

# Fluid intake adherence and its associated factors in patients receiving maintenance hemodialysis: a cross-sectional study utilizing the COM-B model

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## Research Article

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# Abstract

## Background

Controlling fluid intake plays an important role in reducing complications and mortality among patients receiving maintenance hemodialysis (MHD). The Capability-Opportunity-Motivation-Behavior (COM-B) model provides a theoretical framework for understanding the factors that influence health behavior. However, few studies have applied this model to investigate the factors associated with fluid intake adherence among patients receiving maintenance hemodialysis.

## Methods

From February to April 2026, a questionnaire survey was conducted among 411 patients receiving maintenance hemodialysis. Fluid intake adherence was assessed using the Fluid Intake Adherence Scale. The COM-B model was used as the theoretical framework, and potential related factors were assessed using a general information questionnaire, a Hemodialysis Knowledge Questionnaire, a Family Care Scale, and a Chronic Disease Management Self Efficacy Scale.

## Results

The fluid intake adherence score among patients receiving maintenance hemodialysis was  $18.57 \pm 4.81$ , indicating a moderate level of adherence. Multiple linear regression analysis identified five significant factors associated with fluid intake adherence ( $R^2 = 0.519$ ), hemodialysis knowledge, family support, and self efficacy were positive correlates, whereas obesity and a dialysis frequency other than three times per week were negative correlates. Pathway analysis showed that hemodialysis knowledge and family support were directly associated with fluid intake adherence (direct effects of 0.331 and 0.463,  $P < 0.05$ ) and were also indirectly associated with fluid intake adherence through self efficacy (indirect effects of 0.175 and 0.104,  $P < 0.05$ ).

## Conclusions

Interventions based on the COM-B model should focus on disease knowledge education, opportunity support, and motivation, with particular attention to improving self efficacy. These strategies may help improve fluid intake adherence and quality of life among patients receiving maintenance hemodialysis.

## 1 Introduction

Chronic kidney disease (CKD) has become an increasing global disease burden. In 2023, approximately 788 million adults worldwide were affected by CKD, including 156 million in China [1]. According to relevant data, CKD is expected to become the fifth leading cause of death worldwide by 2040 [2]. When

the glomerular filtration rate (GFR) falls below 15 mL/(min·1.73 m<sup>2</sup>), CKD reaches its final stage, known as end-stage renal disease (ESRD) [3]. Maintenance hemodialysis (MHD) is one of the main renal replacement therapies for patients with ESRD [4]. According to the China Hemodialysis Industry Development Survey Report [5], the number of patients receiving dialysis in mainland China reached 1 million by the end of 2022, including 844,000 patients receiving MHD. Adherence to dietary recommendations, fluid restriction, prescribed medication, and regular dialysis is important for effective treatment of ESRD [6]. Among these requirements, fluid restriction is considered the most difficult to follow.

Fluid intake adherence refers to the extent to which a patient's actual fluid intake matches the recommended amount. It is an important indicator of fluid intake behavior among patients receiving maintenance hemodialysis. Renal failure reduces the ability to excrete water and sodium. Patients may develop fluid overload when they do not control their fluid intake during the interdialytic period. Previous studies have shown that fluid overload is a common and serious complication in dialysis patients. It can prolong hospital stays, increase the risk of readmission, and affect patient survival and prognosis. It is also an important factor associated with mortality [3–5]. Although international kidney disease guidelines emphasize the importance of fluid intake management [2], fluid intake adherence remains poor among patients receiving maintenance hemodialysis. A systematic review and meta-analysis showed that the rate of non-adherence to fluid restriction ranged from 50.0% to 70.7%. Therefore, improving fluid intake adherence remains an important issue in hemodialysis care.

Fluid intake adherence refers to the consistency between a patient's actual fluid intake and the recommended amount. It is an important indicator for evaluating fluid intake behavior among patients receiving maintenance hemodialysis [7]. Renal failure reduces the ability to excrete water and sodium. Patients are prone to volume overload when they cannot effectively control their fluid intake during the interdialytic period. Previous studies have shown that volume overload is a common and serious complication among dialysis patients. It can increase hospital stays and the risk of readmission among patients receiving maintenance hemodialysis. It is also closely related to patient survival and prognosis and is an important factor associated with mortality risk [8–10]. Although international nephrology guidelines emphasize the importance of fluid intake management [3], fluid intake adherence remains poor among patients receiving maintenance hemodialysis. A systematic review and meta-analysis showed that the rate of non-adherence to fluid restriction among patients receiving maintenance hemodialysis was high, ranging from 50.0% to 70.7% [11]. Therefore, improving adherence to fluid intake recommendations remains an important issue in the management of patients receiving maintenance hemodialysis.

Against this background, developing interventions that can improve fluid intake adherence is clinically important, but it remains challenging. Existing interventions are mostly implemented in relatively controlled settings. They often improve short-term adherence, but their long-term effects remain limited [12, 13]. Traditional interventions pay less attention to individual behavioral factors and do not fully explain why patients have difficulty maintaining fluid restrictions over time. Therefore, more effective and

sustainable fluid management strategies require a systematic assessment of modifiable factors associated with fluid intake adherence among patients receiving maintenance hemodialysis and their pathways of action.

To better understand the behavioral factors related to fluid intake adherence, this study used the Capability, Opportunity, Motivation and Behaviour (COM-B) model as a theoretical framework. The model was proposed by Michie et al. and explains key behavioral factors through the interaction of capability, opportunity, and motivation [14]. It has been widely used to integrate evidence and guide clinical interventions. In recent years, the COM-B model has been increasingly used to study treatment adherence among patients with chronic kidney disease, including medication adherence [15], qualitative studies of dietary adherence [16], and mixed-method reviews of barriers and facilitators in chronic kidney disease care [17]. However, few studies have used this model to quantitatively examine factors associated with fluid intake adherence among patients receiving maintenance hemodialysis.

Based on the above findings, this study used the COM-B model as a theoretical framework to explore factors related to fluid intake behavior based on a literature review (Fig. 1). For patients receiving maintenance hemodialysis, this study included three key variables that correspond to the core dimensions of the COM-B model. For the capability dimension, hemodialysis knowledge was selected as a key variable to reflect patients' knowledge related to disease management. Family care plays an important role in the long-term management of chronic diseases in China. Therefore, family support was included as an opportunity factor to reflect the external environment that may support appropriate patient behavior [18]. Self efficacy was included as a motivation factor to reflect the psychological process involved in patients' active participation in disease management. Sociodemographic and clinical characteristics were also included in the framework as background factors that may be associated with fluid intake adherence.

Therefore, this study had two specific objectives: (1) to describe the level of fluid intake adherence among patients receiving maintenance hemodialysis; and (2) to examine the hypothesized relationships among hemodialysis knowledge, family support, self efficacy, and fluid intake adherence using a mediation model within the COM-B framework.

## 2 Methods

### 2.1 Setting and participants

This single-center cross-sectional study was conducted from February to April 2026 at the Hemodialysis Center of the First Affiliated Hospital of Chongqing Medical University. Convenience sampling was used to recruit patients receiving maintenance hemodialysis who were aged 18 years or older. The inclusion criteria were as follows: (1) diagnosis of end-stage renal disease according to the Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines and regular hemodialysis treatment for  $\geq 3$  months; (2) no history of cerebrovascular accident, neurological disease, or psychiatric illness; and (3) age  $\geq 18$  years

and ability to communicate normally. The exclusion criteria were as follows: (1) hyperthyroidism, tuberculosis, cancer, or other organ failure; and (2) coexisting cognitive impairment.

## 2.2 Sample size calculation

Based on the sampling principles of observational studies, G\*Power 3.1 was used to calculate the required sample size. Multiple linear regression analysis was used, with an effect size ( $f^2$ ) of 0.15 and a statistical power of 0.95. A total of 22 independent variables were included, covering general information and scale dimensions. The calculated minimum sample size was 230 participants. Considering a 10%–20% dropout rate, at least 256–289 participants were recommended. To ensure sufficient statistical power and account for potential screening failures, approximately 430 participants were planned for recruitment.

## 2.3 Measures

### 2.3.1 General information questionnaire

Based on the literature review and research objectives, a self-designed questionnaire was used to collect sociodemographic and clinical data. The questionnaire included 10 independent variables: gender, age, body mass index (BMI), marital status, education level, average monthly household income per capita, primary disease, dialysis duration, vascular access type, and dialysis frequency.

### 2.3.2 Fluid Intake Adherence Scale (FIA)

The Fluid Intake Adherence Scale (FIA) was used to assess the level of fluid intake adherence among patients receiving maintenance hemodialysis. This study used the fluid intake adherence subscale of the Treatment Adherence Scale for Patients with End-Stage Renal Disease Receiving Maintenance Hemodialysis developed by Zhang Yan et al. [19]. The subscale consists of six items. Each item is scored from 1 to 5, with 1 indicating “never” and 5 indicating “completely.” The total score ranges from 6 to 30, with higher scores indicating better fluid intake adherence. The subscale showed good reliability and validity, with a Cronbach’s  $\alpha$  coefficient of 0.838, split-half reliability coefficient of 0.846, test-retest reliability coefficient of 0.894, and content validity index of 0.877 [19]. In the present study, the Cronbach’s  $\alpha$  coefficient was 0.881.

### 2.3.3 Hemodialysis Knowledge Questionnaire (HK)

The Hemodialysis Knowledge Questionnaire (HK) was used to assess patients’ hemodialysis knowledge. The Chinese version of the Hemodialysis Knowledge Level Questionnaire was developed by Curtin RB [20] and translated, modified, and culturally adapted by Li Hui et al. [21]. The questionnaire consists of five domains: anemia (3 items), diet and medication (4 items), kidney function (5 items), dialysis treatment (10 items), and rehabilitation (2 items), with a total of 24 items. Each correct answer is scored 1 point, while an incorrect or unanswered item is scored 0 points. The total score ranges from 0 to 24, with higher scores indicating a higher level of hemodialysis knowledge. The Chinese version showed

good validity and reliability, with a content validity index of 0.940 and a Cronbach's  $\alpha$  coefficient of 0.701 [21]. In the present study, the Cronbach's  $\alpha$  coefficient was 0.844.

### **2.3.4 Self-Efficacy for Managing Chronic Disease Scale (SEMCD)**

The Self-Efficacy for Managing Chronic Disease Scale (SEMCD) was used to assess patients' self efficacy in disease management. The scale was developed by Lorig et al. [22] and translated into Chinese by Hu et al. [23]. It consists of two dimensions: symptom management self efficacy (4 items) and disease commonality management self efficacy (2 items), with a total of 6 items. Each item is scored from 1 to 10, and the mean score of the six items is used to assess the level of chronic disease management self efficacy. Higher scores indicate higher levels of chronic disease management self efficacy. A mean score < 5 indicates a low level, a score of 5–7 indicates a moderate level, and a score > 7 indicates a high level. In the present study, the Cronbach's  $\alpha$  coefficient of the scale was 0.902.

### **2.3.5 Family Care Index Scale (APGAR)**

The Family Care Index Questionnaire (APGAR) was used to assess patients' satisfaction with family functioning. It was developed by Smilkstein in 1978 [18] and translated into Chinese by Lü Fan et al. [24]. The questionnaire consists of five items: adaptability, cooperation, growth support, emotional connection, and close relationship. Each item is rated on a 3-point Likert scale, with “almost never,” “sometimes,” and “often” scored as 0, 1, and 2 points, respectively. The total score ranges from 0 to 10, with higher scores indicating better family functioning. The questionnaire has a test-retest reliability of 0.800–0.830 and a content validity of 0.800 [24]. In the present study, the Cronbach's  $\alpha$  coefficient was 0.869.

## **2.4 Data collection**

Before data collection, the researchers conducted three pre-surveys and revised the wording and content of the questionnaire based on the results. Two trained investigators administered the questionnaires during the patients' hemodialysis sessions. The investigators reviewed clinical records to obtain information about the participants' disease conditions. Given the specific circumstances of hemodialysis treatment, the questionnaires were completed through face-to-face interviews. After obtaining the participants' consent, the investigators asked each question, and the participants provided their answers. The investigators completed the questionnaires based on the participants' responses. After the survey, the investigators checked the questionnaires for completeness and logical consistency. For missing or incorrect responses, the investigators asked the participants to provide additional information and confirm their answers.

## **2.5 Ethical considerations**

This study was reviewed and approved by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University on January 21, 2026 (Approval No. 2026-052-01). All participants provided informed consent, and participation was voluntary. Participants were assured of the confidentiality of

their responses and their right to withdraw from the study at any time without any impact on their medical care. The study was conducted in accordance with the Declaration of Helsinki (2013) and did not involve human trials or the use of human biological samples.

## 2.6 Statistical analysis

All statistical analyses were performed using SAS 9.4 and Mplus 8.3. Normally distributed continuous variables were expressed as mean  $\pm$  standard deviation, and t-tests or analysis of variance were used for group comparisons. Categorical variables were expressed as frequencies and percentages. Pearson correlation coefficients were used to assess correlations between variables. Fluid intake adherence was used as the dependent variable, and variables with  $P < 0.10$  in the univariate analysis were included as independent variables in the multiple linear regression model. Multicollinearity was evaluated using the variance inflation factor ( $VIF < 5$ ). The independence of residuals was assessed using the Durbin-Watson statistic, with values close to 2 indicating acceptable independence. The normality of the residuals was assessed using P-P plots. Path analysis was performed using Mplus 8.3 to examine the hypothesized conceptual framework based on the COM-B model. Model parameters were estimated using the maximum likelihood (ML) method. The bias-corrected percentile bootstrap method with 2,000 resamples was used to examine the direct, indirect, and total effects and to calculate their 95% confidence intervals. All statistical tests were two-tailed, and  $P < 0.05$  was considered statistically significant.

## 3 Results

### 3.1 Participants characteristics

A total of 430 questionnaires were distributed, and 411 valid questionnaires were collected, resulting in a valid response rate of 95.6%. A total of 411 participants were included in the analysis. Among them, 55.5% were male and 67.6% were younger than 65 years. Significant differences in fluid intake adherence were found across age and BMI groups. Age was significantly associated with fluid intake adherence ( $t = 3.392, P < 0.001$ ), and BMI also showed a significant association ( $F = 3.414, P = 0.018$ ) (**Table 1, see the end of the document text file**).

**Table 1** Description of total fluid intake adherence scores in the final analyzed sample (N =411)

| Variables                               | Categories                     | n   | %    | $M \pm SD$ | t/F    | p     |
|-----------------------------------------|--------------------------------|-----|------|------------|--------|-------|
| Gender                                  | Male                           | 228 | 55.5 | 3.06±0.81  | -0.948 | 0.344 |
|                                         | Female                         | 183 | 44.5 | 3.14±0.79  |        |       |
| Age (years)                             | < 65                           | 278 | 67.6 | 3.15±0.81  | 2.034  | 0.043 |
|                                         | ≥ 65                           | 133 | 32.4 | 2.98±0.76  |        |       |
| BMI                                     | Emaciation                     | 43  | 10.5 | 3.02±0.87  | 2.652  | 0.048 |
|                                         | Normal                         | 188 | 45.7 | 3.14±0.78  |        |       |
|                                         | Overweight                     | 87  | 21.2 | 3.23±0.79  |        |       |
|                                         | Obesity                        | 93  | 22.6 | 2.92±0.79  |        |       |
| Marital status                          | Married                        | 342 | 83.2 | 3.09±0.80  | -0.257 | 0.797 |
|                                         | Unmarried/Divorced/widowed     | 69  | 16.8 | 3.12±0.81  |        |       |
| Education                               | Junior middle school and above | 163 | 39.7 | 3.02±0.79  | 2.07   | 0.128 |
|                                         | High school or college         | 175 | 42.6 | 3.10±0.81  |        |       |
|                                         | Bachelor degree and above      | 73  | 17.8 | 3.25±0.78  |        |       |
| Per capita family income, monthly (CNY) | ≤3000                          | 68  | 16.5 | 2.91±0.83  | 2.445  | 0.088 |
|                                         | 3000-5000                      | 150 | 36.5 | 3.10±0.77  |        |       |
|                                         | ≥5000                          | 193 | 47.0 | 3.16±0.81  |        |       |
| Protopathy                              | chronic glomerulonephritis     | 145 | 35.3 | 3.10±0.82  | 0.815  | 0.486 |
|                                         | hypertensive renal damage      | 86  | 20.9 | 3.20±0.80  |        |       |
|                                         | diabetic nephropathy           | 95  | 23.1 | 3.02±0.77  |        |       |
|                                         | Other                          | 85  | 20.7 | 3.06±0.80  |        |       |
| Dialysis age(years)                     | ≤5                             | 190 | 46.2 | 3.10±0.77  | 0.013  | 0.987 |
|                                         | 5~10                           | 117 | 28.5 | 3.09±0.83  |        |       |
|                                         | ≥10                            | 104 | 25.3 | 3.10±0.83  |        |       |
| Type of vascular access                 | AVF                            | 388 | 94.4 | 3.08±0.81  | -1.827 | 0.068 |
|                                         | Other                          | 23  | 5.6  | 3.39±0.64  |        |       |

|                    |                    |     |      |           |       |       |
|--------------------|--------------------|-----|------|-----------|-------|-------|
| Dialysis frequency | Three times a week | 387 | 94.2 | 3.11±0.80 | 1.834 | 0.067 |
|                    | Other              | 24  | 5.8  | 2.81±0.85 |       |       |

Note.  $M \pm SD$  = Mean  $\pm$  Standard Deviation;  $F$ =one-way ANOVA;  $t$ =Independent samples  $t$ -test.

### 3.2 Common method deviation test

All scales in this study were completed through patient self-report, which may have introduced common method bias. Harman's one-factor test was used to assess common method bias. Unrotated exploratory factor analysis identified 10 factors with eigenvalues  $>1$ . The first factor accounted for 24.68% of the total variance, which was below the 40.0% threshold. These results indicated that there was no serious common method bias in this study.

### 3.3 Description and correlations of study variables

The mean scores for HK, APGAR, SEMCD, and FIA were  $13.67 \pm 3.92$ ,  $7.18 \pm 2.47$ ,  $39.05 \pm 7.90$ , and  $18.57 \pm 4.81$ , respectively. Pearson correlation analysis showed that HK and APGAR were significantly positively correlated with SEMCD ( $r = 0.219$ ,  $P < 0.001$ ;  $r = 0.364$ ,  $P < 0.001$ , respectively) and FIA ( $r = 0.425$ ,  $P < 0.001$ ;  $r = 0.609$ ,  $P < 0.001$ , respectively). HK was also significantly positively correlated with APGAR ( $r = 0.483$ ,  $P < 0.001$ ). SEMCD was significantly positively correlated with FIA ( $r = 0.532$ ,  $P < 0.001$ ) (**Table 2**).

**Table 2** Descriptive statistics and correlation of study variables (N = 411)

| Variables | Total score<br>M±SD | 1        | 2        | 3        | 4 |
|-----------|---------------------|----------|----------|----------|---|
| 1. HK     | 13.67±3.92          | 1        |          |          |   |
| 2. APGAR  | 7.18±2.47           | 0.483*** | 1        |          |   |
| 3. SEMCD  | 39.05±7.90          | 0.219*** | 0.364*** | 1        |   |
| 4. FIA    | 18.57±4.81          | 0.425*** | 0.609*** | 0.532*** | 1 |

Note. HK= hemodialysis knowledge; APGAR = family care index; SEMCD = self-efficacy for managing chronic disease; FIA =fluid intake adherence; M=Mean; SD=standard deviation; \*\*\* $P < 0.001$ .

### 3.4 Linear regression analysis of fluid intake adherence

Fluid intake adherence was used as the dependent variable. Variables that were statistically significant in the univariate analysis ( $P < 0.01$ ) and correlation analysis were included as independent variables in

the multiple linear regression analysis. The variables were coded as follows: (1) age (years):  $\geq 65 = 0$  and  $< 65 = 1$ ; (2) BMI: dummy variables were created with underweight as the reference group: normal weight = ( $Z1 = 1, Z2 = 0, Z3 = 0$ ), overweight = ( $Z1 = 0, Z2 = 1, Z3 = 0$ ), and obesity = ( $Z1 = 0, Z2 = 0, Z3 = 1$ ); (3) average monthly household income per capita (yuan): dummy variables were created with  $< 3000$  yuan as the reference group:  $3000-5000$  yuan = ( $Z1 = 1, Z2 = 0$ ) and  $> 5000$  yuan = ( $Z1 = 0, Z2 = 1$ ); (4) vascular access type: other = 0 and arteriovenous fistula (AVF) = 1; (5) dialysis frequency: three times per week = 0 and other = 1; and (6) hemodialysis knowledge, family support, and self efficacy were entered using their original scores. The results of the multiple linear regression analysis are presented in **Table 3**.

**Table 3** Linear regression analysis of fluid intake adherence (N = 411)

| Variables                                            | $\beta$ | Standard error | B      | t      | p         | VIF   |
|------------------------------------------------------|---------|----------------|--------|--------|-----------|-------|
| Constant                                             | 0.333   | 0.164          | —      | 2.035  | 0.042     | 0.001 |
| <b>BMI</b> (Emaciation as reference)                 |         |                |        |        |           |       |
| Normal                                               | -0.071  | 0.096          | -0.044 | -0.738 | 0.461     | 2.970 |
| Overweight                                           | 0.047   | 0.105          | 0.024  | 0.444  | 0.657     | 2.414 |
| Obesity                                              | -0.212  | 0.104          | -0.111 | -2.045 | 0.042     | 2.463 |
| dialysis frequency (Three times a week as reference) |         |                |        |        |           |       |
| Other                                                | -0.286  | 0.118          | -0.084 | -2.419 | 0.016     | 1.005 |
| HK                                                   | 0.031   | 0.008          | 0.149  | 3.763  | $< 0.001$ | 1.319 |
| APGAR                                                | 0.113   | 0.012          | 0.348  | 9.346  | $< 0.001$ | 1.449 |
| SEMCD                                                | 0.249   | 0.025          | 0.409  | 9.847  | $< 0.001$ | 1.162 |

Note. HK= hemodialysis knowledge; APGAR = family care index; SEMCD = self-efficacy for managing chronic disease; B=Standardized coefficients; B=Unstandardized coefficients; VIF=variance inflation factor;  $R^2=0.519$ , after adjustment  $R^2=0.512$ ,  $F=241.409$ ,  $p<0.001$ . Durbin-Watson=0.309.

### 3.5 Pathway analysis of factors associated with fluid intake adherence among patients receiving maintenance hemodialysis

Mediation analysis was conducted using Mplus 8.3. After controlling for demographic variables, including gender, age, and BMI, the path coefficients were tested using the bootstrap method. The results are shown in **Table 4 (see the end of the document text file)** and **Fig. 2**. Hemodialysis knowledge

( $\beta = 0.443$ , 95% CI: 0.364–0.522) and family support ( $\beta = 0.262$ , 95% CI: 0.180–0.336) were both significantly positively associated with self efficacy and together explained 36.1% of the variance in self efficacy. Hemodialysis knowledge ( $\beta = 0.156$ , 95% CI: 0.071–0.241), family support ( $\beta = 0.359$ , 95% CI: 0.287–0.432), and self efficacy ( $\beta = 0.396$ , 95% CI: 0.310–0.485) were all significantly positively associated with fluid intake adherence. The model explained 52.9% of the variance in fluid intake adherence (all  $P < 0.05$ ).

**Table 4** Standardized coefficients of pathways in the final model(N = 411)

| Structural Paths | Standardized coefficients | Bootstrapping 95 % confidence interval |       | p     | Proportion of mediating effect (%) |
|------------------|---------------------------|----------------------------------------|-------|-------|------------------------------------|
|                  |                           | Lower                                  | Upper |       |                                    |
| Total effects    |                           |                                        |       |       |                                    |
| HK → SEMCD       | 0.443                     | 0.364                                  | 0.522 | <0.05 |                                    |
| APGAR → SEMCD    | 0.262                     | 0.180                                  | 0.336 | <0.05 |                                    |
| HK→ FIA          | 0.156                     | 0.071                                  | 0.241 | <0.05 |                                    |
| APGAR→ FIA       | 0.359                     | 0.287                                  | 0.432 | <0.05 |                                    |
| SEMCD → FIA      | 0.396                     | 0.310                                  | 0.485 | <0.05 |                                    |
| Indirect effects |                           |                                        |       |       |                                    |
| HK → SEMCD→ FIA  | 0.175                     | 0.132                                  | 0.231 | <0.05 | 52.9%                              |
| APGAR→SEMCD→ FIA | 0.104                     | 0.069                                  | 0.147 | <0.05 | 22.5%                              |
| Direct effects   |                           |                                        |       |       |                                    |
| HK→ FIA          | 0.331                     | 0.248                                  | 0.411 | <0.05 |                                    |
| APGAR→ FIA       | 0.463                     | 0.386                                  | 0.540 | <0.05 |                                    |
| SEMCD → FIA      | 0.396                     | 0.310                                  | 0.485 | <0.05 |                                    |

Note. HK= hemodialysis knowledge; APGAR = family care index; SEMCD = self-efficacy for managing chronic disease; FIA =fluid intake adherence.

Path analysis showed that self efficacy had an indirect effect of 0.175 (95% CI: 0.132–0.231) on the association between hemodialysis knowledge and fluid intake adherence, accounting for 52.9% of the total effect. The indirect effect of self efficacy on the association between family support and fluid intake adherence was 0.104 (95% CI: 0.069–0.147), accounting for 22.5% of the total effect. The bootstrap 95% CIs for both indirect effects did not include 0. Both direct effects were also statistically significant, indicating that self efficacy partially mediated the associations between hemodialysis knowledge and family support and fluid intake adherence.

## 4 Discussion

Despite broad recognition of the importance of fluid management for patients receiving maintenance hemodialysis, this study found that fluid intake adherence among Chinese patients receiving maintenance hemodialysis remains inadequate. The results showed that fluid intake adherence was primarily associated with hemodialysis knowledge, family support, and self efficacy, as well as obesity and a dialysis frequency other than three times per week. Furthermore, self efficacy was found to partially mediate the relationships between hemodialysis knowledge/family support and fluid intake adherence, accounting for mediation proportions of 17.5% and 10.4%, respectively.

Fluid management is crucial for reducing complications, improving quality of life, and enhancing clinical outcomes in patients receiving maintenance hemodialysis. In this study, the fluid intake adherence score among patients receiving maintenance hemodialysis was  $18.57 \pm 4.81$ , indicating a moderate level of adherence. This finding was similar to that of a previous study [25], but was significantly lower than the score reported by Che et al. [26] ( $22.61 \pm 2.91$ ). All three studies used the same validated tool to assess fluid intake adherence and were conducted in tertiary hospitals in China. These similarities increased the comparability of the findings and suggested that the difference was unlikely to be due to the measurement tool itself. The difference may be related to the characteristics of the study participants.

In this study, 23.1% of the participants had diabetes. Patients with diabetes may be more likely to have a reduced resting salivary flow rate, which can worsen dry mouth and thirst and make fluid restriction more difficult [27]. In addition, 44.5% of the participants were female. Previous studies have shown that female patients are more likely to adhere to fluid restrictions than male patients. Women tend to be more actively involved in self-care practices. This may be related to biological, psychological, and sociocultural factors, including greater health awareness and stronger motivation to adhere to treatment recommendations [28]. Differences in medical resources, health education, and support for volume management across regions may also affect patients' opportunities to receive professional guidance. Therefore, healthcare professionals should provide tailored health education and continuous support based on patients' individual characteristics and needs to improve fluid intake adherence.

The results of this study showed that hemodialysis knowledge was positively associated with fluid intake adherence among patients receiving maintenance hemodialysis. From the perspective of the COM-B framework, this finding is consistent with the "psychology capability" domain. It suggests that knowledge and skills related to disease management may help patients understand the disease and fluid restriction requirements more clearly. This finding is consistent with previous research [29]. The knowledge-attitude-practice (KAP) theory suggests that knowledge is the basis of behavior. A better understanding of disease-related knowledge and a more positive attitude may increase patients' motivation to adopt appropriate health behaviors [30]. A cross-sectional study [31] and a systematic review [32] showed that patients receiving maintenance hemodialysis had limited knowledge about fluid intake and low confidence in following fluid restrictions. Improving patients' knowledge and attitudes may help improve their health behaviors. Previous studies support this view [33–35] and show that

health education interventions can have positive effects on patients' health behaviors and attitudes. Therefore, future interventions should strengthen health education and related support for fluid restriction among patients receiving maintenance hemodialysis.

The results of this study showed that family support was significantly and positively associated with fluid intake adherence among patients receiving maintenance hemodialysis through both direct and indirect pathways. From the perspective of the COM-B framework, this finding highlights the role of "social opportunity" in supporting health behaviors. Family members are important influences on health behaviors and play an important role in patients' disease management and mental health. These findings are consistent with previous studies [36–38]. Family support includes companionship, encouragement, and supervision. These forms of support may help reduce psychological stress, such as anxiety and depression, and support self-management, thereby improving self efficacy. In addition, Temel et al. [39] emphasized that spousal support plays an important role in improving adherence to fluid restrictions. It may also help patients manage volume load and improve prognosis. Therefore, healthcare professionals should make full use of family support by providing joint health education for patients and their families, supporting family involvement in fluid restriction management, and encouraging family members to provide active supervision to improve patients' fluid intake adherence.

In this study, self efficacy was a key psychological factor that was positively associated with fluid intake adherence among patients receiving maintenance hemodialysis, which was consistent with the findings of Wilandika et al. [40]. From the perspective of the COM-B theory, this finding highlights the important role of the motivation domain. Based on Bandura's social learning theory, self efficacy refers to an individual's confidence in their own ability and is influenced by personal expectations and goals [41]. Higher self efficacy may help improve treatment adherence among patients receiving maintenance hemodialysis. This study further assessed self efficacy in relation to fluid intake behavior among patients receiving maintenance hemodialysis. Previous studies have shown that self efficacy is an important factor associated with patients' treatment behaviors [42]. Although previous studies have found that self efficacy mediates the relationship between disease knowledge and medication behavior [15], this study is the first to report a mediating relationship of self efficacy between hemodialysis knowledge, family support, and fluid intake adherence. This finding requires further verification.

Multivariate analysis showed that obesity and a dialysis frequency other than three times per week were important sociodemographic and clinical characteristics associated with fluid intake adherence among patients receiving maintenance hemodialysis. Studies have shown that water and sodium balance regulation may be impaired in individuals with obesity [43]. Increased adipose tissue can alter the distribution of body water, resulting in a relative decrease in total body water per unit of body weight and making individuals with obesity more prone to water depletion. However, individuals with obesity may also have impaired thirst mechanisms and reduced sensitivity of osmoreceptors, making fluid intake more difficult to control. A lower dialysis frequency may increase water and sodium retention. Patients receiving twice-weekly hemodialysis may also require more antihypertensive medication [44]. These findings may help identify key populations for intervention, especially individuals with obesity and those

receiving dialysis less frequently, and provide a basis for developing stratified volume management programs for patients receiving maintenance hemodialysis.

Path analysis showed that the COM-B framework could help explain the factors associated with fluid intake adherence among patients receiving maintenance hemodialysis. This finding is consistent with previous studies on fluid intake in nursing homes [45]. More importantly, self efficacy played a central mediating role by linking hemodialysis knowledge and family support with fluid intake adherence. This finding is consistent with existing systematic reviews [46]. These findings suggest that strategies targeting knowledge gaps, social opportunities, and motivation may work together to promote fluid intake adherence. However, this study used a cross-sectional design. Therefore, the mediation pathways indicate statistical associations between variables rather than causal relationships. Improving self efficacy may therefore be an important entry point for improving fluid intake adherence among patients receiving maintenance hemodialysis. Strategies such as tiered education, family involvement, peer support, motivational interviewing, goal setting, and positive feedback may help patients build confidence in fluid management and improve their active participation in long-term volume management.

## Limitations

Several limitations of this study should be noted. First, the cross-sectional design limited the determination of causal relationships between the variables. Future longitudinal studies are needed to examine the long-term effects of hemodialysis knowledge, family support, and self efficacy on fluid intake adherence among patients receiving maintenance hemodialysis. Second, this study relied only on subjective self-report scales to assess fluid intake adherence and did not include objective measures such as relative-interdialytic weight gain (R-IDWG), which may have introduced recall bias. Finally, due to time constraints, this study included only patients receiving maintenance hemodialysis from one tertiary hospital in Chongqing, China. Therefore, the generalizability of the findings to patients from different regions, cultural backgrounds, or countries remains uncertain.

## 5 Conclusion

This study indicates that fluid intake adherence among patients receiving maintenance hemodialysis in China remains inadequate. Drawing on the COM-B framework, key factors associated with fluid intake adherence were identified, including hemodialysis knowledge, family support, and self efficacy, as well as clinical characteristics such as obesity and dialysis frequency. Path analysis demonstrated statistical associations linking these variables to fluid intake adherence, with direct associations involving hemodialysis knowledge, family support, and self efficacy, as well as indirect relationships mediated by self efficacy. These findings provide practical insights for identifying patients who may need greater support and informing the design of future interventions that integrate knowledge education with family support and motivational strategies based on the COM-B framework.

## Declarations

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## Author Contribution

Q.Z.: Guarantor of integrity of the entire study, Study Concepts, Study Design, Definition of Intellectual Content, Clinical Studies, Experimental Studies, Statistical Analysis, Manuscript Preparation, Manuscript Editing, Manuscript Review. C.C.: Research Plan Preparation, Data Acquisition. H.L.: Research Plan Preparation. C.Y.X.: Data Acquisition. X.L.L.: Conceptualization, Writing-Review, Funding Acquisition. All authors reviewed and approved the final manuscript.

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Figures

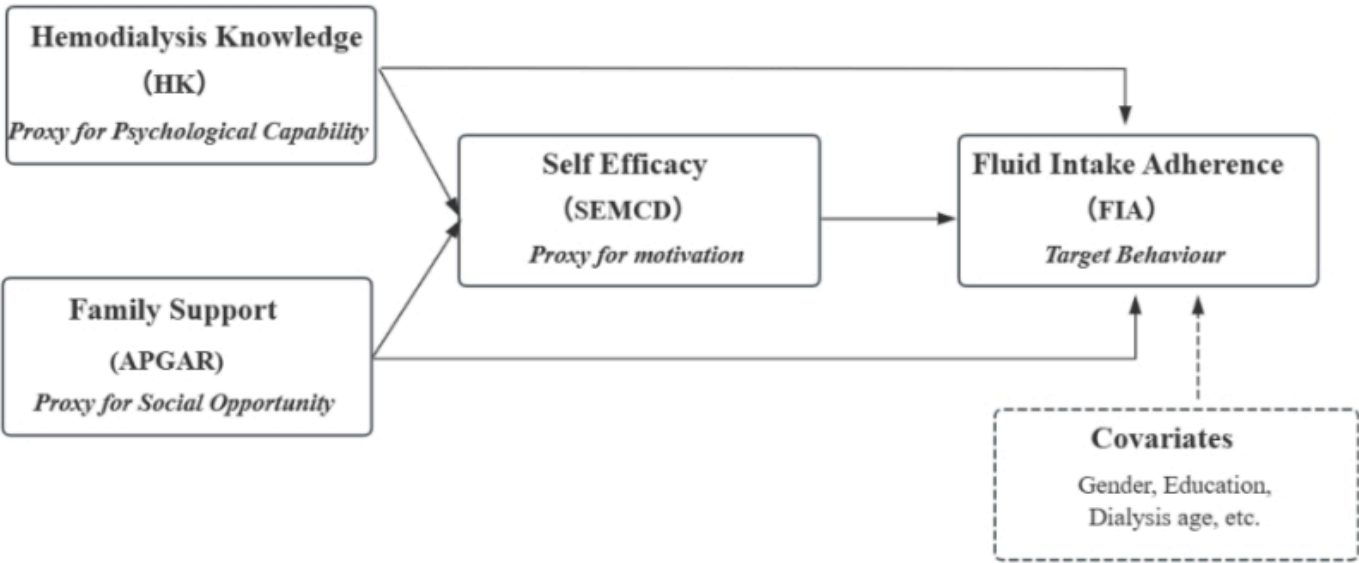


Figure 1

Hypothesized conceptual framework based on the COM-B model. Note: Validated instruments (HK, APGAR, SEMCD) were used as proxy measures for the COM-B domains. Solid arrows indicate statistical associations tested via mediation effect modeling, rather than causal relationships; dashed arrows indicate adjustments for sociodemographic and clinical covariates.

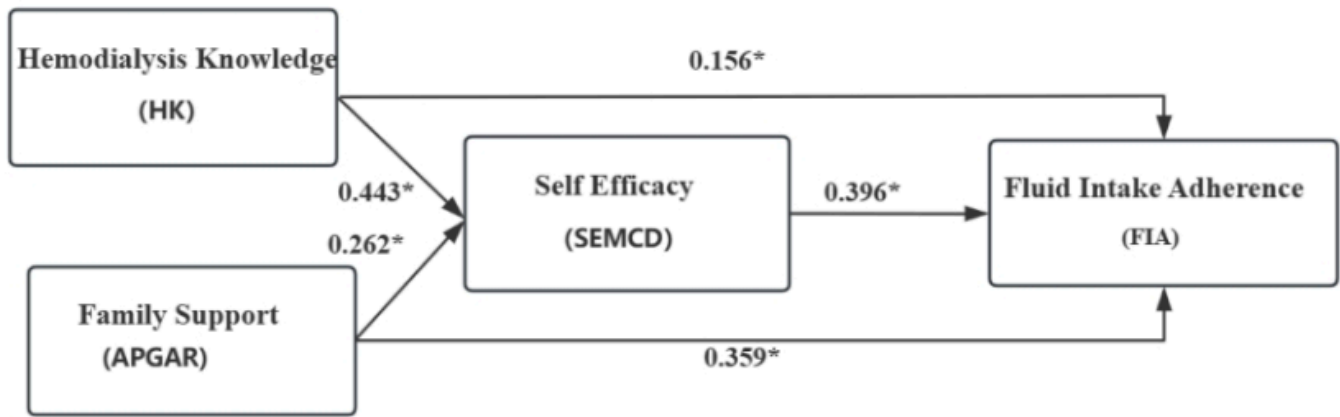


**Figure 2**

Mediation model of fluid intake adherence in maintenance hemodialysis patients. Note. The analysis was adjusted for gender, age, BMI, marital status, education level, average monthly household income per capita, primary disease, dialysis duration, vascular access type, and dialysis frequency. \* $P < 0.001$ .