

e-Health Literacy in Maintenance Hemodialysis Patients: A Multi-Center Cross-Sectional Study

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Objective: This cross-sectional study aimed to explore the level of electronic health literacy (e-HL) among maintenance hemodialysis (MHD) patients and identify its influencing factors.

Methods: A cross-sectional survey was conducted from June to October 2024, involving 350 MHD patients from three tertiary hospitals in Baoding, Hebei Province, China. The e-Health Literacy Scale (e-HEALS) was used to assess the patients' e-HL levels across its three domains: application ability, judgement ability, and decision-making ability. Univariate analysis and generalized linear regression models were employed to analyze the factors influencing e-HEALS scores. The Cronbach's α for the e-HEALS in this study was 0.966.

Results: The results revealed that the average e-HEALS score among MHD patients was 29.58 ± 4.87 , indicating a moderate to low level of e-HL. Generalized linear regression analysis identified education level, monthly income, and medical payment methods as independent influencing factors of e-HL.

Conclusion: The findings suggest that MHD patients generally exhibit sub-optimal e-HL, highlighting the need for healthcare providers, particularly nephrology professionals, to pay attention to this issue. Targeted interventions should be developed to enhance e-HL, thereby empowering patients to better manage their health conditions.

Keywords: end-stage kidney disease, hemodialysis, health literacy, cross-sectional study, quality of life

Introduction

With the rapid development of the internet, the field of public health research has begun to focus on electronic health literacy (e-HL).¹ E-HL refers to the ability to search for, understand, and evaluate health information through electronic resources, and to use this information to address or identify health issues.²⁻⁵ E-HL is a relatively new concept that has emerged in recent years. With the continuous advancement and development of internet-based societies, this concept has been widely applied in online health interventions for various diseases.⁶⁻⁸ It enables individuals to efficiently access health-related information from the internet, demonstrating strong feasibility and practicality.

Maintenance hemodialysis (MHD) is the primary alternative treatment for patients with end-stage kidney disease (ESKD), and the number of ESKD patients continues to grow steadily. Relevant studies have shown that for MHD patients, knowing how to monitor their condition, including adhering to prescribed medication regimens, dietary and fluid restrictions, and managing dialysis vascular access in daily life, can help reduce complications and hospitalization rates.⁹ Enhanced e-HL empowers MHD patients to more effectively self-manage their condition, which in turn is associated with improved quality of life (QoL). Unlike general health literacy, which focuses on processing information from traditional media (eg, brochures, face-to-face communication), e-HL emphasizes skills for navigating the digital environment. This is particularly crucial for MHD patients, who require ongoing complex self-management in daily life, including strict adherence to dietary and fluid restrictions, monitoring vascular access status, medication management, and seeking information about kidney transplantation. The Internet has become a vital channel for accessing such knowledge and support. Some studies indicate that individuals with higher levels of e-HL are more likely to engage in

healthy nutritional behaviors, exercise, and sleep practices.¹⁰ Therefore, to enhance the QoL and extend the survival period of MHD patients, healthcare providers should pay attention to the e-HL levels of MHD patients. However, research on e-HL has predominantly focused on cancer patients, diabetic patients, and outpatients, with limited studies on MHD patients.^{11–15} This study aimed to investigate the current status of e-HL among MHD patients, understand the influencing factors, and develop effective intervention strategies to improve their e-HL levels.

Materials and Methods

A cross-sectional study was conducted from June to October 2024, enrolling 350 MHD patients from three tertiary hospitals in Baoding City, Hebei Province, China (Figure 1). The inclusion criteria were as follows: age ≥ 18 years; regular hemodialysis with MHD duration ≥ 3 months and a dialysis frequency of \geq twice per week; informed consent and voluntary participation in the study; patients not in the acute complication phase. The exclusion criteria included: individuals with language or cognitive impairments who were unable to complete the questionnaire; patients with severe tumor diseases or other organ-related conditions; those with psychiatric disorders; patients undergoing emergency hemodialysis.

The sample size was calculated a priori using G.Power software (version 3.1.9.7) for a multiple linear regression analysis. With an anticipated medium effect size ($f^2 = 0.15$), an alpha level of 0.05, a statistical power of 0.90, and 10 predictor variables, the minimum required sample size was 150. To account for potential non-response or invalid questionnaires (estimated at 20%), the target sample size was adjusted to approximately 180–190. The final sample of 350 patients recruited not only meets but exceeds this requirement, ensuring adequate power for the analysis, which falls within the statistically recommended range and ensures sufficient power for the regression analysis. This study was approved by the Ethics Committee of Baoding No.1 Central Hospital (No. 2024–199).

This study utilized a general questionnaire alongside the e-HL Scale (e-HEALS) to conduct a comprehensive survey. The general questionnaire was developed based on a thorough literature review and included variables such as age, educational level, gender, marital status, dialysis duration, occupation, monthly income, and healthcare payment methods. In China, dialysis costs are primarily covered by public health insurance schemes, including Urban Employee Basic Medical Insurance (UEBMI), Urban Resident Basic Medical Insurance (URBMI), and the New Rural Cooperative Medical Scheme (NRCMS). Out-of-pocket payment usually applies to uninsured individuals or those seeking services/treatments beyond the insurance coverage. The type of medical payment method often reflects the patient's socioeconomic status, residence (urban vs rural), and employment type. The e-HEALS, originally designed by Norman, was translated into Chinese by Guo Shuaijun et al.¹⁶ This scale comprises three dimensions—application ability, judgement ability, and decision-making ability—and consists of eight items. Responses were measured using a 5-point Likert scale (1 = “strongly agree”, 2 = “agree”, 3 = “neutral”, 4 = “disagree”, 5 = “strongly disagree”), with the total score ranging from 8 to 40. The Cronbach's alpha

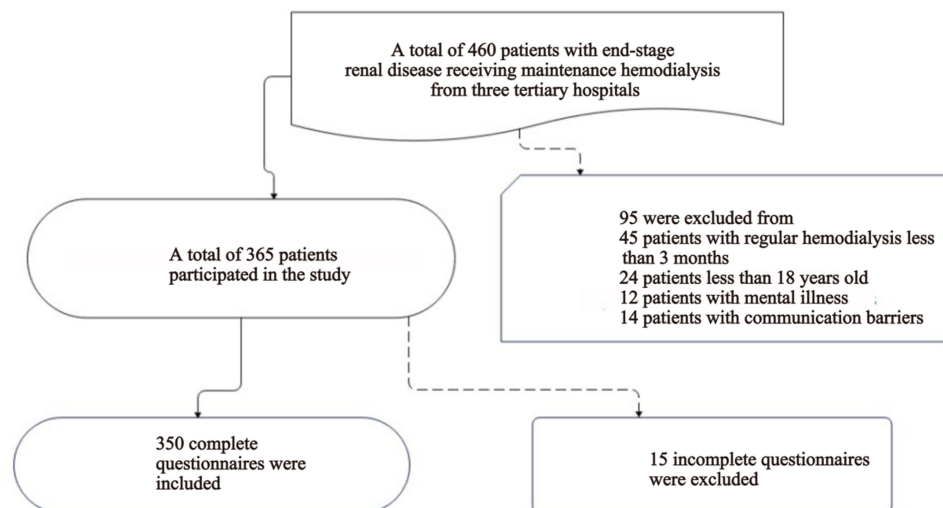


Figure 1 Flowchart of the study.

coefficient for this scale in the current study was 0.966, indicating high reliability. The survey was administered by nursing staff with the rank of senior nurse practitioner or higher using the “Wenjuanxing” platform. Prior to the survey, the researchers explained the purpose, methodology, and precautions of the study to the participants. Upon providing informed consent, participants were instructed to scan a QR code to complete the electronic questionnaire. For participants unable to complete the questionnaire independently, the researchers conducted face-to-face interviews and collected the questionnaires on-site. It is acknowledged that the requirement to scan a QR code or complete an online survey may inherently select for participants with a baseline level of digital literacy and access to smartphones/Internet. This could potentially introduce selection bias by underrepresenting individuals with very low digital proficiency. Incomplete questionnaires or those with missing responses were excluded from the analysis.

All statistical analyses were conducted using the statistical software package SPSS, version 26.0. Descriptive statistics characterized participant demographics: categorical variables were reported as frequencies and percentages, while normally distributed continuous variables were expressed as mean \pm standard deviation. For univariate analysis: Independent samples t-tests compared e-HEALS scores between two groups. One-way ANOVA assessed differences across ≥ 3 groups when homogeneity of variance assumptions were met. Non-parametric alternatives (Wilcoxon rank-sum for two groups; Kruskal–Wallis- H test for ≥ 3 groups) were utilized where data violated normality or equal variance assumptions. Candidate variables identified as statistically significant ($P < 0.05$) in univariate analyses were deemed eligible for inclusion in the subsequent multiple linear regression model. The total e-HEALS score served as the continuous dependent variable. Categorical predictors were converted into dummy variables. Model assumptions (linearity, homoscedasticity, independence of errors, absence of multicollinearity) were verified. Multicollinearity was assessed using the Variance Inflation Factor (VIF); all VIF values for the independent variables included in the final model were below 10.0, indicating no significant multicollinearity. Results were reported as unstandardized beta coefficients (β) with 95% confidence intervals. Statistical significance was evaluated at $\alpha = 0.05$ using two-tailed tests. The e-HEALS scale exhibited high internal consistency (Cronbach’s $\alpha = 0.966$), confirming its reliability within the study population. Effect sizes were interpreted based on conventional thresholds: strong for $r > 0.5$, moderate for $r = 0.3–0.5$, and weak for $r < 0.3$. Regression coefficients quantified the magnitude of association between predictors and e-HL after covariate adjustment. All statistical tests were two-sided, and a p -value of less than 0.05 was considered statistically significant.

Results

A total of 350 MHD patients were included in the final analysis. No participants were excluded due to an inability to scan the QR code or complete the online survey. For the 41 patients who could not complete the questionnaire independently, data were collected successfully via face-to-face interviews conducted by the researchers, ensuring comprehensive data inclusion. The study included 350 MHD patients, with 44.6% being male and 55.4% female. The average e-HEALS score among MHD patients was 29.58 ± 4.87 . The mean e-HL score was 29.15 ± 4.78 for males and 29.89 ± 5.52 for females, with no significant difference ($P = 0.218$). Age significantly influenced e-HL, with scores decreasing from 33.78 ± 5.21 in the 18–45 age group to 18.14 ± 6.96 in those over 65 ($P < 0.001$). Education level also showed a significant impact, with higher education associated with higher e-HL scores ($P < 0.001$). Occupation and monthly income were significant factors, with workers and higher income groups showing better e-HL ($P = 0.016$ and $P = 0.002$, respectively). Payment methods also significantly affected e-HL scores ($P = 0.012$) (Table 1).

The results of the e-HL scale for MHD patients are presented in Table 2. The mean score for application ability was 18.86 ± 5.96 , indicating moderate proficiency in utilizing e-health resources. Judgement ability scored 6.88 ± 2.07 , reflecting a reasonable capacity to evaluate health information. Decision-making ability had the lowest mean score at 3.82 ± 0.96 , suggesting limited confidence in making health-related decisions based on online information. The total e-HL score was 29.58 ± 4.87 , indicating an overall moderate level of e-HL among the participants.

Table 3 presents correlation coefficients (r) between e-HL (Y) and significant demographic variables (X) in maintenance hemodialysis patients. Age demonstrated a moderate negative correlation with e-HL ($r = -0.386$, $P < 0.001$). Monthly income showed a strong positive correlation ($r = 0.657$, $P < 0.001$), while education level exhibited a moderately strong positive association ($r = 0.546$, $P < 0.001$). Occupation had a weak positive correlation ($r = 0.216$,

Table 1 General Information and e-Health Literacy Scores Among Maintenance Hemodialysis Patients

Variables	N (%)	e-Health Literacy ($x \pm s$)	P
Gender		29.58 \pm 4.87	
Male	156 (44.6)	29.15 \pm 4.78	0.218
Female	194 (55.4)	29.89 \pm 5.52	
Age (years)			
18–45	164 (46.8)	33.78 \pm 5.21	<0.001
46–65	121 (34.6)	22.12 \pm 9.37	
>65	65 (18.6)	18.14 \pm 6.96	
Education level			
Primary school or below	24 (6.8)	23.38 \pm 5.67	<0.001
Middle school	117 (33.4)	28.67 \pm 8.43	
College or above	209 (59.8)	32.38 \pm 7.75	
Dialysis duration (years)			
<2	85 (24.2)	29.86 \pm 6.57	0.947
2–5	186 (53.1)	29.98 \pm 5.96	
>5	79 (22.7)	29.72 \pm 6.48	
Marital status			
Unmarried	38 (10.8)	29.46 \pm 6.96	0.442
Married	224 (64.0)	29.18 \pm 7.18	
Divorce	37 (10.5)	29.37 \pm 6.87	
Widowhood	59 (14.7)	29.02 \pm 7.03	
Occupation			
Worker	165 (47.1)	31.28 \pm 6.67	0.016
Farmer	139 (39.7)	24.45 \pm 6.72	
Others	46 (13.2)	27.18 \pm 5.43	
Monthly income (Rmb)			
<3000	84 (24.0)	21.85 \pm 5.82	0.002
3000–5000	196 (56.0)	24.48 \pm 6.14	
>5000	70 (20.0)	33.72 \pm 4.29	
Payment methods			
Health insurance	118 (33.7)	31.47 \pm 6.42	0.012
New Rural Cooperative Medical Care	195 (55.7)	28.86 \pm 7.89	
Others	37 (10.6)	22.67 \pm 8.32	
Living Alone, n (%)			
Yes	48 (13.7)	29.35 \pm 7.14	0.753
No	302 (86.3)	29.66 \pm 6.92	
Complications, n (%)			
<3	78 (22.3)	28.86 \pm 6.96	0.502
\geq 3	272 (77.7)	28.36 \pm 7.12	

Table 2 Total Scores and Sub-Scale Scores of e-Health Literacy Scale for Maintenance Hemodialysis Patients

Project	Score Range	Scores ($x \pm s$)
Items		
Application ability	0–25	18.86 \pm 5.96
Judgement ability	0–10	6.88 \pm 2.07
Decision-making ability	0–5	3.82 \pm 0.96
Total Scores	0–40	29.58 \pm 4.87

Table 3 Correlation Analysis of e-Health Literacy (Y) and Each Statistically Significant Variable (X)

Variables	E-Health Literacy (Y)				
	Age	Monthly Income	Education Level	Occupation	Payment Methods
r-value	-0.386	0.657	0.546	0.216	0.681
P-value	<0.001	<0.001	<0.001	0.016	0.012

$P = 0.016$). Notably, payment methods demonstrated the strongest positive correlation ($r = 0.681$, $P = 0.012$) among all variables examined, indicating that insurance coverage is strongly associated with higher levels of e-HL. All correlations were statistically significant.

Multicollinearity was assessed using the VIF. The VIF values for each variable category in the final model were as follows: Age (VIF=9.15), education level (VIF=9.86), Occupation (VIF=8.42), monthly income (VIF=8.67), and payment method (VIF=9.72). All VIF values were well below the threshold of 10, indicating no substantial multicollinearity. The results of the multivariate regression analysis revealed significant associations between several demographic factors and the outcome variable. Specifically, higher education levels (college or above: $\beta = 4.453$, $p = 0.004$; middle school: $\beta = 2.143$, $p = 0.015$) and higher monthly income (>5000 RMB: $\beta = 3.247$, $p = 0.014$; 3000–5000 RMB: $\beta = 2.134$, $p = 0.046$) were positively associated with the outcome. Additionally, the use of health insurance ($\beta = 2.567$, $p = 0.021$) and New Rural Cooperative Medical Care ($\beta = 1.986$, $p = 0.038$) were also significant predictors. No significant associations were found for age groups or occupation categories (Tables 4 and 5).

Discussion

This study provides the first comprehensive assessment of e-HL levels and their associated factors among MHD patients in Northern China. Our findings identify education level, monthly income, and healthcare payment methods as independent predictors of e-HL, with patients exhibiting notably deficient decision-making abilities (3.82 ± 0.96). These results not only reinforce the social gradient phenomenon in health literacy but also underscore the vulnerability of MHD populations in the digital health era.

In this study, the total score of e-HL among MHD patients was (29.58 ± 4.87) points, which is similar to the findings of some studies on e-HL scores among cancer patients, indicating a relatively low level.¹⁷ However, this score is lower than that reported in previous studies on e-HL among otolaryngology patients (29.76 ± 5.97) points, which may be related to differences in internet penetration rates and healthcare environments between countries.¹⁸ Among the three dimensions assessed, the highest average score was for the ability to apply online health information and services. This may be attributed to the gradual increase in self-management awareness among MHD patients in recent years, as well as their growing awareness of utilizing social resources.¹⁹ This suggests that MHD patients have, to some extent, been able to use online health resources to assist themselves. The notably low scores in the decision-making ability dimension suggest that MHD patients struggle to apply online health information to manage their condition effectively. This deficiency in e-HL could have direct negative consequences on clinical outcomes.

Overall, the scores across all three dimensions were relatively low. Low e-HL could have direct negative consequences on key clinical outcomes for MHD patients. For instance, deficient e-HL may impair the ability to access and

Table 4 Categorical Variables Assignment Methodology

Variables	Values
Age (Years)	18~45=1, 46~65=2, >65=3
Education level	Primary school or below=1, Middle school=2, College or above=3
Occupation	Farmer (Z1=0, Z2=0), Others (Z1=1, Z2=0), Worker (Z1=0, Z2=1)
Monthly Income(Yuan)	<3000=1, 3000~5000=2, >5000=3
Payment Methods	Self funded (Z1=0, Z2=0), New Rural Cooperative Medical Care (Z1=1, Z2=0), Health insurance (Z1=0, Z2=1)

Table 5 Linear Regression Analysis of e-Health Literacy Among Maintenance Hemodialysis Patients

Variables	β	P	95% CI
Intercept	19.357	0.000	(12.571, 29.438)
Age (years)			
18–45	3.165	0.241	(–1.587, 5.326)
46–65	2.754	0.146	(–0.982, 6.581)
>65	Reference	–	–
Education level			
College or above	4.453	0.004	(0.589, 5.254)
Middle school	2.143	0.015	(1.254, 3.412)
Primary school or below	Reference	–	–
Occupation			
Worker	3.473	0.086	(–1.146, 5.349)
Others	1.257	0.146	(–0.576, 3.157)
Farmer	Reference	–	–
Monthly income (Rmb)			
>5000	3.247	0.014	(1.547, 4.863)
3000–5000	2.134	0.046	(0.845, 2.479)
<3000	Reference	–	–
Payment methods			
Health insurance	2.567	0.021	(0.589, 5.531)
New Rural Cooperative Medical Care	1.986	0.038	(0.241, 4.217)
Other	Reference	–	–

Abbreviation: CI, confidence interval.

comprehend reliable information on sodium and fluid restrictions, potentially leading to poorer adherence and an increased risk of excessive interdialytic weight gain and uncontrolled hypertension.²⁰ Similarly, difficulties in evaluating online information about vascular access care might contribute to higher rates of infection or thrombosis.²¹ Furthermore, low e-HL could hinder patients' ability to seek out and understand information about kidney transplantation, potentially delaying referral and evaluation, thus affecting transplant preparedness.²² Ultimately, these deficits in self-management behaviors may be associated with higher hospitalization rates, poorer quality of life, and potentially survival. Therefore, improving e-HL is not merely about information access but is potentially linked to critical health outcomes. With the digitalization of the information age and the rapid development of the internet, the promotion of electronic health information has become an inevitable trend in modern society.²³ Therefore, nephrology healthcare professionals should emphasize the training of e-health education for MHD patients, helping them to filter high-quality online health information and directly recommending trustworthy information sources to patients or their families when providing health services.

This study showed that educational level was one of the independent influencing factors of e-HL among MHD patients. The higher the educational level, the higher the e-HL score, which aligns with findings from other researches on e-HL.²⁴ Previous studies have indicated that e-HL was closely associated with the level of education, and a lack of education was a significant factor contributing to the deficiency of e-HL in individuals.²⁵ One possible explanation is that patients with higher educational levels tend to have stronger health awareness and place greater emphasis on healthy lifestyles and health-related information and knowledge. As a result, they are more proactive in seeking and collecting disease-related information from online sources. Additionally, patients with higher educational levels possess certain advantages in searching, filtering, and comprehending information. They also exhibit critical thinking skills, enabling them to evaluate and discern the accuracy and relevance of disease-related knowledge and information obtained from the internet.²⁶

This study revealed that MHD patients with higher incomes tend to have higher e-HL scores. This phenomenon may be attributed to the fact that MHD patients with higher incomes are generally more financially independent, enabling

them to access healthcare services and treatments without significant economic stress. Consequently, they are better equipped to meet their medical and daily care needs, possess stronger self-care awareness, and are more proactive in seeking health-related information, which contributes to their higher e-HL levels.²⁷ In contrast, MHD patients with lower incomes often lack sufficient financial resources to address their basic healthcare and long-term care needs. As a result, they tend to focus primarily on meeting their immediate living expenses and pay less attention to health maintenance and related information. Therefore, it is crucial for society to provide more medical subsidies and support for economically disadvantaged MHD patients, increase awareness of their needs, alleviate their financial burdens, and encourage them to pay greater attention to their health. Such measures could help improve their e-HL and overall well-being.

This study also revealed that the medical payment method was independently associated with the e-HL of MHD patients. In China, the cost of maintenance hemodialysis is primarily covered by public insurance schemes (eg, UEBMI, URBMI and NRCMS), with typical reimbursement rates ranging from 70% to 90%.²⁸ Patients are responsible for the remaining out-of-pocket portion. There is no universal income-based sliding scale for reimbursement within the standard insurance schemes; however, a separate Medical Assistance program provides a safety net for qualifying low-income individuals, further reducing their effective out-of-pocket costs. This financial protection associated with insurance coverage may indirectly foster better e-HL by freeing up household resources that can be allocated to digital infrastructure (eg, smartphones, internet plans) and reducing the stress associated with medical costs, potentially allowing greater capacity to engage with health information. Conversely, patients relying predominantly on out-of-pocket payment often face significant financial toxicity, which may directly limit their access to digital tools and diminish their opportunity to develop e-HL skills. Thus, the payment method variable likely captures broader socioeconomic disparities and differential access to resources beyond mere payment classification, highlighting systemic influences on digital health equity.^{29,30} Specifically, MHD patients who pay out-of-pocket for their medical expenses exhibited significantly lower e-health literacy scores compared to those who utilize medical insurance or the New Rural Cooperative Medical Scheme. This finding, to some extent, reflects the demographic differences among individuals using various medical payment methods. Compared to self-paying MHD patients, those covered by medical insurance are predominantly urban residents who generally enjoy higher living standards, greater access to electronic devices, better educational backgrounds, and more frequent internet usage.³¹ These factors collectively contribute to their enhanced e-health literacy.

Our study found that patients enrolled in the NRCMS had better e-HL than those paying out-of-pocket. The NRCMS is a basic medical insurance scheme for rural residents in China, designed to reduce the financial burden of major illnesses.³² However, effectively utilizing this scheme itself requires a certain level of HL and administrative navigation skills, such as understanding the reimbursement catalog, knowing the claim procedures, and preparing necessary documents. This information is increasingly disseminated and processed through digital platforms (eg, official social media accounts, mobile apps). Consequently, patients with low e-HL may be disadvantaged not only in accessing general health information but also face additional barriers in understanding and utilizing the very insurance benefits intended to support them, potentially exacerbating health inequities.

This study has several limitations that should be acknowledged. First, the cross-sectional nature of the design precludes causal inferences, longitudinal studies are warranted to elucidate the temporal dynamics of these associations. Second, the sample was drawn from a single geographic region, which may affect the generalizability of the findings. Future studies involving more diverse populations are needed to validate and extend these results. Third, e-HL was assessed using self-reported measures, which may be subject to reporting biases such as recall or social desirability bias. Fourth, While our regression model identified education, income, and payment method as independent factors, it is important to acknowledge their conceptual interconnection. Although statistical checks ($VIF < 10.0$) did not indicate severe multicollinearity, these factors are inherently correlated components of socioeconomic status (SES). Therefore, caution is needed in interpreting their strictly independent effects; they collectively represent a broader SES dimension that influences e-HL. Finally, as noted in the Methods, the data collection method (QR code/online survey) might have introduced selection bias by potentially underrepresenting individuals with very low digital access or literacy, even though face-to-face interviews were offered as an alternative.

Conclusion

In summary, the findings of this cross-sectional study indicate that the level of e-HL among MHD patients remains relatively low and is associated with lower educational attainment, lower monthly income, and self-payment of medical costs. Based on these associative findings, healthcare professionals should prioritize support for these vulnerable subgroups. Actionable strategies include developing and implementing targeted, low-literacy friendly education programs—possibly using illustrated guides, video tutorials, or structured one-on-one sessions—specifically designed for older, less educated, low-income, or self-paying patients. These interventions should aim to improve patients' skills in accessing and evaluating reliable online health information. Enhancing e-HL has the potential to empower MHD patients towards better self-management and ultimately improve their quality of life. Future longitudinal or interventional studies are needed to confirm these associations and establish causal pathways.

Data Sharing Statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Ethics Approval and Consent to Participate

This study received ethical approval from the Ethics Committee of Baoding No. 1 Central Hospital (Approval No. 2024199). All procedures were conducted in compliance with relevant guidelines and regulations. Written informed consent was obtained from all participants prior to their inclusion in the study.

Consent for Publication

Written informed consent was obtained from the patients for publication of this study.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declared that they had no competing interests in this work.

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