethical considerations were observed during the study, including informed consent obtained in writing from participants, keeping all data anonymous and confidential, and maintaining the participants' right to withdraw at any stage without any

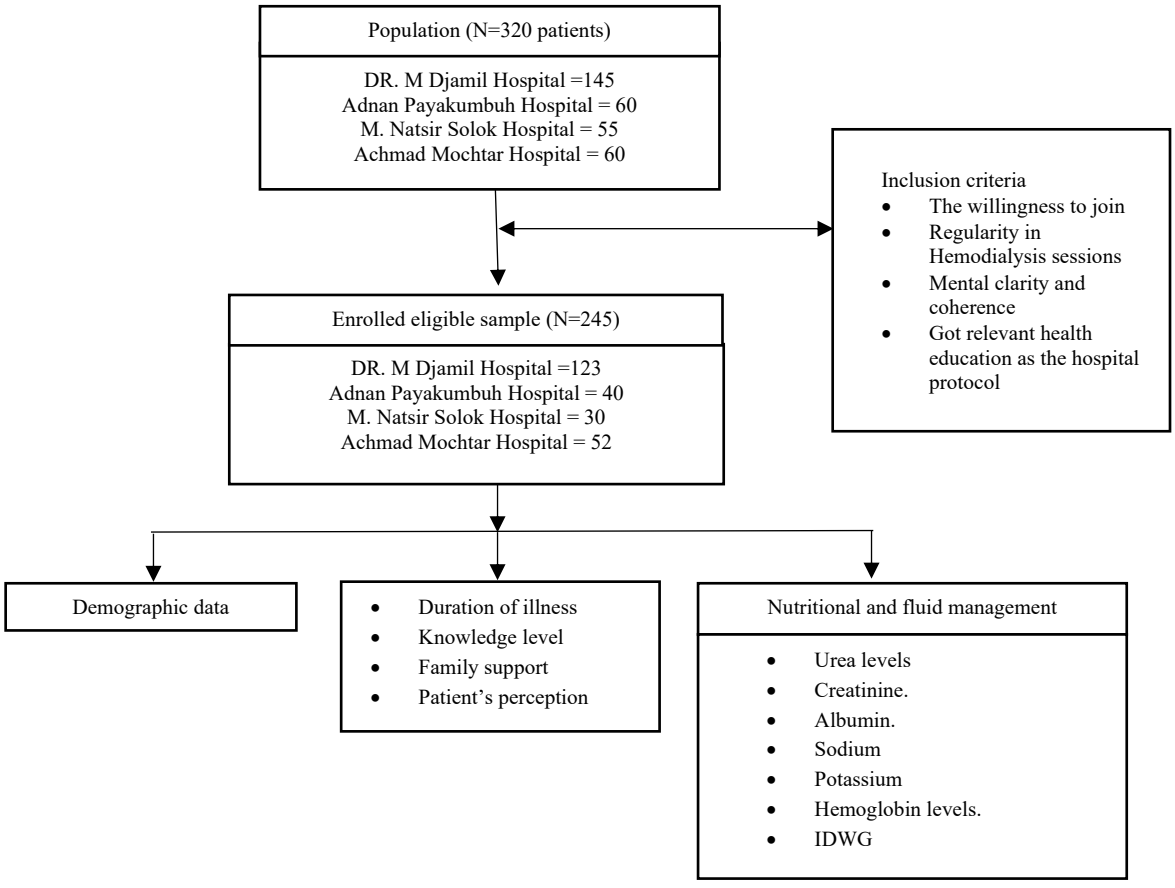

Table 1. Characteristics of the respondents (n = 245)

Variable	*n*	%	Mean	SD
Age			51.37	11.804
Genders				
Male	147	60.0		
Female	98	40.0		
Education Level				
Elementary	37	15.1		
Junior High School	46	18.8		
Senior High School	107	43.7		
Diploma	13	5.3		
Bachelor	35	14.3		
Postgraduate	7	2.9		
Employment Status				
Unemployed	169	69.0		
Employee	76	31.0		
Comorbidity				
1 Comorbidity	170	69.4		
2 Comorbidities	66	26.9		
>2 Comorbidities	9	3.7		
Vascular Access				
Cimino	166	67.5		
Double Lumen Catheter	78	31.7		
Femoral	1	0.4		
Body Weight				
Dry Body Weight (Kg)			57.26	1.058
Wet Body Weight (Kg)			62.18	4.983
Blood pressure (mmHg)				
Systolic			149.87	22.861
Diastolic			85.98	14.351

Table 2. Variables of the study (n = 245)

Variable	*n*	%	Mean	SD
Duration of Hemodialysis				
≤ 5 years	210	85.7	0.351	0.351
> 5 years	35	14.3		
Knowledge level				
Good	200	81.6	18.00	3.544
Sufficient	43	17.6		
Insufficient	2	0.8		
Family Support				
Good	222	90.6	63.75	8.390
Insufficient	23	9.4		
Perception				
Good	201	82.0	58.80	12.037
Insufficient	44	18.0		
Predictors of Nutritional Status				
Urea (mmol/L)	-	-	99.62	40.38
Creatinine (µmol/L)	-	-	9.44	6.71
Albumin (g/L)	-	-	2.92	0.72
Sodium (mmol/L)	-	-	137.9	11.21
Potassium (g/dL)	-	-	4.44	1.00
Hemoglobin (g/dL)	-	-	9.11	1.63
IDWG (%)				
Heavy	24	9.8		
Medium	66	26.9	3.25	2.00
Mild	155	63.3		

consequence. Ethical issues within the study were based on the principles of the Declaration of Helsinki.

Data Analysis

The data distribution was examined using frequency distributions and measures of central tendency. Data were tested for normality using the Kolmogorov-Smirnov test. Relationships between variables were determined using Pearson biserial correlation and independent t-tests with a 95% confidence interval and a significance level of α=5%.

Results

Enrollment and trial flow

A total of 320 patients undergoing hemodialysis were identified across four major referral hospitals in the West Sumatra Province. A convenience sampling approach was employed, whereby eligible patients who were available and willing to participate in the study were included. Of these, 16 declined participation, 8 exhibited symptoms of delirium, and 31 provided incomplete or invalid responses. Consequently, 245 patients who met the inclusion criteria were included in the final analysis.

Demographic and Clinical Characteristics

The mean age of the respondents was 51.37 ± 11.804 years. Most of the respondents were male, comprising 60% (147 individuals). Regarding the educational background, the largest group consisted of senior high school graduates, representing 43.7% (107 individuals). In addition, 31% (76 individuals) of the respondents were employed. A significant portion of 68.6% (168 individuals) had one comorbidity. The average systolic pressure for the cohort was 149.87 ± 22,861 mmHg, while the diastolic pressure averaged 85.98 ± 14.351 mmHg. Notably, 67.8% (166 individuals) of the patients used the Cimino method for hemodialysis access (Table 1).

Of the total patients, 85.7% had been undergoing hemodialysis for less than 5 years. A significant majority (81.6%, 200 participants) demonstrated a good level of knowledge. Family support was rated as good by 90.6% (222 participants). Additionally, 82% (201 participants)

Table 3. Analysis of the Correlation between Demographic Factors and Nutrition and Fluid Management

variable	Urea		Creatinine		Albumin		Sodium		Potassium		Hb		IDWG	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
Age[a]	-0.043	0.499	0.023	0.723	-0.043	0.504	-0.026	0.689	0.055	0.387	0.087	0.177	-0.111	0.082
Gender[b]	0.036	0.571	-0.043	0.504	0.005	0.941	0.073	0.255	0.082	0.199	-0.038	0.552	-0.068	0.291
Education[b]	-0.022	0.732	-0.098	0.125	-0.026	0.684	0.010	0.878	0.002	0.974	-0.041	0.524	0.010	0.876
Work[b]	0.092	0.153	0.000	0.998	-0.008	0.902	-0.017	0,793	-0.040	0.534	0.029	0.656	-0.114	0.076
Comorbid[b]	-0.040	0.534	-0.055	0.390	-0.141	0.028*	0.039	0.544	-0.040	0.538	-0.066	0.303	0.001	0.983
Vaskuler acces[b]	0.107	0.094	-0.066	0.305	0.049	0.444	-0.018	0.780	-0.046	0.469	0.006	0.920	-0.198	0.062
Systole[a]	-0.127	0.048*	0.011	0.858	-0.013	0.836	0.014	0.826	0.052	0.415	-0.039	0.541	0.116	0.069
Diastole[a]	0.047	0.461	-0.039	0.540	0.060	0.347	0.014	0.831	0.005	0.932	-0.007	0.908	-0.003	0.958

Note: *p<0.05, [a]Pearson's correlation, [b]independent t-test
Abbreviations: **Hb** = Hemoglobin; **IDWG** = Interdialytic Weight Gain

Table 4. Interaction between Demographic Variables and Determinants of Nutrition and Fluid Management

Variable	Duration of Illness		Knowledge		Family Support		Perception	
	r	*p*	r	*p*	r	*p*	r	*p*
Age[a]	-0.184	0.004*	-0.070	0.277	0.031	0.625	-0.098	0.125
Gender[b]	-0.097	0.132	0.067	0.299	-0.108	0.093	0.125	0.052
Education[b]	0.039	0.547	0.058	0.365	-0.049	0.477	0.080	0.214
Work[b]	0.004	0.955	0.020	0.758	0.034	0.593	0.035	0.581
Comorbid[b]	-0.117	0.067	0.066	0.302	0.091	0.155	-0.063	0.329
Vasculer access[b]	-0.084	0.191	-0.025	0.702	0.044	0.491	-0.054	0.369
Systole[a]	0.126	0.050	0.076	0.237	-0.117	0.067	0.135	0.034*
Diastole[a]	0.025	0.698	-0.046	0.475	-0.034	0.601	0.066	0.303

Note: *p<0.05, [a]Pearson's correlation, [b]independent t-test

had positive perceptions. The mean scores for Nutrition and Fluid Management were as follows: Urea = 99.62 ± 40.38; creatinine, = 9.44 ± 6.71; albumin, = 2.92 ± 0.72; sodium, = 137.9 ± 11.21; potassium, = 4.44 ± 1.00; hemoglobin, = 9.11 ± 1.63; and IDWG 3.25 ± 2.00 (Table 2).

The analysis showed a significant negative correlation between the number of comorbidities and albumin levels (r = -0.141, p = 0.028). The higher the number of comorbidities, the lower the albumin levels. This indicates that patients with multiple comorbidities tend to have poorer nutritional status. There was a significant negative correlation between systolic blood pressure and urea levels (r = -0.127, p = 0.048), indicating that higher urea levels tended to lower systolic blood pressure.

The analysis revealed a significant correlation between the duration of illness and age (p<0.05), with a Pearson's correlation coefficient (r) of -0.184. Additionally, a significant relationship was observed between the perception scores and systolic blood pressure (p<0.05), as evidenced by a Pearson's correlation coefficient (r) of 0.135.

A significant correlation was identified between the duration of illness and IDWG, as indicated by a p-value of less than 0.05 and a Pearson 's correlation coefficient (r) of 0.153. This finding shows a proportional relationship, in which an increase in the duration of illness is paired with an increase in IDWG levels. Second, the study found a weak negative correlation between knowledge level and urea levels, as depicted by a p-value of less than 0.05, and a Pearson's correlation coefficient (r) of -0.127. This implies that subjects with higher knowledge levels had lower urea levels. However, most correlations between the variables under study and biomarkers were not statistically significant, according to the criterion of p<0.05.

Discussions

This study identified three key predictors of nutritional status and fluid balance among ESRD patients on hemodialysis: higher knowledge levels were associated with lower urea levels, a greater number of comorbidities predicted lower albumin concentrations, and a longer duration of hemodialysis predicted higher IDWG. Low levels of albumin and hemoglobin are prevalent among hemodialysis patients, primarily due to impaired erythropoietin production resulting from renal damage, which leads to reduced red blood cell synthesis(Moszak *et al.*, 2017; Gluba-Brzózka *et al.*, 2020; Wu *et al.*, 2022; Cao *et al.*, 2023; Fitmawati, Rosyidah and Hartanto, 2023). In addition, hemoglobin levels in these patients are influenced by several factors, including dialysis-related blood loss, disruption of iron metabolism, and insufficient intake(Gluba-Brzózka *et al.*, 2020). A diminished Glomerular Filtration Rate (GFR) in ESRD patients leads to the inadequate elimination of urea and creatinine(Kirkeskov *et al.*, 2021; Kim, Jeong and Cho, 2022).

Our results indicated a weak negative correlation between comorbidities and albumin levels (r = – 0.141, p = 0.028). This finding corroborates prior evidence indicating that comorbid conditions via chronic inflammation and metabolic stress exacerbate hypoalbuminemia beyond nutritional influences(Bawazir, 2020). This highlights the need to combine comorbidity management with culturally appropriate dietary support in West Sumatra.

The study showed that the length of dialysis did not have a significant effect on the levels of urea, creatinine, sodium, potassium, or hemoglobin. This has an impact on the IDWG by causing the fluid management capacity to gradually decrease over time(Jalalzadeh *et al.*, 2021). Excessive IDWG, typically due to excessive fluid intake, may result in complications including dyspnea, peripheral edema, and fatigue(Dantas *et al.*, 2019;

Table 5. Correlation between Determinant Factors and the Management of Nutrition and Fluids

Variable	Urea		Creatinine		Albumin		Sodium		Potassium		Hemoglobin		IDWG	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Duration of Illness	-0.048	0.458	0.028	0.668	0.075	0.240	-0.048	0.455	-0.027	0.673	0.014	0.833	0.153	0.017*
Knowledge	-0.127	0.048*	-0.055	0.388	-0.019	0.766	0.014	0.827	-0.47	0.468	-0.018	0.775	0.012	0.849
Family Support	0.065	0.309	-0.066	0.302	-0.023	0.721	-0.62	0,336	0.020	0.755	0.009	0.894	-0.085	0.183
Perception	-0.024	0.714	0.008	0.910	0.047	0.464	-0.052	0.420	0.035	0.590	-0.069	0.285	0.007	0.919

Note: *p<0.05, Pearson's correlation

Wahyuni *et al.*, 2019; Maimani *et al.*, 2021). The findings of this study suggest that patients undergoing prolonged hemodialysis are likely to exhibit elevated IDWG, which is potentially indicative of diminished compliance with fluid restrictions over time. This condition is frequently linked to treatment fatigue or burnout, characterized by physical and psychological exhaustion from prolonged therapeutic regimens, alongside dietary fatigue stemming from the challenges of consistently adhering to a stringent diet. Recent studies indicate that fatigue, pruritus, and thirst distress adversely affect the quality of life by reducing adherence(Sharif-Nia *et al.*, 2024), whereas meta-analyses have revealed that the efficacy of adherence-enhancing interventions diminishes in the absence of continuous support(Kim, Jeong and Cho, 2022). These results highlight the necessity for interventions that are both educational and centered on enduring psychosocial support to avert diminished adherence.

This research also substantiates a direct correlation between patient knowledge and urea levels, thereby highlighting the significance of knowledge in fostering self-care regarding nutritional and fluid intake(Spies, van den Berg and Nel, 2021). Sound knowledge encourages mutual behaviors in restructuring food habits, but the absence of knowledge can act as a motivator for forgetful health actions resulting from escalated conditions and added clinical laboratory values(Isa and Chan, 2020).

Perceived health, depending on the length of hemodialysis, is the main indicator of adherence to food and fluid restrictions(Yanmış and Ergüney, 2020). Increased perceived health corresponds to increased adherence, a predictor of why there is a requirement for healthcare professionals to evaluate and facilitate patients' perceptions of health and offer recommendations in the interpretation of dietary and fluid restrictions.

While the majority of patients received extensive family support, no correlation was found between family support and levels of urea, creatinine, hemoglobin, sodium, and potassium(Ozen *et al.*, 2019; Fitmawati, Rosyidah and Hartanto, 2023). Personal behavior and eating habits determine the efficiency of family support in nutritional and fluid management. Nevertheless, family support remains crucial for compliance with management protocols, mental health, and improvement in quality of life. Lack of family support could lead to reduced life expectancy and depression scores(Jiang *et al.*, 2015; Isdiarti and Ardian, 2020; Hulu, Prasetyo Budi and Sari, 2021).

The findings of this study are not significant in the Indonesian context, particularly in West Sumatra. This area has its own social and cultural traits, close family ties, and various ways of receiving medical care. While most patients in this study rated family support as excellent, there was no significant link between family support and the clinical outcomes that were measured. This might show a difference between how much support a family gives and how well a patient takes care of themselves, which can be affected by their level of health literacy and how their culture views chronic diseases.

This study was constrained by its cross-sectional design, dependence on self-reported metrics, and the analysis of only specific psychosocial variables, neglecting a comprehensive analysis. Heterogeneity in disease progression and treatment duration may also have affected the results; however, these therapy-related factors were not comprehensively evaluated. Future research in West Sumatra and comparable settings should employ longitudinal designs and incorporate broader determinants, including economic barriers, health literacy, cultural beliefs, and patient–provider communication, to better capture the complex interplay between psychosocial and clinical factors. Such approaches are crucial for developing culturally tailored and sustainable strategies to strengthen adherence and optimize outcomes among ESRD patients with ESRD undergoing hemodialysis.

Conclusion

This study demonstrated that higher patient knowledge is significantly associated with better biochemical profiles, particularly lower urea levels, suggesting improved adherence to dietary and fluid restrictions. Conversely, a longer hemodialysis duration was correlated with greater IDWG, indicating increased challenges in fluid balance over time. Although family support was generally high, it was not significantly associated with biochemical parameters. These findings suggest that strengthening patient knowledge and aggressively managing comorbid conditions, together with close monitoring of IDWG, may help optimize nutritional and fluid outcomes in hemodialysis patients. Given the cross-sectional design, the observed predictors should be interpreted as correlates, and longitudinal or interventional studies are required to confirm their causal impact on nutritional status and fluid balance.

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Availability of data and materials

The data produced and/or examined in this research can be obtained from the corresponding author upon request.

Authors' contributions

All authors contributed equally to the research, from significant input in the research conception to the publication process.

Declaration of Interest

The authors declare no financial or commercial conflicts of interest throughout this study.

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