








## Research Article

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## Association of Dialysis Adequacy with Health-Related Quality of Life Among Maintenance Hemodialysis Patients: A Cross-Sectional Study

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## Abstract

**Background:** Hemodialysis is used as renal replacement treatment to extend patients' lives. Adequate and effective dialysis can improve patients' quality of life; however, there is a lack of data regarding dialysis adequacy and its impact on quality of life (QOL) among hemodialysis patients in the Yemeni context. **Objective:** To assess the association between dialysis adequacy and health-related quality of life (HRQOL) among hemodialysis patients. **Methods:** A descriptive cross-sectional study was conducted among 77 patients selected from the hemodialysis center of the 22 May Hospital Authority in Amran City, Yemen, from December 2024 to April 2025, using a convenience sampling method. Data were collected through face-to-face interviews using a validated Arabic version of the Kidney Disease Quality of Life (KDQOL™-36) questionnaire and by measuring dialysis adequacy (Kt/V) according to standardized procedures. **Results:** This study showed 58.4% of patients received inadequate dialysis, and 41.6% achieved adequate dialysis based on KT/V values. The mean KDQOL score was 40.66, highest for symptoms/problems (49.11) and lowest for burden of kidney disease (25.65). Patients with adequate dialysis had significantly better scores for symptom/problem, effect, and burden subscales. Dialysis adequacy correlated positively with overall HRQOL ( $r=0.54$ ,  $p<0.001$ ). Hemoglobin  $>10$  g/dL was also linked to higher HRQOL ( $p=0.006$ ). **Conclusions:** Most HD patients experienced inadequate dialysis and impaired HRQOL. Dialysis adequacy and anemia control emerged as key determinants of better HRQOL.

**Keywords:** Adequacy; Hemodialysis; Health-related quality of life; Patients.

ارتباط كفاية الغسيل الكلوي بجودة الحياة الصحية بين مرضى الغسيل الكلوي الدموي المنتظم: دراسة مقطعية

## الخلاصة

**الخلفية:** يستخدم الغسيل الكلوي الدموي كعلاج بديل لوظائف الكلى بهدف إطالة حياة المرضى. ويمكن أن يسهم غسيل الكلى الدموي الكافي والفعال في تحسين جودة حياة المرضى؛ إلا أن هناك نقصاً في البيانات المتعلقة بكفايته وتأثيره على جودة الحياة (QOL) لدى مرضى الغسيل الكلوي الدموي في اليمن. **الهدف:** بتقييم العلاقة بين كفاية الغسيل الكلوي وجودة الحياة المرتبطة بالصحة (HRQOL) لدى مرضى الغسيل الكلوي الدموي. **الطرائق:** أجريت دراسة وصفية مقطعية على 77 مريضاً تم اختيارهم من مركز الغسيل الكلوي في مستشفى 22 مايو بمدينة عمران، اليمن خلال الفترة من ديسمبر 2024 إلى أبريل 2025، باستخدام أسلوب العينة المتاحة. جمعت البيانات من خلال مقابلات وجهاً لوجه باستخدام النسخة العربية المعتمدة من استبيان جودة الحياة لمرضى أمراض الكلى (KDQOL™-36)، إضافة إلى قياس كفاية الغسيل الكلوي (Kt/V) وفق إجراءات معيارية. **النتائج:** أظهرت الدراسة أن 58.4% من المرضى تلقوا غسيلاً كلويًا غير كافٍ، في حين حقق 41.6% غسيلاً كافياً استناداً إلى قيم (Kt/V). بلغ متوسط درجة (KDQOL) نحو 40.66، حيث كانت أعلى الدرجات في مجال الأعراض/المشكلات (49.11)، وأدناها في مجال عبء مرض الكلى (25.65). كما حقق المرضى الذين تلقوا غسيلاً كافياً درجات أفضل بشكل ملحوظ في مجالات الأعراض/المشكلات، والتأثير، والعبء. وُجد ارتباط إيجابي بين كفاية الغسيل الكلوي وجودة الحياة المرتبطة بالصحة بشكل عام ( $r=0.54$ ,  $p<0.001$ ) كما ارتبط مستوى الهيموغلوبين أكبر من 10 جرام/ديسيلتر بتحسين جودة الحياة ( $p=0.006$ ). **الاستنتاجات:** يعاني معظم مرضى الغسيل الكلوي الدموي من عدم كفاية الغسيل وتدني جودة الحياة المرتبطة بالصحة. وتعد كفاية الغسيل الكلوي والحد من فقر الدم من العوامل الرئيسية المحددة لتحسين جودة الحياة.

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## INTRODUCTION

Chronic kidney disease (CKD) is a significant health problem that affects approximately 697 million people globally, with a global prevalence of 13.4% [1]. In Asia alone, over 434 million patients suffer from this disease, with prevalence ranging from 7.0 to 34.3% [2]. The disease represents an especially large burden in low- and middle-income countries (LMICs), which often lack adequate healthcare infrastructure and financial resources to manage its complications [3]. Hemodialysis (HD) plays an essential role in

extending their lives and serves as a life-sustaining treatment in the absence of kidney transplantation [4]. As such, the dialysis population has been growing rapidly in recent years, particularly in low-resource settings [5]. However, HD can have a major impact on health-related quality of life (HRQOL) as a complex therapeutic regimen, requiring strict adherence to mitigate complications and improve outcomes [6]. According to previous studies, long hemodialysis therapy often leads to physical dysfunction, psychological impairment, financial difficulties, and social disruptions, profoundly affecting patients and

their families, especially in patients who received inadequate dialysis [7, 8]. In turn, optimal dialysis adequacy reduces morbidity and mortality while improving HRQoL by alleviating uremic symptoms and associated complications [8, 9]. Dialysis adequacy, measured by Kt/V and urea reduction ratio (URR), is a critical determinant of clinical outcomes in MHD patients according to the Renal Physicians Association and the Kidney Disease Outcomes Quality Initiative (KDOQI) [8, 10]. Several studies reported that patients who received adequate HD (Kt/V more than 1.3) showed a significant improvement in HRQoL subscales, mainly in cognitive abilities, energy, emotional well-being, and physical function [11-13]. In contrast, suboptimal HD (Kt/V < 1.3) was associated with a worse quality of life, including lower HG levels and malnutrition, which exacerbated tiredness and lowered functional ability [14, 15]. These findings support the need for optimizing dialysis adequacy to enhance patient-reported outcomes and general well-being in CKD populations, as well as the need for regular monitoring and intervention to ensure adequate dialysis administration [13, 14]. In Yemen patients undergoing MHD face severe challenges due to a lack of dialysis supplies, working dialysis equipment, and staff compensation [16]. Therefore, evaluating dialysis adequacy and its impact on HRQoL is crucial to improving patient care. This study aims to assess the association between dialysis adequacy and HRQoL among MHD patients at President Martyr Al-Sammad Hospital Authority (formerly 22 May Central Teaching Hospital) in Amran City, Yemen. The findings may inform strategies to optimize dialysis delivery and enhance patient well-being in similar resource-constrained settings, such as implementing tailored educational programs for patients and healthcare providers to improve understanding and management of dialysis adequacy.

## **METHODS**

### ***Study design and setting***

This hospital-based cross-sectional study took place between December 2024 and April 2025. It was conducted to assess the association between dialysis adequacy and health-related quality of life among patients at the hemodialysis center of President Martyr Al-Sammad Hospital Authority (formerly 22 May Central Teaching Hospital) in Amran City, Yemen. This facility serves as the primary referral for most patients, being the only hemodialysis center available in the region. Thus, it provides a representative sample of maintenance hemodialysis patients in this area.

### ***Participants and sampling***

The study included patients diagnosed with end-stage kidney disease (ESKD) of both genders and older than 18 years who had been undergoing maintenance hemodialysis for more than 6 months, were willing to

participate, and were available during the data collection period. Patients with cognitive impairment or acute health conditions that could affect quality-of-life assessments were excluded. The total population of eligible MHD at the center was 97 patients. Using Epi Info™ software (version 7.2.2.6, CDC, Atlanta, GA, USA), the required sample size was calculated as 77 patients. This calculation was based on an expected frequency of 50% (to maximize sample size), a 95% confidence level, a 5% margin of error, and a design effect of 1.0. Due to the dialysis unit having a small, fixed patient population and operating under strict treatment scheduling and ethical or logistical constraints that prevent randomization, a convenience sampling technique was employed to enroll patients across different dialysis shifts until the target sample size was achieved.

### ***Data collection***

A structured, three-part questionnaire was the primary tool to collect data. The first part of the questions was related to demographic data and clinical characteristics, including age, sex, marital status, education level, and occupation. Clinical information such as duration of hemodialysis treatment, session frequency and period, and baseline laboratory values was collected from patients' medical records. The second part reported dialysis adequacy results that were objectively assessed through the withdrawal of blood samples from all subjects before and after the same HD session to ensure accurate assessment of urea reduction. The calculation of Kt/V using the established formula:  $Kt/V = -\ln(R - 0.03) + [(4 - 3.5 \times R) \times (UF/Wt)]$

Where R represents the post-/pre-dialysis blood urea nitrogen ratio, UF is ultrafiltration volume in liters, and Wt is post-dialysis weight in kilograms. Based on National Kidney Foundation guidelines, a Kt/V threshold of  $\geq 1.3$  was used as a target to define adequate dialysis [17]. The final part was related to health-related quality of life using the validated Kidney Disease Quality of Life (KDQOL™-36) instrument, which evaluates five subscales. The Physical and Mental Component Summaries (items 1-12) provide generic quality of life measures, while three kidney disease-specific domains assess burden (items 13-16), symptoms/problems (items 17-28), and disease effects (items 29-36) [18,19]. These domains have a score from 0 to 100 using Likert summated ratings. To enable consistent interpretation of results across study participants, the score was distributed as  $\leq 50$ , indicating poor quality of life, and  $> 50$ , representing good quality of life [20,21]. A validating Arabic version was used to collect data from participants [22]. The data was collected through face-to-face interviews in Arabic within the dialysis unit over a four-week period. The pretesting of the instrument was done on 10 non-participating patients, and necessary corrections and modifications were done based on the feedback. The modified translated survey has shown acceptable reliability and internal

consistency (Cronbach's alpha values of 0.80). Clinical data was verified through medical record review, and anthropometric measurements were taken immediately post-dialysis to support accurate Kt/V calculations. Standardized protocols were followed for all laboratory procedures and data collection processes, with researchers receiving specific training to ensure consistency. Although patients generally received two sessions per week, the mean Kt/V was relatively high ( $1.51 \pm 0.69$ ). These results may be attributed to the smaller body mass of most Yemeni patients, the use of high-efficiency dialyzers, and standardized blood sampling protocols that ensured accurate post-dialysis measurement.

### Ethical considerations

Ethical approval and clearance were obtained from the Faculty of Medicine and Health Sciences Directorate at Amran University (Ethics Clearance No. 523, 10/12/2025). Formal permission was also obtained from the hospital administration. Participants were informed of the study purpose, procedures, and confidentiality. Verbal informed consent was obtained because many patients have limited literacy and limited access to written materials; the ethics committee approved this consent procedure as appropriate for the setting. All consent interactions were documented by the research team.

### Data analysis

Data were tabulated, coded, and then analyzed using the Statistical Package for the Social Sciences (SPSS), Version 27 (IBM Corp., Chicago, Illinois, USA). Descriptive statistics (frequencies, percentages, means, and standard deviations) summarized the data. Inferential statistics included chi-square to explore the association between dialysis adequacy and overall HRQOL as well as between HRQOL and demographic and clinical variables. Additionally, Pearson correlations were employed to explore the association between dialysis adequacy and domains of HRQOL. A *p*-value of  $< 0.05$  was considered statistically significant.

## RESULTS

As shown in Table 1, among 77 participants included in the study, the majority were older than 45 years old (53.2%), were married (80.5%), and a notable proportion were either illiterate (37.7%) or had only primary education (31.2%) and were unemployed (71.4%). Regarding clinical characteristics, more than half (53.2%) of the patients had been undergoing HD for 2–5 years; most of them received dialysis twice per week (96.1%), which lasted either 2 hours (51.9%) or 3 hours (45.4%). For baseline laboratory values, the majority had a hemoglobin level below 10 g/dl (80.5%) and a serum creatinine level above 8 mg/dl (59.7%) (Table 1).

**Table 1:** Demographic and Clinical characteristics of haemodialysis patients participating in the study (n = 77)

Characteristic	n(%)
<i>Age (year)</i>	
≤45	36(46.8)
>45	41(53.2)
<i>Gender</i>	
Male	44(57.1)
Female	33(42.9)
<i>Marital status</i>	
Single	15(19.5)
Married	62(80.5)
<i>Education level</i>	
Illiterate	29(37.7)
Primary	24(31.2)
Secondary	21(27.3)
University Education or higher	3(3.9)
<i>Employment status</i>	
Employed	22(28.6)
Unemployed	55(71.4)
<i>Monthly family income</i>	
≤ 80000 YER (150 USD)	18(23.4)
> 80000 YER (150 USD)	59 (76.6)
<i>Duration of haemodialysis (year)</i>	
1.0	18(23.4)
2-5	41(53.2)
> 5	18(23.4)
<i>Frequency of hemodialysis/week</i>	
2	74(96.1)
3	3(3.9)
<i>Period of session (hour)</i>	
2	40(51.9)
3	35(45.4)
4	2(2.6)
<i>Hemoglobin (g/dl)</i>	
<10	62(80.5)
10-12	12(15.6)
>12	3(3.9)
<i>Serum creatinine (mg/dl)</i>	
≤8	31(40.3)
>8	46(59.7)

n, number of participants; YER, Yemeni riyals; USD, United States Dollars.

The mean Kt/V parameter used to assess the dialysis adequacy was  $1.51 \pm 0.69$ . Thirty-two (41.6%) of HD patients received adequate dialysis (mean kt/V =  $2.03 \pm 0.84$ ), while the majority (58.4%) did not achieve adequate dialysis (mean kt/V =  $1.15 \pm 0.12$ ) (Table 2).

**Table 2:** Dialysis adequacy among maintenance hemodialysis patients by using the parameter KT/V (n = 77)

Dialysis Adequacy Group	n(%)	Mean ± SD
Inadequate Kt/V (<1.3)	45(58.4)	1.15±0.12
Adequate Kt/V (≥ 1.3)	32(41.6)	2.03±0.84
Overall dialysis adequacy		1.51±0.69

n: number of participants; Kt/V: A formula used to measure haemodialysis adequacy where K = dialyzer clearance of urea, t = treatment time, and V = volume of distribution of urea.

Health-Related Quality of Life – (KDQOL™-36) scoring indicated that the overall KDQOL score averaged  $40.66 \pm 12.24$ , with individual scores ranging from 19.68 to 67.79. From the sub-scales, the score of symptoms and problems of kidney disease (SPKD) was the highest ( $49.11 \pm 23.57$ ), followed by effects of kidney disease ( $48.18 \pm 23.06$ ) and mental health composite ( $46.06 \pm 6.91$ ). The Physical Health Composite showed a lower mean score ( $34.33 \pm 6.21$ ), while the lowest mean score was on the burden of kidney disease summary (BKD) ( $25.65 \pm 25.78$ ) (Table 3).

**Table 3:** Kidney Disease Quality of Life (KDQOL) subscales scores among haemodialysis patients participating in the study (n=77)

KDQOL subscales	Range	Mean±SD
Symptom/problem list	4.17-87.50	49.11±23.57
Effects of kidney disease	0.00-93.75	48.18±23.06
Burden of kidney disease	0.00-93.75	25.65±25.78
Physical Health Composite	17.02-52.45	34.33±6.21
Mental Health Composite	29.92-59.62	46.06±6.91
Overall KDQOL score	19.68-67.79	40.66±12.24

SD: standard deviation; KDQOL: Kidney Disease Quality of Life Survey.

Analysis revealed significant associations between dialysis adequacy and several KDQOL domains. Patients with adequate dialysis ( $Kt/V \geq 1.3$ ) showed significantly better scores in the Symptom/problem list (57.55 vs. 43.10,  $p=0.007$ ), Effects of kidney disease (57.23 vs. 41.74,  $p=0.003$ ), and Burden of kidney disease (34.38 vs. 19.44,  $p=0.011$ ) compared to those with inadequate dialysis. The overall KDQOL score was also significantly higher in the adequate dialysis group (46.13 vs. 36.78,  $p=0.001$ ). However, Physical and Mental Health Composite scores showed no significant differences between the groups ( $p=0.680$  and  $p=0.117$ , respectively) (Table 4).

**Table 4:** Association between Kidney Disease Quality of Life (KDQOL) subscales and Dialysis Adequacy (n = 77)

KDQOL-36 subscales	Dialysis Adequacy group		p-value
	Adequate $Kt/V \geq 1.3$	Inadequate $Kt/V < 1.3$	
Symptom/problem list	57.55±22.73	43.10±22.52	0.007
Effects of kidney disease	57.23±22.36	41.74±21.55	0.003
Burden of kidney disease	34.38±24.59	19.44±25.04	0.011
Physical Health Composite	33.98±5.38	34.58±6.79	0.680
Mental Health Composite	47.53±5.93	45.02±7.41	0.117
Overall KDQOL	46.13±10.44	36.78±12.04	0.001

Values are presented as mean±SD. The p-value indicates the statistical significance of the difference in mean scores between the adequate and inadequate dialysis groups. p-values < 0.05 are considered statistically significant. SD: standard deviation; KDQOL-36: Kidney Disease Quality of Life 36-Item Survey; Kt/V: a measure of dialysis adequacy.

**Table 5:** Sociodemographic and baseline clinical characteristics associated with Overall Kidney Disease Quality of Life (KDQOL) Scores

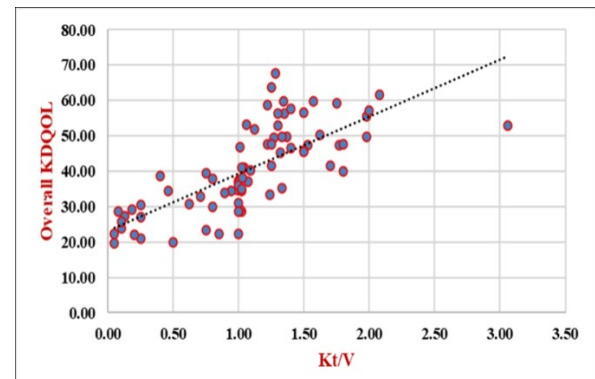
Variable	Category	KDQOL	p-value
Age (year)	≤45	42.80±12.44	0.153
	>45	38.79±11.9	
Sex	Male	41.40±12.75	0.549
	Female	39.69±11.66	
Marital status	Single	44.94±13.39	0.133
	Married	39.63±11.83	
Occupation	Employed	42.88±11.23	0.544
	Not employed	40.33±12.43	
Monthly family income	≤ 80000 YER (\$150)	39.20±11.38	0.057
	> 80000 YER (\$150)	45.47±14.02	
Duration of hemodialysis (year)	< 2	38.56±13.52	0.408
	≥ 2	41.31±11.88	
Frequency of hemodialysis/week	2	40.87±12.29	0.474
	3	35.66±12.15	
Hemoglobin (g/dl)	≤ 10 g/dl	38.81±11.6	0.006
	> 10 g/dl	48.34±12.2	
Serum creatinine (mg/dl)	≤ 8	41.20±13.78	0.755
	> 8	40.30±11.24	

Values are presented as mean±SD. The p-value indicates the statistical significance of the difference in mean KDQOL scores between categories. p-values < 0.05 are considered statistically significant. HRQoL: Health-Related Quality of Life; SD: standard deviation; YER: Yemeni Riyals.

## DISCUSSION

Patients in maintenance hemodialysis have a complex treatment and experience numerous physical and emotional limitations that severely impact their daily living activities and clinical outcomes [23]. Doing

The scatter plot demonstrated a significant positive correlation between overall KDQOL scores and dialysis adequacy ( $r=0.54$ ,  $p=0.0001$ ), indicating that better dialysis adequacy was associated with improved quality of life scores among the hemodialysis patients studied (Figure 1).



**Figure 1:** Scatterplot Demonstrating the Positive Correlation Between Overall Kidney Disease Quality of Life (KDQOL) Scores and Dialysis Adequacy (Kt/V) Among Studied Hemodialysis (HD) Patients ( $r=0.54$ ,  $p=0.0001$ ).

Among the various sociodemographic and clinical factors analyzed, hemoglobin level emerged as the only statistically significant factor associated with KDQOL ( $p=0.006$ ). Patients with hemoglobin levels >10 g/dl showed significantly higher KDQOL scores ( $48.34 \pm 12.20$ ) compared to those with levels ≤10 g/dl ( $38.81 \pm 11.60$ ). While monthly family income showed a trend toward significance ( $p=0.057$ ), other factors, including age, sex, marital status, employment status, duration of hemodialysis, frequency of sessions, and serum creatinine levels, did not demonstrate significant associations with KDQOL scores (Table 5).

adequate and effective dialysis can improve patients' quality of life and reduce kidney failure complications [10]. Therefore, the findings from the current study regarding the relationship between dialysis adequacy and health-related quality of life (HRQOL) resonate with existing literature while also offering unique

insights into the challenges faced by hemodialysis patients in resource-limited settings. The study revealed that more than half (53.2%) of hemodialysis patients were aged >45 years; male participants accounted for 57.1% of the study sample. Nearly one-third (37.7%) of patients were illiterate, indicating a generally low educational level, which may impact health literacy and self-care capabilities. These findings align with a study from Egypt, where 51% of hemodialysis patients were males, with a mean age of  $48 \pm 5.89$  [14,24]. Similarly, a study from Iraq found that only 36.2% of patients could read and write. Most (76.6%) had insufficient monthly income. This finding is consistent with a study done in Mosul City, which demonstrated that the majority (57.1%) of participants had a poor economic status [25]. In contrast, a study from Iraq found that most (77.6%) of the patients had sufficient monthly income [8,26]. In relation to clinical characteristics, more than half of the patients (53.2%) had been on dialysis for 2–5 years, and the overwhelming majority (96.1%) received HD only twice per week—falling short of the KDOQI-recommended thrice-weekly sessions [17]. Additionally, 51.9% underwent two-hour sessions, which may contribute to inadequate dialysis delivery. These findings are in the same context as an Iraq study, which reported that 75.9% of the study participants had experienced hemodialysis for two to six years [8,26]. Similarly, a study conducted at the Erbil hemodialysis center reported that most patients received insufficient treatment, typically twice weekly for around three hours per session (64.8%) [8,26]. Contributing factors may include limited machine availability, transportation difficulties, economic constraints, and patient non-compliance. This suboptimal treatment regimen helps explain the high prevalence of inadequate dialysis (58.4% with  $Kt/V < 1.3$ ) and associated laboratory abnormalities (80.5% with  $Hb < 10$  g/dL, 59.7% with  $Cr > 8$  mg/dL). These results align with those documented in analogous resource-constrained environments. For example, studies from Egypt and other developing regions documented mean hemoglobin levels of  $9.17 \pm 0.78$  g/dL and creatinine levels of  $9.94 \pm 2.12$  mg/dL, highlighting a shared pattern of underdialysis and associated metabolic disturbances [14,24]. The HRQoL assessment using KDQOL™-36 revealed several noteworthy findings. The overall mean score of  $40.66 \pm 12.24$  indicates significantly impaired quality of life compared to general population norms [4]. These findings are aligned with studies in Addis Ababa, Ethiopia, which demonstrated that the mean score of HRQoL was  $49.08 \pm 11.09$  [27]. Similarly, a study in Saudi Arabia found that the mean total QoL score was  $49.5 \pm 13.7$  [28]. Domain-specific analysis showed the most severe impairment in Burden of Kidney Disease ( $25.65 \pm 25.78$ ), reflecting the profound psychosocial impact of chronic dialysis dependence [23]. This could reflect the compounded effects of socioeconomic challenges and limited healthcare access, emphasizing the need for targeted interventions [3]. Physical Health Composite scores ( $34.33 \pm 6.21$ ) were notably worse than Mental Health

Composite scores ( $46.06 \pm 6.91$ ), consistent with other studies, suggesting that social support mechanisms may provide some mental health resilience [8]. Our findings demonstrated significant positive associations between dialysis adequacy and multiple HRQoL domains. Patients with adequate dialysis ( $Kt/V \geq 1.3$ ) showed substantially better scores in Symptom/Problem List, Effects of Kidney Disease, and Burden of Kidney Disease. The strong correlation between overall KDQOL scores and  $Kt/V$  provides compelling evidence that dialysis adequacy is a key determinant of quality of life, which reinforces prior research but suggests a more pronounced impact in resource-limited settings [14]. These findings align with previous studies showing that optimal solute clearance reduces uremic symptoms and improves well-being [10], though our effect sizes appear larger, possibly reflecting the greater impact in this underserved population. Similarly, the 2022 Greek study by Tsironi found that higher  $Kt/V$  was significantly associated with better scores across all dimensions of KDQOL and better sleep quality [29]. However, not all prior work is uniform. A 2016 study found no significant link between dialysis adequacy and HRQoL in a group of Greek HD patients [30]. Interestingly, the physical and mental health composite scores did not differ significantly between patients with adequate and inadequate dialysis, consistent with findings from [29,30]. This lack of association may be attributed to the multifactorial nature of physical and mental well-being in hemodialysis patients. General health status is influenced not only by solute clearance but also by age, comorbidities, anemia, nutritional status, depression, and socioeconomic constraints. Furthermore, most of the studied patients received twice-weekly dialysis of relatively short duration, which may contribute to residual fatigue and fluid overload even among those achieving biochemical adequacy. Psychological adaptation to chronic illness and limited sensitivity of the SF-12 composite scales may also explain the absence of significant correlation. Thus, dialysis adequacy appears to exert a stronger effect on disease-specific quality-of-life domains than on the broader constructs of physical and mental health. Among modifiable factors, hemoglobin level emerged as particularly significant, with patients maintaining  $Hb > 10$  g/dL showing better KDQOL. This pronounced difference underscores the critical importance of anemia management in hemodialysis patients, aligning with previous findings that highlight the detrimental effects of anemia on quality of life [6]. The trend toward significance for monthly family income suggests socioeconomic factors may also play a role, though our study may have been underpowered to fully characterize this relationship. These results emphasize that interventions must address both clinical (e.g., anemia, dialysis dose) and social determinants (e.g., poverty, education) to improve HRQoL [14].

## Limitations of the study

This study has some limitations. Its cross-sectional design prevents establishing causal relationships between dialysis adequacy and HRQOL. Being single-center, the findings may not be generalizable to other regions or dialysis units with different patient characteristics or practices. The use of convenience sampling could introduce selection bias, as participation depended on patients' availability and willingness. Moreover, HRQOL was self-reported using the KDQOL™-36, which may be influenced by recall or response bias, potentially affecting the accuracy of the findings regarding patients' quality of life. Despite these limitations, the research offers helpful information about the relationship between dialysis adequacy and quality of life among maintenance hemodialysis patients in Yemen.

## Conclusion

The current study revealed the majority of the maintenance hemodialysis patients had poor levels of health-related quality of life (HRQOL), and the majority demonstrated inadequate dialysis based on KT/V measurement. A significant positive correlation was observed between dialysis adequacy and overall HRQOL. Moreover, the study identified a statistically significant correlation between dialysis adequacy and several HRQOL domains, including Burden of Kidney Disease, Symptoms and Problems of Kidney Disease, and Effects of Kidney Disease. Additionally, a significant association was found between overall HRQOL and hemoglobin level.

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## Conflict of interests

The authors declared no conflict of interest.

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## Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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