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Fluid restriction adherence and interdialytic weight gain associated with intradialytic mean arterial pressure among hemodialysis patients

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Abstract

Background: Intradialytic mean arterial pressure (MAP) status is one of the most common cardiovascular indicators among patients with chronic kidney disease undergoing maintenance hemodialysis. Poor adherence to fluid restriction and excessive interdialytic weight gain (IDWG) are considered major contributors to hemodynamic alterations during dialysis sessions.
Purpose: To examine the factors associated with intradialytic mean arterial pressure (MAP) among patients receiving maintenance hemodialysis.
Method: An analytical cross-sectional study was conducted among patients with chronic kidney disease undergoing maintenance hemodialysis at a hospital in Indonesia. A total of 136 participants were recruited through a total sampling approach. Adherence to fluid restriction was measured using the Fluid Control in Hemodialysis Patients Scale (FCHPS), a 28-item instrument rated on a 5-point Likert scale, which demonstrated high internal consistency (Cronbach's α = 0.88). Interdialytic weight gain (IDWG) was calculated as the percentage increase in body weight relative to the preceding post-dialysis dry weight. Intradialytic blood pressure was assessed using the mean arterial pressure (MAP) recorded two hours after initiation of dialysis. Data analysis was performed using multiple linear regression to examine associations between adherence and clinical outcomes.
Results: Descriptive analysis showed a mean IDWG of 3.67% of dry body weight, a mean fluid restriction adherence score of 42.70, and a mean intradialytic MAP of 102.44 mmHg. Multiple linear regression demonstrated that interdialytic weight gain was positively associated with intradialytic MAP (β = 0.282, p = 0.001), whereas adherence to fluid restriction was negatively associated (β = −0.245, p = 0.003). Together, these variables explained 15.1% of the variance in intradialytic MAP (F = 13.000, p < 0.001).
Conclusion: Adherence to fluid restriction and interdialytic weight gain are important variables associated with mean arterial pressure stability in patients undergoing maintenance hemodialysis. Continuous nursing education and behavioral interventions aimed at improving fluid management are essential to reduce the risk of acute cardiovascular complications in this patient population.

Keywords: Fluid Restriction Adherence; Hemodialysis; Interdialytic Weight Gain; Mean Arterial Pressure.

INTRODUCTION

End-stage chronic kidney disease (CKD) necessitates lifelong kidney replacement therapy, with hemodialysis remaining the most widely utilized treatment modality in Indonesia. Despite substantial advances in dialysis technology, cardiovascular complications continue to represent the leading cause of morbidity and mortality among patients undergoing maintenance hemodialysis. One important yet frequently underrecognized clinical concern is intradialytic MAP stability, characterized by marked fluctuations in blood pressure during dialysis sessions. Blood pressure stability reflects both vascular integrity and optimal intravascular fluid balance, making it an essential indicator of

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cardiovascular health in this patient population (Iatridi, Carrero, Cornec-Le Gall, Kanbay, Luyckx, Shroff, & Ferro, 2025; Francis, Harhay, Ong, Tummalapalli, Ortiz, Fontana, & Fogo, 2024).

From a physiological perspective, the loss of renal excretory function results in the progressive accumulation of extracellular fluid within the intravascular and interstitial compartments during the interdialytic period (Warisyu, Nurachmah, Nova, & Mulyadi, 2022; Thanalakshmi, Maheshkumar, Kannan, Sundareswaran, Venugopal, & Poonguzhali, 2020). Clinically, this fluid accumulation is assessed using the parameter of interdialytic weight gain (IDWG). An IDWG exceeding the recommended threshold of 3% of dry body weight is considered indicative of fluid overload (Borzych-Dużałka, Shroff, Ranchin, Zhai, Paglialonga, Kari, & Schmitt, 2024). Hypervolemia subsequently increases cardiac preload, cardiac output, and systemic vascular resistance, ultimately leading to elevated intradialytic mean arterial pressure (MAP) during hemodialysis (Omega, Putri, Marcory, Juhdeliena, & Wikliv, 2023; Wahida, & Rumahorbo, 2023; Suryansyah & Thaha, 2019).

In addition to physiological mechanisms, patient-related behavioral factors play a pivotal role in the development of cardiovascular complications during hemodialysis. Adherence to daily fluid restriction is often particularly challenging because persistent thirst, stimulated by activation of the renin–angiotensin–aldosterone system and elevated blood urea concentrations, frequently compromises patients' ability to limit fluid intake. Non-adherence is a multifactorial phenomenon influenced by psychological distress, social support, and patients' understanding of the clinical consequences associated with fluid overload (Borzych-Dużałka et al., 2024; Geng, Song, Hou, Ma, & Wang, 2020).

Although previous studies have independently examined the relationship between IDWG and blood pressure, limited evidence has simultaneously evaluated fluid restriction adherence and IDWG as associated factors of MAP within a cross-sectional framework. Addressing this knowledge gap is essential for improving the clinical management of patients receiving maintenance hemodialysis. Therefore, this study aimed to examine the collective association of fluid restriction adherence and interdialytic weight gain with intradialytic MAP. The findings are expected to provide baseline clinical evidence to support the refinement of nursing assessment protocols and target-specific fluid management strategies in hemodialysis units.

RESEARCH METHOD

This quantitative study employed an analytical descriptive design with a cross-sectional approach to examine the relationships among the study variables at a single point in time. The study was conducted in February 2026 at the Hemodialysis Unit of Sekarwangi Regional General Hospital, Sukabumi Regency, Indonesia. The target population comprised 136 patients with chronic kidney disease undergoing maintenance hemodialysis twice weekly. Since the study invited all eligible patients available during the data collection period, a total sampling (exhaustive sampling) approach was utilized. Eligible participants were adults who had received maintenance hemodialysis for at least one month (selected to capture early-stage fluid management adaptation patterns in our clinical setting), were fully conscious (*compos mentis*), and provided written informed consent prior to data collection. Patients with acute comorbid conditions, including severe congestive heart failure or septic shock, were excluded.

The independent variables were adherence to fluid restriction and interdialytic weight gain (IDWG), whereas the dependent variable was intradialytic mean arterial pressure (MAP). Adherence to fluid restriction was assessed using the Fluid Control in Hemodialysis Patients Scale (FCHPS). The FCHPS contains 28 items rated on a 5-point Likert scale, where higher scores indicate better fluid control behavior. The instrument has been previously validated in dialysis populations (Cosar & Pakyuz, 2016), and the Cronbach's alpha coefficient for the current sample was 0.88, with a retest reliability correlation of 0.94 ($P < 0.001$), demonstrating that the FCHPS is a psychometrically reliable instrument for measuring fluid control in hemodialysis patients.

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IDWG was calculated as the difference between the patient's current predialysis body weight and the post-dialysis dry weight recorded during the previous dialysis session, expressed as a percentage of dry body weight:

$$\text{IDWG (\%)} = \frac{Predialysis\ Weight - Previous\ Postdialysis\ Dry\ Weight}{\text{Previous Post-dialysis Dry Weight}} \times 100$$

To represent hemodynamic status, intradialytic blood pressure was evaluated using the MAP value measured two hours after the dialysis session commenced. Blood pressure measurements were obtained using a calibrated digital sphygmomanometer with appropriate cuff sizes. Measurements were performed on the non-fistula arm while the patient was in a relaxed, reclined position. MAP was calculated using the standard established formula:

$$\text{MAP} = \frac{SBP + 2(DBP)}{3}$$

Ethical approval was obtained from the Research Ethics Committee of Sukabumi Institute of Health Sciences under the number 002960/KEP-STIKES SUKABUMI/2026. Data analysis began with classical assumption testing to ensure compliance with the assumptions underlying multiple linear regression. Subsequently, multiple linear regression analysis was performed, including the F-test to evaluate the simultaneous effects of the independent variables, the t-test to assess their individual effects, and the coefficient of determination (adjusted R^2) to estimate the proportion of variance explained by the regression model. Statistical significance was established at a two-tailed p-value of < 0.05.

RESEARCH RESULTS

Table 1. Characteristics of Respondents (N=136)

Variables	Results
Age (Mean±SD)(Range)(Year)	(52.65±11.03)
Age (n/%)	
17–25	3/2.20
26–35	7/5.15
36–45	28/20.59
46–55	47/34.56
56–65	38/27.94
>65	13/9.56
Gender (n/%)	
Male	58/42.65
Female	78/57.35
Education (n/%)	
Elementary School	71/52.21
Junior High School	27/19.85
Senior High School	29/21.32
College	9/6.62

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Variables	Results
Marital Status (n/%)	
Married	117/86.03
Unmarried	4/2.94
Divorced	15/11.03
Employment Status (n/%)	
Working	18/13.24
Not Working	118/86.76
Long Time Undergoing Hemodialysis (Month) (n/%)	
<12	45/33.09
12-24	59/43.38
>24	32/23.53

Table 1 presents the demographic and clinical characteristics of the study population. The mean age of participants was 52.65 years (SD = 11.03), with the largest proportion (34.56%) falling within the 46–55 year age group. Female patients comprised the majority (57.35%), and the majority of respondents were married (86.03%). In terms of education, primary school was the most common level attained (52.21%). A high proportion of participants were unemployed (86.76%). Clinically, the largest group had been receiving maintenance hemodialysis for 12–24 months (43.38%).

Table 2. Univariate Test Results of Variables (N=136)

Variable	Min	Max	Mean	Std. Dev
IDWG (%)	0.00	8.30	3.67	1.84
Fluid Restriction Adherence Score	30	55	42.70	4.87
Blood Pressure (MAP) (mmHg)	72.65	191.60	102.44	12.98

The mean interdialytic weight gain (IDWG) among participants was 3.67 ± 1.84%, with values ranging from 0.00% to 8.30%. The mean fluid restriction adherence score was 42.70 ± 4.87, with a minimum score of 30 and a maximum score of 55. Mean arterial pressure (MAP) values ranged from 72.65 to 191.60 mmHg, with an overall mean of 102.44 ± 12.98 mmHg.

Table 3. Normality Test Results (N=136)

Variable	Kolmogorov-Smirnov (Z)	*p*-value (Sig.)
Unstandardized Residual	1.133	0.153

Table 3 indicated that the standardized test statistic (Z) for the unstandardized residuals was 1.133, with a corresponding *p*-value of 0.153 ($p > 0.05$). These results confirm that the residuals followed a normal distribution, thereby fulfilling the normality assumption required for the application of multiple linear regression analysis.

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Table 4. Multicollinearity Test Results

Independent Variables	Collinearity Statistics	
	Tolerance	VIF
IDWG	0.970	1.031
Fluid Restriction Adherence	0.970	1.031

Table 4 indicated that both independent variables—interdialytic weight gain (IDWG) and fluid restriction adherence—had a tolerance value of 0.970 (> 0.10) and a variance inflation factor (VIF) of 1.031 (< 10). These findings demonstrate the absence of multicollinearity between the independent variables, indicating that the regression model satisfied the multicollinearity assumption.

Table 5. Heteroscedasticity Test Result

Independent Variables	t-value	*p*-value (Sig.)
(Constant)	0.292	0.711
IDWG	-1.659	0.099
Fluid Restriction Adherence	0.176	0.860

Table 5 showed that the significance values were 0.099 for interdialytic weight gain (IDWG) and 0.860 for fluid restriction adherence (both $p > 0.05$). These findings indicate that the regression model was free from heteroscedasticity, thereby satisfying the assumption of homoscedasticity.

Overall, the results confirmed that all assumptions underlying multiple linear regression were met. Therefore, the regression model was considered appropriate for subsequent hypothesis testing.

Table 6. Results of the Model Feasibility Test (*F* Test) and Coefficient of Determination (R^2)

Model	R	R^2	Adjusted R^2	*F*-Test	*p-value*
1	0.404	0.164	0.151	13.000	<0.001

The multiple linear regression analysis yielded a model correlation coefficient (R) of 0.404, indicating a moderate collective relationship between the independent factors and intradialytic MAP. The model generated an F-statistic of 13.000 with a highly significant p-value of 0.001 (p<0.01), confirming that the combined regression model is highly stable and statistically viable for explaining the dependent variable. Furthermore, the Adjusted R^2 value was determined to be 0.151. This demonstrates that interdialytic weight gain and fluid restriction adherence collectively account for 15.1% of the total variance in intradialytic mean arterial pressure (MAP) among maintenance hemodialysis patients, while the remaining 84.9% is attributable to other clinical and physiological variables not included in the current equation.

Table 7. Partial Hypothesis Test Results (t-Test)

Variables	B Coefficient	SE	Beta *(β)*	*t*-value	*p*-value
(Constant)	5.477	0.315		17.369	<0.001
IDWG	0.062	0.018	0.282	3.499	0.001
Fluid Restriction Adherence	-0.252	0.083	-0.245	-3.044	0.003

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The partial regression analysis (t-test) showed that both behavioral and fluid metrics were independently and significantly associated with intradialytic mean arterial pressure (MAP) levels. First, the interdialytic weight gain demonstrated a significant positive association with intradialytic MAP, yielding an unstandardized coefficient (B) of 0.062, a standardized beta (β) of 0.282, a t-value of 3.499, and a p-value of 0.001 ($p<0.05$). Higher fluid accumulation between dialysis sessions was significantly associated with increased intradialytic MAP. Second, fluid restriction adherence displayed a significant inverse association with intradialytic MAP, with an unstandardized coefficient (B) of −0.252, a standardized beta (β) of −0.245, a t-value of −3.044, and a p-value of 0.003 ($p<0.05$). These mathematical results imply that greater patient adherence to daily fluid restrictions is heavily associated with achieving a lower and more controlled arterial pressure status during hemodialysis.

The multiple linear regression model was expressed by the following equation: $Y = 5.477 + 0.062(X_1) – 0.252(X_2)$. The calculated intercept value of 5.477 represents the mathematical baseline estimate for intradialytic MAP in a scenario where both clinical predictors are theoretically absent or equal to zero. The positive slope coefficient obtained for interdialytic weight gain (B=0.062) demonstrates that each incremental increase in IDWG is independently associated with an increase of 0.062 units in the intradialytic MAP value, assuming the behavioral adherence metric remains constant.

Conversely, the negative coefficient observed for fluid restriction compliance (B=-0.252) reveals an inverse relationship, whereby each unit of increase in the compliance score corresponds to a 0.252-unit reduction in the intradialytic MAP. This statistical analysis demonstrated that enhanced behavioral self-regulation regarding fluid intake is a statistically significant factor in maintaining lower and more stable intradialytic arterial pressure.

DISCUSSION

The findings of this study demonstrate that both behavioral and clinical factors are significantly associated with intradialytic mean arterial pressure (MAP) among patients receiving maintenance hemodialysis. The inferential analysis revealed a significant association between interdialytic weight gain (IDWG) and intradialytic MAP. From a pathophysiological perspective, elevated IDWG reflects excessive retention of sodium and water within the intravascular compartment during the interdialytic period (Bossola, Mariani, Strizzi, Piccinni, & Di Stasio, 2025; Wijayanti, Winoto, & Nursalam, 2021). In patients with end-stage chronic kidney disease, severely impaired renal excretory function limits the body's ability to eliminate excess fluid, culminating in progressive intravascular volume expansion. This hypervolemic state increases cardiac preload and stroke volume, which subsequently elevates systemic vascular resistance and raises intradialytic MAP levels (Warisyu et al., 2022; Whelton, Carey, Aronow, Casey Jr, Collins, Dennison Himmelfarb, & Wright Jr, 2018). Although the regression model is a simplified representation of hemodynamic status, the underlying clinical mechanism consistently highlights that poorly managed fluid accumulation directly compounds hemodynamic stress during the evaluation window.

These findings reinforce current concepts of fluid management in chronic kidney disease, emphasizing that maintaining IDWG within the recommended range is essential for preventing adverse cardiovascular outcomes, including left ventricular remodeling and cardiovascular mortality. The present findings are consistent with previous studies which identified fluid overload as a major pathophysiological determinant of blood pressure instability among patients undergoing maintenance hemodialysis (Bossola et al., 2025; Jalalzadeh, Mousavinasab, Villavicencio, Aameish, Chaudhari, Baumstein, & Villavicencio, 2021). The present study also highlights the protective role of adherence to fluid restriction. The significant inverse association observed between fluid restriction adherence and MAP indicates that patients who consistently comply with prescribed fluid restrictions are less likely to experience blood pressure instability during dialysis. Appropriate self-management of fluid intake minimizes excessive fluid accumulation, thereby reducing cardiovascular workload and maintaining vascular homeostasis within physiological limits (Kristanti, Pujiastuti, & Wibowo, 2024; Trisnaningtyas, Indriyawati, Dwiningsih, Elisa, Ariyanti, & Maksuk, 2023).

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Nevertheless, maintaining strict adherence to fluid restriction remains a substantial physical and psychosocial challenge for many patients because persistent thirst associated with uremia and sodium retention frequently compromises treatment adherence. Even minor deviations from prescribed fluid intake may disrupt fluid balance, increasing the risk of pulmonary edema and intradialytic hypertension. These findings are consistent with previous reports (Bandola, Artini, & Nancye, 2023; Herlina & Rosaline, 2021; Komsiyah, Sumarno, Kumalasari, & Candra, 2024) which emphasize that effective fluid management is a cornerstone of clinical care for maintaining hemodynamic stability and optimizing cardiovascular outcomes in patients receiving maintenance hemodialysis.

Furthermore, the demographic profile of the participants in this study provides critical context for tailoring future nursing interventions. Over half of the respondents had only completed primary education (52.2%), and a vast majority were unemployed (86.8%). This low educational attainment suggests that conventional, complex health education materials regarding fluid restriction may not be fully understood or sustained by the patients. Therefore, nephrology nurses must pivot toward highly visual, simplified, and culturally tailored counseling. Utilizing simple, daily-marked water containers and actively engaging family members as home-based support systems ('family-centered empowerment') are more likely to translate into sustained adherence to fluid restriction and better control of IDWG, ultimately stabilizing intradialytic MAP.

Simultaneously, the combined model of fluid restriction adherence and IDWG was significantly associated with intradialytic MAP, as demonstrated by the significant F-test ($F=13.000$, $p<0.001$). Although the adjusted R^2 value indicated that the model accounted for only 15.1% of the total variance in intradialytic MAP, this level of explanatory power is expected given the highly complex and multifactorial nature of blood pressure regulation in end-stage renal disease. This study intentionally focused on patient-led behavioral and fluid metrics; however, intradialytic MAP is concurrently driven by a myriad of unmeasured clinical confounding factors. The low adjusted R^2 constitutes a notable limitation of this study, as critical clinical and physiological variables were not controlled or included in the regression analysis. These uncontrolled factors include patient age, the presence of diabetes mellitus, history of cardiovascular disease, ultrafiltration rates, and activation of the renin–angiotensin–aldosterone system (RAAS). Additionally, arterial stiffness, the type and timing of antihypertensive medication use, and the adequacy of uremic toxin clearance (such as Kt/V) achieved during previous dialysis sessions are also known to drive intradialytic MAP (Smeltzer & Bare, 2018). Therefore, future research employing longitudinal frameworks should incorporate these clinical confounders to construct a more robust and holistic predictive model for intradialytic hemodynamic behavior

Overall, these findings have important implications for nephrology nursing practice. Rather than relying solely on conventional patient education, nursing interventions should increasingly emphasize behavioral modification strategies that promote sustained adherence to fluid restriction and regular monitoring of IDWG. Such approaches may contribute to improved hemodynamic stability and reduce the risk of secondary cardiovascular complications among patients undergoing maintenance hemodialysis.

LIMITATIONS

This study has several limitations that warrant acknowledgment. First, the cross-sectional design precludes the ability to establish temporal relationships or causal inferences between the examined variables and intradialytic MAP. Second, data collection was conducted within a single-center setting at a regional general hospital, which may restrict the external validity and generalizability of the findings to broader hemodialysis populations in different geographical or institutional contexts. Third, compliance with fluid restriction was evaluated using a self-reported instrument (the FCHPS), which may introduce potential recall bias or social-desirability bias among the respondents. Finally, although the updated regression model demonstrated a highly significant overall fit, it yielded a modest adjusted R^2 value of 0.151. This indicates that 15.1% of the variance in intradialytic MAP is accounted for by interdialytic weight gain and fluid restriction adherence, leaving 84.9% of the variance driven by unmeasured clinical and physiological parameters.

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Consequently, future multi-center studies utilizing longitudinal or prospective cohort frameworks are highly recommended to control for broader clinical confounders and build a more robust predictive model.

CONCLUSION

This study demonstrated that both interdialytic weight gain (IDWG) and adherence to fluid restriction were significantly associated with intradialytic mean arterial pressure (MAP) among patients undergoing maintenance hemodialysis, both individually and collectively. Higher IDWG was positively associated with elevated MAP levels, confirming that excessive fluid accumulation between dialysis sessions is linked to higher intradialytic arterial pressure. Conversely, greater adherence to fluid restriction was inversely associated with MAP, indicating that effective self-management of fluid intake serves as an important factor associated with maintaining lower and more controlled intradialytic mean arterial pressure. These findings underscore the importance of integrating IDWG and fluid restriction adherence into routine nursing assessments to enhance hemodynamic monitoring and fluid management in maintenance hemodialysis.

RECOMMENDATIONS

Future studies are encouraged to employ longitudinal study designs, such as prospective cohort studies, to better characterize temporal changes in fluid status and intradialytic mean arterial pressure behaviors among patients undergoing maintenance hemodialysis. Furthermore, future research should incorporate additional clinical confounding variables, including dialysis adequacy (Kt/V), neurohormonal profiles, and adherence to antihypertensive therapy, to develop more comprehensive predictive models of long-term cardiovascular outcomes in this patient population.

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