Patient Preference and Adherence

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ORIGINAL RESEARCH

Demand Analysis of Mobile Health Applications for Patients with Chronic Kidney Disease Across Different E-Health Literacy Levels

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Purpose: Chronic kidney disease (CKD) requires innovative strategies to support long-term self-management. This study is novel in applying the Kano model to examine preferences for mobile health (mHealth) apps among Chinese patients with CKD and to compare these preferences across different levels of e-health literacy.

Patients and Methods: A multicenter cross-sectional survey was conducted among 484 patients with CKD in China. Face-to-face questionnaires were used to assess self-management needs and user interface (UI) preferences for CKD-related mHealth apps. App attributes were classified using the Kano model, and their priorities were further evaluated using Better-Worse coefficients and ranking analysis.

Results: Low e-health literacy users prioritized foundational features: must-be attributes included disease knowledge, while one-dimensional attributes were symptom and medication management. High e-literacy users emphasized medical insurance information (must-be) and disease management (one-dimensional). Both groups valued an intuitive UI, in addition to considering privacy protection as must-be attributes, low e-health literacy users required simplified navigation, whereas high e-health literacy users preferred efficient data entry.

Conclusion: Preferences for CKD mHealth apps varied by e-health literacy level. Patients with lower e-health literacy may benefit more from basic health education and simplified interfaces, whereas those with higher e-health literacy expect more advanced and efficient functionalities. These findings highlight the value of the Kano model in identifying differentiated user needs and can inform the development of tailored mHealth apps to support equitable CKD self-management.

Keywords: chronic kidney disease, e-health literacy, mHealth apps, Kano model

Introduction

Chronic kidney disease (CKD) remains a significant global health issue, affecting many and placing heavy burdens on healthcare systems.[1] In China, factors like an aging population, lifestyle changes, and increasing diabetes and hypertension rates have driven CKD prevalence among adults to 8.2% over the past decade.[2] CKD progression to end-stage kidney disease (ESKD) necessitates costly dialysis treatments, underscoring the urgency for effective management through continuous monitoring, medication adherence, lifestyle changes, and regular healthcare interactions.[3] However, traditional care models often fail to support patient self-management, resulting to poorer outcomes and higher costs.

Self-management significantly benefits individuals with chronic illnesses by empowering them to actively participate in their care, thereby improving outcomes and quality of life.[4] For CKD patients, developing a personalized management

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plan requires close collaboration with healthcare professionals. While traditional in-person consultations offer limited scalability, digital health technologies like mobile health applications (mHealth apps) provide new possibilities for enhancing healthcare delivery.[5] mHealth apps have become valuable tools for managing chronic diseases like CKD, providing medication reminders, symptom tracking, dietary guidance, educational resources, and direct communication with healthcare teams.[6] For this study, "mobile health applications" refer specifically to smartphone-native apps that deliver health-related content, enable self-monitoring, and support provider–patient communication. To avoid confounding user preference assessment due to differing interfaces and capabilities, this definition excludes responsive websites, tablet-optimized apps, and web platforms accessed via mobile browsers.[6]

Central to the success of digital tools is e-health literacy, the ability to seek, understand, and apply online health information.[7] E-health literacy directly influences how patients interact with mHealth apps, particularly among middle-aged and older populations who may face challenges due to limited technological exposure, cognitive decline, or physical impairments.[8] Critically, patients with low e-health literacy often struggle to navigate complex interfaces or interpret health data, whereas those with higher literacy may demand advanced functionalities.[9] This relationship between e-health literacy and interface design preferences has direct implications for UI decisions: low-literacy users require simplified navigation with visual cues and reduced cognitive load, while high-literacy users can accommodate more complex data entry and information architecture.[10] Tailoring app features and user interfaces (UI) to these divergent needs is essential to ensure accessibility and usability across literacy levels.[10] For instance, simplified navigation or visual aids may be indispensable for low-literacy users but less critical for others.[11] In China, high smartphone penetration and widespread use of super-apps such as WeChat, together with national policies prioritizing "Internet+ healthcare" and digital chronic-disease management, make literacy-sensitive design directly actionable.[12] However, e-health literacy varies by age, education, and urban–rural residence.[13] Thus, assessing self-management needs and UI requirements based on e-health literacy levels ensures that apps address disparities in technological access and capability, bridging the digital divide.[14]

To develop effective mHealth apps for CKD patients, understanding their needs, preferences, and expectations regarding app features and functionalities is crucial. Utilizing the Kano model, introduced by Professor Noriaki Kano in the 1980s (Figure 1), offers a methodological framework to evaluate and priorities these aspects.[15] This model categorizes customer preferences into must-be attributes (M), one-dimensional attributes (O), attractive attributes (A), indifferent attributes (I), and reverse attributes (R), providing a systematic approach to enhance user satisfaction and engagement.[16] Must-be attributes are the basic requirements that users expect. If these needs are unmet, users will be dissatisfied but fulfilling them does not significantly enhance satisfaction. One-dimensional attributes are directly related to user satisfaction, the better they are executed, the higher the satisfaction. Attractive attributes are features that users do not explicitly expect but can significantly increase satisfaction when present. Indifferent attributes do not significantly affect satisfaction, whether present or absent. Users typically do not care about these features, which can vary based on individual preferences. Reverse attributes are features that can lead to dissatisfaction if present.[16] Unlike alternative frameworks such as the Technology Acceptance Model, which focuses broadly on perceived usefulness and ease of use,[17] the Kano model specifically prioritizes features based on their capacity to drive satisfaction or dissatisfaction.[18] A recent study using the Kano model to assess telenursing for chronically ill elderly highlighted its effectiveness in identifying key user needs and improving service quality.[19]

Nevertheless, a specific research gap persists in CKD: few studies explicitly stratify Kano priorities by e-health literacy and translate them into actionable UI patterns and modular roadmaps within the Chinese healthcare context. By tailoring app features to the unique needs, cultural contexts, and healthcare system specifics of Chinese patients, developers can significantly boost user satisfaction and health outcomes.[20] By addressing this gap, the present study utilizes the Kano model to identify and prioritize the self-management needs and UI requirements of an mHealth app tailored for Chinese CKD patients with varying e-health literacy levels. The findings may inform future app design and feature prioritization in the Chinese healthcare context.

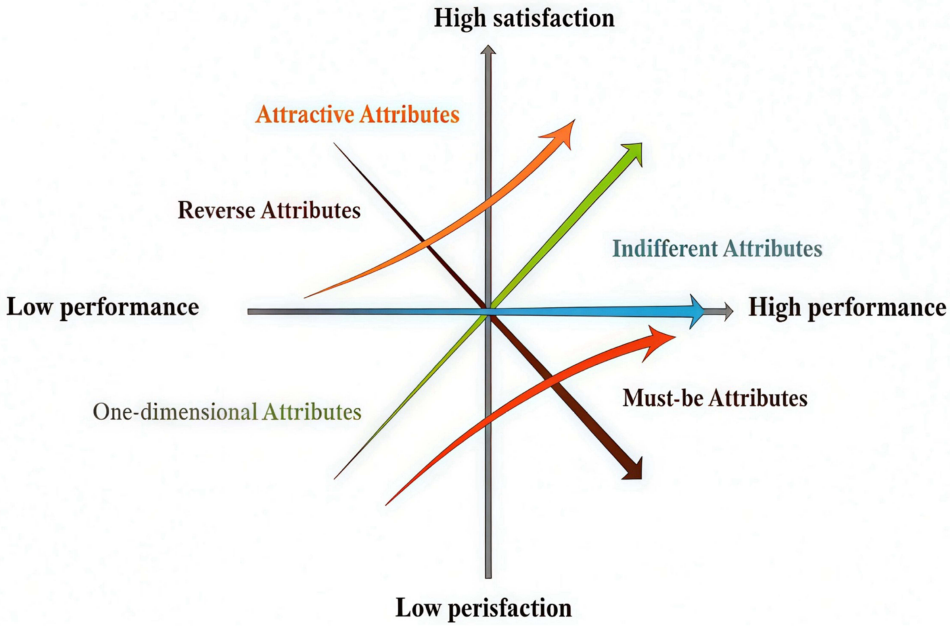

Figure 1 The Kano Model Theoretical Framework. A visualization of the five-attribute model illustrating the non-linear relationship between product performance (fulfillment of a requirement) and user satisfaction. The curves represent: Attractive (satisfaction increases rapidly with fulfillment), One-dimensional (satisfaction is proportional to fulfillment), Must-be (fulfillment is expected; absence causes extreme dissatisfaction), Indifferent (no impact on satisfaction), and Reverse (fulfillment causes dissatisfaction).

Materials and Methods

To enhance the study design and article quality, this research utilized the Strengthening the Reporting of Observational Studies in Epidemiology Checklist to ensure rigorous reporting of observational studies.[21]

Design and Participants

This study adopted a multicentre cross-sectional survey design, conducted from April to September 2023 at five hospitals located in the provinces of Sichuan, Shandong, Guangdong, and Shaanxi, China, with participants selected via convenience sampling. Participants were included in the study if they: 1) were diagnosed with CKD according to the "Guidelines for early screening, diagnosis, prevention and treatment of chronic kidney disease (2022 edition)";[22] 2) voluntarily participated and provided informed consent. Participants who were unable to complete the questionnaire due to communication difficulties or other reasons were excluded. Exclusions were made for those unable to complete the questionnaire due to communication difficulties or other reasons. Although convenience sampling may limit external validity, participants were recruited from multiple provinces and detailed demographic characteristics were reported to enhance the assessment of transferability.[21] In this multicenter convenience sample, all eligible and consenting participants were consecutively recruited during the prespecified study period.

Sample Size

Based on the criteria proposed by Hulland et al for the Kano model,[23] the sample size should be at least ten times the number of survey items and exceed 200 participants. For this study, with 32 variables and allowing for a potential 5% rate of invalid questionnaires, the minimum required sample size was 336.

Measurements

Sociodemographic Data

Sociodemographic data was collected using a self-designed form. This form gathered information on participants' age, gender, marital status, education level, CKD stage. Wording of items and response options was standardized, and skip-logic was minimized to reduce missing data.

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Data Survey Questionnaire for a Mobile Healthcare App Based on the Kano Model for Self-Management of CKD in the Middle-Aged and Elderly

The Kano questionnaire was developed in a literature-informed and theory-guided manner.[24,25] Candidate attributes were derived from prior literature on CKD self-management and CKD-related mobile health applications,[26] which consistently highlight disease education, symptom management, medication adherence, dietary support, exercise-related self-care, and continuity of care as important domains. User interface attributes were additionally informed by age-friendly mobile design guidance for older adults,[27,28] particularly recommendations on readability, simplified navigation, reduced data-entry burden, clear labelling, adequate button size, and privacy protection. After review by the research team, overlapping or overly technical items were removed, and the remaining attributes were grouped into two domains: self-management content needs (7 items) and user interface requirements (9 items). In accordance with the Kano methodology,[24] each attribute was then converted into paired functional and dysfunctional questions using the standard five response options.

An expert panel comprising renal dietitians, nephrology physicians, and specialist nurses reviewed the initial Kano questionnaire and reached consensus on item wording and overall structure. Subsequently, six independent experts (three nephrology professors, one renal dietitian, one nursing scholar, and one information technology scholar) evaluated the content validity of the questionnaire. The I-CVI ranged from 0.79 to 1.00, and the S-CVI/Ave was 0.92, indicating good content validity.[29] Pretesting and cognitive debriefing interviews with inpatients were also performed to improve item clarity and comprehensibility before the final version was established. In the forward questionnaire, the Cronbach's alpha for the self-management needs section was 0.891, while it was 0.923 for the user interface needs section. In the reverse questionnaire, the alphas were 0.960 for self-management needs and 0.963 for user interface needs. These findings indicate that both the forward and reverse questionnaires exhibit high levels of reliability and internal consistency. The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity were used to examine the structural validity of the questionnaire data. The KMO values for the functional and dysfunctional questionnaires were 0.938 and 0.959, respectively, both above the recommended threshold of 0.70.[30] Bartlett's test of sphericity was significant for both questionnaires ($p < 0.001$), indicating that the data were suitable for factor analysis. All questions were framed specifically for native smartphone applications, with explicit references to touch-based interactions and mobile-specific interface elements to ensure participants responded with a consistent understanding of the platform being evaluated.

Following the methodology of the Kano model, our survey includes both a forward question (functional form) and a reverse question (dysfunctional form) for each feature assessed. For example, the inquiry CKD Diet Management: This feature allows you to learn about dietary considerations and provides recommendations for CKD patients. How do you feel about this feature? Is paired with the reverse question, "Absence of CKD Diet Management: How do you feel if you cannot access information on dietary considerations and recommendations for CKD patients?". This dual-question approach facilitates a comprehensive evaluation of user preferences. Participants can choose from the following response options for each question: "dislike", "can tolerate", "doesn't matter", "deserves it", and "likes it". This approach ensured a thorough assessment of user attitudes toward each feature.

eHealth Literacy Scale

The eHealth Literacy Scale (eHEALS) developed by Norman et al consists of 8 items,[31] which are divided into three categories: application ability to online health information and services (Items 1, 2, 3, 4, and 5), evaluation ability (Items 6 and 7), and decision-making ability (Item 8). Each item is answered using a Likert five-point scale: "Strongly disagree", "Disagree", "Unsure", "Agree", and "Strongly agree", with corresponding scores of 1, 2, 3, 4, and 5, respectively. The total score for each respondent is the sum of the scores from all items. The eHEALS was dichotomized into low and high groups using a cut-off value of 29.5. Participants with scores ≤ 29.5 were classified as having low e-health literacy, while those with scores >29.5 were classified as having high e-health literacy. The Chinese version of eHEALS demonstrated excellent internal consistency, with a Cronbach's α of 0.962.[32]

Evaluation Strategy

Attribute Partitioning

By analysing the positive and negative questions of the participants, a 5×5 combination of answers can be obtained, with each entry corresponding to six Kano attributes (O, M, A, I, R, Q) (Table 1). The attribute category is determined by the Better-Worse coefficient.[33] According to the formula,[19]: $Better = (A + O)/(A + O + M + I)$, $Worse = -1 * (O + M)/(A + O + M + I)$ we calculate Better and worse values. Among them, the Better value is closer to 1, indicating that the demand has greater impact on the satisfaction of the survey subjects; The Worse value is closer to −1, which means that if a service is not provided, the user's satisfaction will decline. With the Better value as the ordinate and the Worse value as the abscissa, the matrix diagram is drawn with the mean value of both as the origin. The first quadrant is the one-dimensional qualities, the second quadrant is the attractive qualities, the third quadrant is the indifference qualities, and the fourth quadrant is the must-be qualities.

Priority Ordering

According to the Kano model, the priority of product development requirements is: M>O>A>I. The average satisfaction coefficient (ASC) is used to compare prioritising within the same attribute.[34] The formula is as follows: $ASC = (Better + \text{Worse})/2$. ASC was used only for within-class ranking to avoid overinterpretation across classes.

Statistical Analysis

The data analysis was performed using IBM SPSS Statistics 26.0 software. Descriptive statistics, such as frequency and percentage, were utilized to describe the sociodemographic characteristics of the study participants. According to the Kano model, Better-Worse values were calculated to clarify the demand attributes of self-managed mobile health care for middle-aged and elderly people, and the priority ranking of product development needs was determined according to the attribute division and ASC values. As a sensitivity analysis, this study estimated the hospital-level intraclass correlation coefficient (ICC) for the eHealth literacy score using an intercept-only mixed-effects model with hospital as a random effect.

Ethics Approval

All participants participated voluntarily in this study, completing questionnaires anonymously without any connection between their identity and their answers. Written informed consent was obtained from all participants prior to their involvement in the study. This study has been approved by the West China Hospital Sichuan University Ethics Committee (Approval No.: 2021[1721]). All procedures in this study were conducted in accordance with the Declaration of Helsinki and its subsequent revisions or equivalent ethical standards.

Results

Sociodemographic Characteristics and eHealth Literacy Level of the Participants

In this study, 523 questionnaires were initially collected. After removing 25 that were completed in under 5 minutes and 14 with identical answers, 484 valid responses were obtained, resulting in a 92.54% response rate. Among these, 57.2% of participants were male, and 58.9% were aged between 45 to 59 years. A majority (75.4%) of participants

Table 1 Comparison Table of Kano Model Positioning

		Reverse Questionnaires				
		Likes it	**Deserves it**	**Does not Matter**	**Can Tolerate**	**Dislike**
Forward questionnaires	Likes it	Q	A	A	A	O
	Deserves it	R	I	I	I	M
	Does not matter	R	I	I	I	M
	Can tolerate	R	I	I	I	M
	Dislike	R	R	R	R	Q

Abbreviations: M, must-be attributes; O, one-dimensional attributes; A, attractive attributes; I, indifferent attributes; R, reverse attributes; Q, Questionable attributes.

were in CKD stage 5. Only a small fraction were not familiar with smartphones (1.2% very unfamiliar, 3.3% unfamiliar). Regarding mHealth app usage for self-management, 46.6% were willing and 23.1% very willing. Notably, 71.49% had low e-health literacy (Table 2). The hospital-level ICC for the eHealth literacy score was very low (ICC = 0.001), indicating minimal between-hospital clustering. A sensitivity analysis using a one-way random-effects ANOVA yielded a similarly low estimate (ICC = 0.003).

Evaluation of the Attributes of Self-Management Needs Using Kano Model

Low e-Health Literacy Group

The Supplementary Table 1 indicated that diet management, with a Better coefficient of 65.6%, significantly enhanced satisfaction among CKD patients with low e-health literacy when included. Conversely, symptom management showed

Table 2 Distribution of Participants' Sociodemographic Characteristics (N=484)

Characteristics	Observation (N)	Percentage (%)
Gender		
Male	277	57.23
Female	207	42.77
Age		
18~44	176	36.36
45~59	285	58.88
≥60	23	4.75
Educational level		
Primary and below	53	10.95
Junior high school	126	26.03
High school or technical secondary school	151	31.20
College or junior college	91	18.80
Master's degree or above	63	13.00
Marital status		
Married	301	62.19
Unmarried	125	25.83
Divorced or widowed	58	11.98
Residence		
Rural	236	48.76
Urban	248	51.24
CKD stage		
1	27	5.58
2	41	8.47
3	26	5.37
4	25	5.17
5	365	75.41
Familiarity with smart phones		
Very unfamiliar	6	1.24
Unfamiliar	16	3.31
Neutral	147	30.37
Familiar	191	39.46
Very familiar	124	25.62
Willingness to use mobile medical apps for self-management of diseases		
Very unwilling	5	1.03
Unwilling	11	2.27
Neutral	130	26.86
Willing	226	46.69
Very willing	112	23.14
Low e-health literacy	346	71.49
High e-health literacy	138	28.51

the lowest Worse score, implying a 68.0% drop in patient satisfaction if omitted. From the Better-Worse matrix analysis, symptom and medication management were categorized as one-dimensional attributes. Diet management, exercise guidance, and medical insurance information provision were identified as attractive attributes. Psychosocial support was seen as an indifferent attribute, while introducing CKD-related knowledge was considered a must-be attribute (Figure 2).

Based on the attribute division and ASC coefficient detailed in Supplementary Table 1 and Figure 2, the priority ranking of self-management needs for CKD patients with low e-health literacy was as follows: CKD disease-related knowledge introduction was the highest priority, followed by symptom management, medication management, diet management, provide medical insurance information, exercise guidance and psychosocial support.

High e-Health Literacy Group

The data from Supplementary Table 2 shows that symptom management has a Better coefficient of 83.1%, indicating that including this feature could enhance satisfaction among CKD patients with high e-health literacy. Conversely, the introduction of CKD disease-related knowledge, with the lowest Worse score, suggests a potential 78.8% decrease in satisfaction if omitted. The Better-Worse matrix analysis identified symptom management, medication management, and CKD disease-related knowledge introduction as one-dimensional attributes (Figure 3). Diet management was an attractive attribute, psychosocial support and exercise guidance were indifferent attributes, and providing medical insurance information was a must-be attribute.

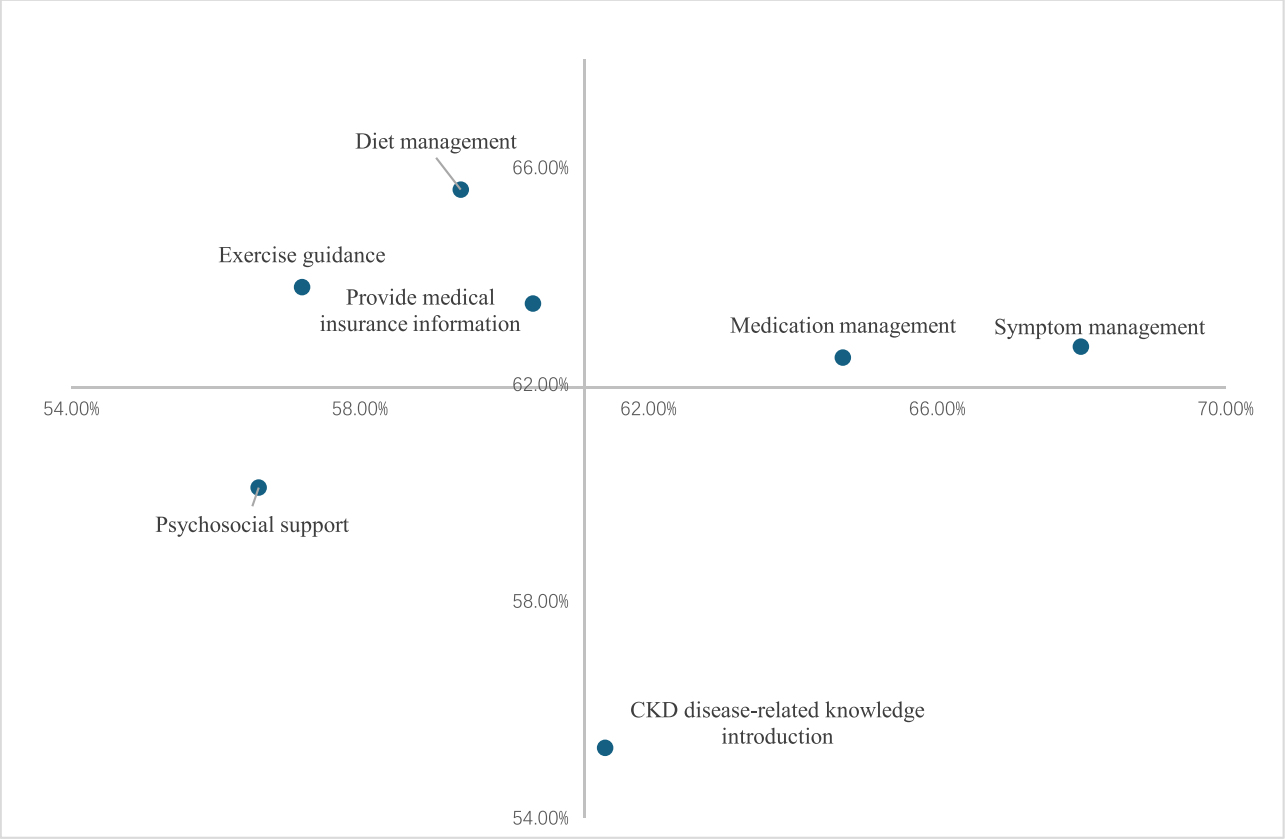

Figure 2 Better–Worse matrix of self-management needs among patients with chronic kidney disease and low e-health literacy. Each point represents one self-management feature and is positioned according to its Better coefficient (y-axis) and the absolute magnitude of its Worse coefficient (x-axis). The reference lines indicate the mean Better and Worse values, which divide the plot into Kano quadrants. In the low e-health literacy group, CKD disease-related knowledge introduction was classified as a must-be attribute; symptom management and medication management as one-dimensional attributes; diet management, exercise guidance, and provision of medical insurance information as attractive attributes; and psychosocial support as an indifferent attribute.
Abbreviation: CKD, chronic kidney disease.

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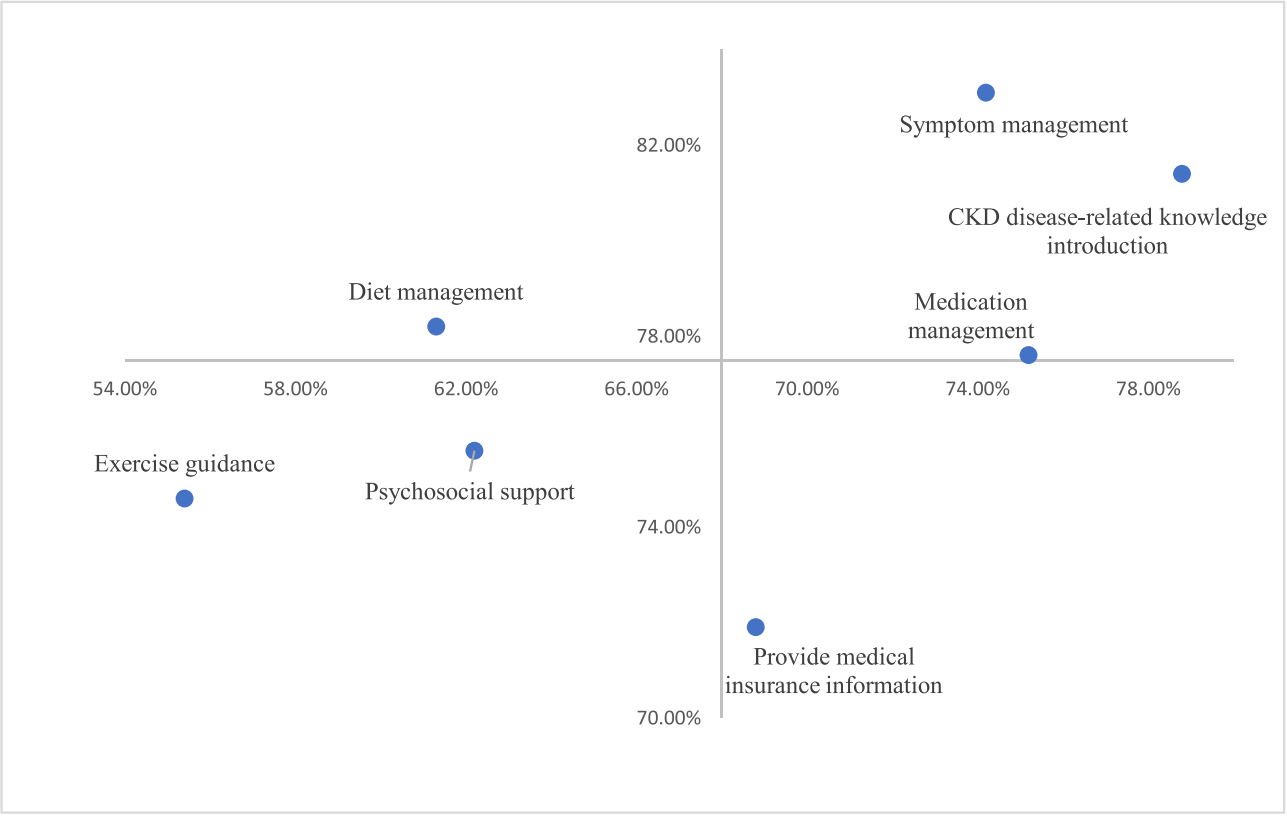

Figure 3 Better–Worse matrix of self-management needs among patients with chronic kidney disease and high e-health literacy. Each point represents one self-management feature and is positioned according to its Better coefficient (y-axis) and the absolute magnitude of its Worse coefficient (x-axis). The reference lines indicate the mean Better and Worse values, which divide the plot into Kano quadrants. In the high e-health literacy group, provision of medical insurance information was classified as a must-be attribute; CKD disease-related knowledge introduction, symptom management, and medication management as one-dimensional attributes; diet management as an attractive attribute; and exercise guidance and psychosocial support as indifferent attributes.
Abbreviation: CKD, chronic kidney disease.

Based on the division of attributes and ASC coefficient outlined in Supplementary Table 2 and Figure 3, the prioritised ranking of self-management needs among CKD patients with high e-health literacy was as follows: provide medical insurance information ranked highest, followed by the CKD disease-related knowledge introduction, symptom management, medication management, diet management, psychosocial support and exercise guidance.

Evaluation of the Attributes of UI Needs Using Kano Model

Low e-Health Literacy Group

The survey results from Supplementary Table 3, utilising the Kano model for CKD patients with low e-health literacy, reveal key insights into mobile medical program UI preferences. The feature simplifying data entry process, with a Better coefficient of 54.2%, significantly boosted user satisfaction. In contrast, the absence of privacy protection, with a Worse coefficient of −60.6%, greatly reduced satisfaction. One-dimensional attributes identified include simplifying data entry process, simplify the function, number of buttons, beginner navigation and simplify in-app navigation. Buttons/ICONS are suitably sized and spaced, keep all button sizes and labels consistent, and use colour as a tool to classify different groups of options/ICONS were identified as indifferent attributes. Attractive attributes included appropriate text size, while privacy protection was deemed a must-be attribute, critical for user satisfaction (Figure 4).

According to the attribute partition and ASC coefficient Supplementary Table 3 and Figure 4, the priority order of UI requirements was as follows: privacy protection, followed by simplifying the data entry process, simplify the function and number of buttons, and simplify in-app navigation. Next came beginner navigation, text size appropriate, use colour as a tool to classify different groups of options/ICONS, keep all button sizes and labels consistent, and finally, buttons/ICONS are suitably sized and spaced.

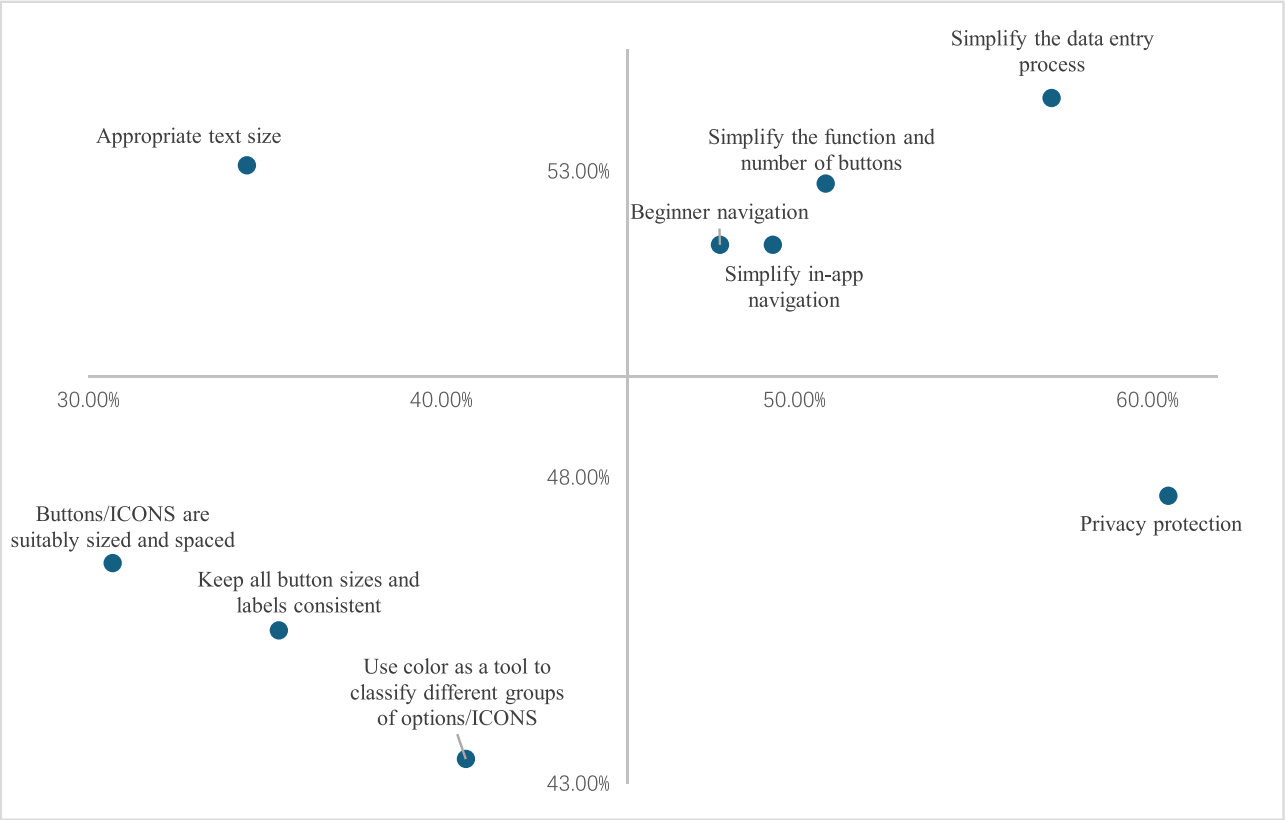

Figure 4 Better–Worse matrix of user interface needs among patients with chronic kidney disease and low e-health literacy. Each point represents one user interface feature and is positioned according to its Better coefficient (y-axis) and the absolute magnitude of its Worse coefficient (x-axis). The reference lines indicate the mean Better and Worse values, which divide the plot into Kano quadrants. In the low e-health literacy group, privacy protection was classified as a must-be attribute; simplifying the data entry process, simplifying in-app navigation, simplifying the function and number of buttons, and beginner navigation as one-dimensional attributes; appropriate text size as an attractive attribute; and suitably sized/spaced buttons or icons, consistent button sizes and labels, and use of colour to classify different groups of options or icons as indifferent attributes.
Abbreviation: CKD, chronic kidney disease.

High e-Health Literacy Group

The Kano model survey results for CKD patients with high e-health literacy in Supplementary Table 4 revealed that a simplified data entry process increases user satisfaction by 79.7%. Conversely, the absence of privacy protection reduces satisfaction by 58.3%. The simplifying the data entry process and in-app navigation were identified as one-dimensional attributes. Buttons/ICONS are suitably sized and spaced, simplify the function and number of buttons, beginner navigation, and keep all button sizes and labels consistent were identified as indifferent attributes. Attractive attributes include use colour to classify options/icons and appropriate text sizes. Privacy protection was also considered a must-be attribute (Figure 5).

According to the attribute partition and ASC coefficient in Supplementary Table 4 and Figure 5, the priority order of UI requirements was: privacy protection, followed by simplify data entry process and simplify in-app navigation, then text size appropriate, use colour as a tool to classify different groups of options/ICONS, simplify the function and number of buttons, keep all button sizes and labels consistent, buttons/ICONS are suitably sized and spaced, and finally, beginner navigation.

Discussion

The results of this study provide valuable insights into the self-management needs and user interface requirements for the mHealth app using the Kano model among CKD patients. The identification of must-be, one-dimensional, attractive, indifferent, and reverse allows developers to focus on essential features that meet patients' expectations and improve overall satisfaction. The prioritization of self-management needs enables resource allocation and targeted interventions

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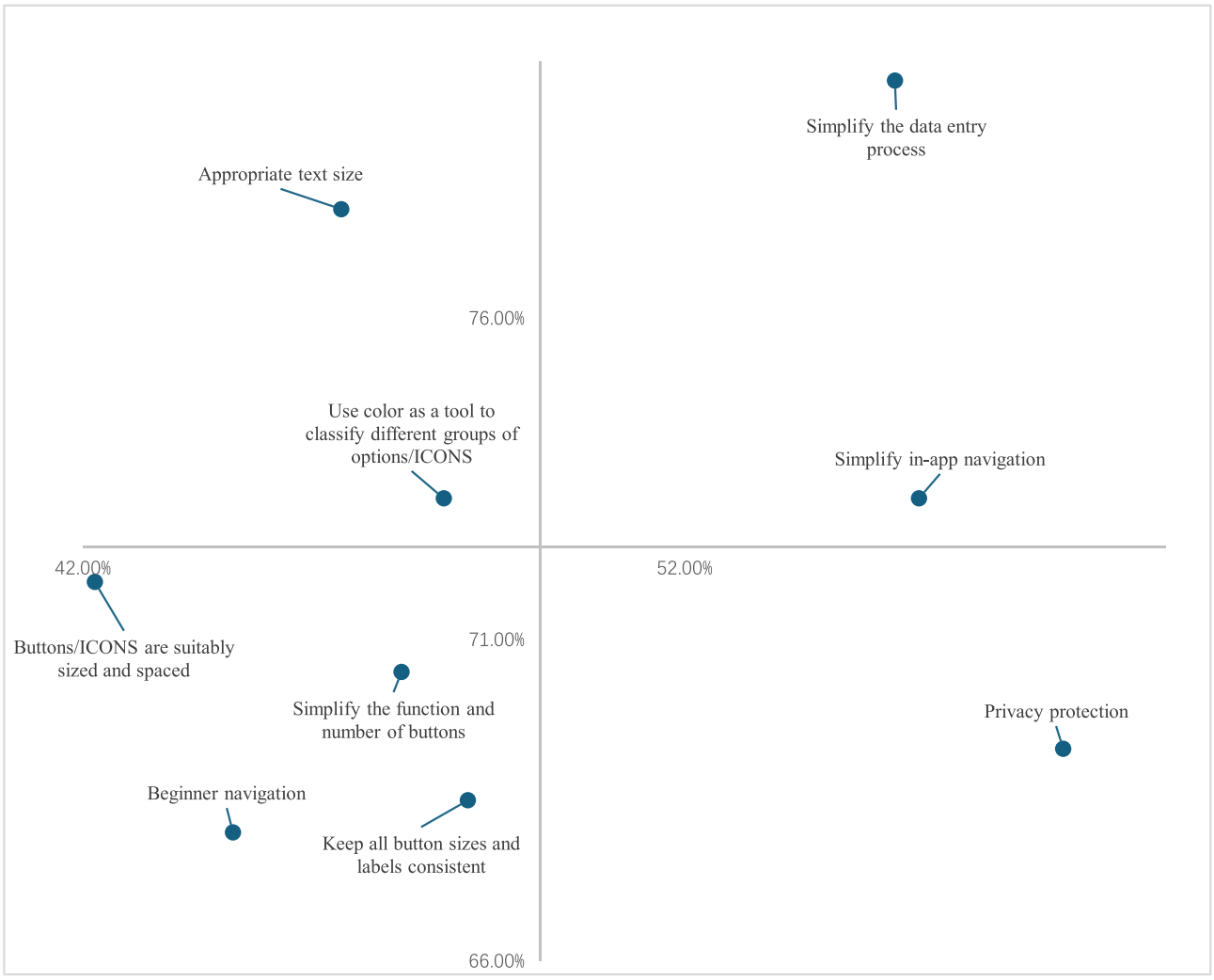

Figure 5 Better–Worse matrix of user interface needs among patients with chronic kidney disease and high e-health literacy. Each point represents one user interface feature and is positioned according to its Better coefficient (y-axis) and the absolute magnitude of its Worse coefficient (x-axis). The reference lines indicate the mean Better and Worse values, which divide the plot into Kano quadrants. In the high e-health literacy group, privacy protection was classified as a must-be attribute; simplifying the data entry process and simplifying in-app navigation as one-dimensional attributes; appropriate text size and use of colour to classify different groups of options or icons as attractive attributes; and suitably sized/spaced buttons or icons, simplifying the function and number of buttons, beginner navigation, and consistent button sizes and labels as indifferent attributes.
Abbreviation: CKD, chronic kidney disease.

based on patients' literacy levels. Moreover, understanding the UI requirements enhances app usability and accessibility for diverse user groups.

Must-Be Attributes

In this study, must-be attributes for CKD patients with low e-health literacy included the introduction of disease-related knowledge and privacy protection, while for those with high e-health literacy, must-be attributes were the provision of medical insurance information and privacy protection. These features significantly increased patient satisfaction. Previous research indicated that patients with limited e-health literacy crucially need to understand their condition to actively manage their health and communicate with healthcare providers.[35] For the predominantly advanced-stage CKD population in this sample, understanding complex disease information is particularly critical given their intensive self-management demands, such as dialysis preparation and comorbidity management. For low e-health literacy patients, providing CKD-related disease knowledge emerged as a foundational requirement, aligning with evidence that basic health literacy was pivotal for engagement in self-care among underserved populations.[36] In contrast, high-literacy users

prioritized medical insurance information, reflecting their need to navigate complex healthcare systems,[37] a concern that becomes especially salient for advanced-stage CKD patients facing substantial healthcare costs and insurance coverage decisions related to dialysis and transplantation.

Besides, CKD patients with both low and high e-health literacy identified privacy protection as a critical need. This consensus likely stems from the fact that in mHealth apps, privacy protection was essential to maintain the confidentiality of health information, which in turn builds trust, enhanced user engagement, ensured compliance with privacy laws, and reduced the risk of data breaches.[38] These aspects were vital for fostering effective self-care and improving health outcomes in individuals managing chronic conditions.[39]

One-Dimensional Attributes

One-dimensional attributes directly affect user satisfaction in the Kano model.[40] In this study, symptom and medication management were identified as such attributes for CKD patients with low e-health literacy, which is consistent with a study highlighting their reliance on structured guidance.[41] For those with high e-health literacy, symptom management and the introduction of CKD disease-related knowledge were key, suggesting their preference for deeper engagement with clinical data.[42] The prominence of symptom and medication management as one-dimensional attributes likely reflects the advanced disease stage of the sample, as patients with advanced-stage CKD typically experience significant symptom burdens including fatigue, pain, pruritus, and fluid overload, while managing complex medication regimens involving phosphate binders, erythropoiesis-stimulating agents, and antihypertensive medications.[43] Effective symptom management not only enhances life participation but also improves health-related quality of life by reducing the burden of kidney disease.[43] Additionally, medication management was critical for patients to maintain treatment adherence and prevent disease progression.[44] Patients with limited e-health literacy may struggle to understand complex medication schedules, potential side effects, and the importance of adherence, highlighting the need for simplified and accessible medication information within mHealth apps.[45]

In terms of UI requirements for mHealth apps, key elements like simplifying data entry, in-app navigation, button functionality, and beginner navigation are critical for enhancing user satisfaction. This aligns with previous research on mHealth app usability.[46] Specifically, beginner navigation aids are essential for users with limited experience or low e-health literacy, as clear instructions and guided tools help them navigate and effectively use the app.[47] High e-literacy patients prioritized streamlined data entry, aligning with their preference for efficiency to follow-up clinical data.[42] For advanced-stage CKD patients who frequently monitor symptoms, fluid intake, and laboratory values, efficient data entry becomes particularly important to reduce documentation burden while maintaining comprehensive health tracking.[48] These features collectively improve ease of use, supporting better self-management and overall satisfaction for CKD patients.

Attractive Attributes

Attractive attributes in mHealth apps were features that exceed expectations and significantly enhance satisfaction. In this study, diet management and exercise guidance, along with providing medical insurance information, were identified as attractive attributes for CKD patients with low e-health literacy. For those with high e-health literacy, diet management stood out as an only attractive attribute. These findings mirror the efficacy of personalized lifestyle interventions in CKD care.[49] Evidence from previous studies confirms the effectiveness of mHealth apps in managing diet and physical activity for CKD patients.[50] Lifestyle modifications, including a healthy diet and physical activity, were recommended alongside pharmacological treatments to improve cardiometabolic health and preserve kidney function in CKD patients.[51] For advanced-stage CKD patients, dietary management often involves complex restrictions on phosphorus, potassium, and fluid intake, making attractive attributes like diet management tools potentially valuable enhancements that could improve adherence and quality of life beyond basic care requirements.[52]

In this study, appropriate text size was identified as an attractive attribute for CKD patients, contrasting with previous research which classified it as a must-be attribute.[53] This difference may be attributed to the younger age (range 18 to 54 years old) of participants in this study, who likely have milder visual impairments compared to older populations.[54] Interestingly, using colour to classify options/icons was seen as attractive for patients with high e-health literacy. Colour

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coding could improve navigation and comprehension by providing visual cues that make it easier for users to identify different categories or importance levels of information.[55]

Indifferent Attributes

Indifferent attributes are those that do not significantly impact patient satisfaction. Psychosocial support was identified as an indifferent attribute for CKD patients, despite the potential stress, anxiety, and depression linked with CKD diagnosis, treatment, and lifestyle changes.[56] This indifference may stem from the variability in the quality and efficacy of psychosocial support within mHealth apps, as reported by Firth et al who found that effective psychosocial interventions are often limited in these applications.[57] Patients may prefer in-person interactions, which they perceive as more effective and personal. The classification of psychosocial support as indifferent among predominantly advanced-stage patients is noteworthy, as this population faces substantial psychological burdens including mortality concerns, treatment decisional conflict, and lifestyle disruptions.[58] This finding may reflect inadequate current mHealth psychosocial features rather than genuine lack of need, suggesting opportunities for innovation in this domain. Additionally, CKD patients with high e-health literacy may find exercise guidance indifferent, this may due to exercise recommendations maybe too generic or not tailored to individual needs, patients might feel that the guidance does not address their specific conditions or preferences.[59] Also, patients with high e-health literacy might critically evaluate the information provided. If the guidance does not adequately explain the benefits of exercise or how it can improve their health outcomes, they may disregard it.[60]

In terms of UI requirements for CKD patients, suitably sized and spaced buttons/icons and consistent button sizes and labels were seen as indifferent attributes for both groups. While enhancing the app's aesthetic appeal was beneficial, it was crucial to priorities functionality, especially for those with low e-health literacy who preferred practicality, ease of use, and clear information presentation over visual design.[53] A user-centered mHealth app should be straightforward and easy to navigate to prevent user errors such as accidental presses on the wrong icons.[61] This focus on usability and accessibility could significantly improve the effectiveness of the mHealth app.

Reverse Attributes

Reverse attributes referred to features or services that, if provided, could decrease patient satisfaction. In this study, no reverse attributes were identified for CKD patients with either low or high e-health literacy, indicating that all evaluated features generally contributed positively to patient satisfaction.

Implications

These findings support a tiered, hospital-embedded design strategy for CKD mHealth apps in China. Because privacy protection was a must-be attribute in both literacy groups, secure authentication, transparent consent, and hospital-governed data management should be treated as baseline requirements rather than optional features.[62] For patients with lower e-health literacy, the first-release interface should prioritize disease education, symptom and medication management, simplified navigation, fewer buttons, beginner guidance, and appropriate text size.[37] For patients with higher e-health literacy, the core package should combine medical insurance information with efficient data entry, streamlined navigation, and color-coded displays that speed interpretation without increasing cognitive burden.[31] Given that most participants had advanced-stage CKD, symptom, medication, and diet modules should focus on high-burden issues such as fatigue, pruritus, fluid management, and renal dietary restrictions.[46] In the Chinese context, implementation is likely to be more feasible if these functions are embedded within hospital-affiliated internet-hospital or CKD follow-up services, where they can be linked to outpatient review, laboratory follow-up, medication refill, and insurance navigation.[63] At the same time, uneven e-health literacy among older Chinese adults, urban-rural disparities in internet-based healthcare use, and variable privacy compliance of internet-hospital apps suggest that deployment should include nurse-led onboarding, family support, and low-bandwidth workflows, rather than relying on a standalone app alone.[64]

Limitations

While the findings of this study provide valuable insights into the self-management needs of CKD patients with varying e-health literacy, it is crucial to recognize the limitations inherent in this study. Firstly, these results are based on a specific sample predominantly comprising advanced-stage CKD patients; therefore, generalizability to earlier stages should be interpreted with caution. Future research should aim to validate these findings across larger and more diverse populations, including patients across all CKD stages, to enhance the external validity and generalizability of the results. Second, the cross-sectional design prevents causal inferences about long-term app engagement. Longitudinal studies tracking how user preferences evolve with sustained app use and potential improvements in e-health literacy would provide valuable insights for adaptive design strategies, particularly for advanced CKD patients whose clinical status and self-management needs may change rapidly. Third, the absence of qualitative data restricts insight into why certain features were preferred, therefore, conducting qualitative studies to explore CKD patients' lived experiences and perspectives could yield deeper insights into their self-management challenges and preferences.[65] Fourth, the reliance on self-reported data introduces potential response bias, as participants may have provided socially desirable responses or may have had difficulty accurately assessing their own preferences for features, they have never experienced. Finally, the dichotomization of e-health literacy scores, while methodologically necessary for group comparisons, may obscure important variations within literacy groups and may misclassify participants near the threshold.[66] Fifth, although the hospital-level ICC for the eHealth literacy score was very low, residual center-level effects cannot be entirely excluded. As this study used the Kano model primarily for descriptive classification and prioritization, clustering was not further modelled in the Kano-derived results. Therefore, the literacy-stratified findings should be interpreted with caution. Future multicenter studies with more sites and cluster-adjusted analyses are needed to confirm the robustness and generalizability of these findings.

Conclusion

The results of this study highlight the importance of addressing the self-management needs of CKD patients with varying levels of e-health literacy. The Kano model analysis revealed that for patients with low e-health literacy classified disease knowledge (must-be) and symptom management (one-dimensional) as critical, alongside simplified UI elements like privacy protection and guided navigation. While those with high e-health literacy prioritized medical insurance access (must-be) and disease management (one-dimensional), and preferred efficient interfaces and telehealth integration. By understanding the distinct categories of attributes identified through the Kano model, healthcare providers can develop user-centered interventions and strategies that promote effective self-management and improve patient satisfaction and outcomes.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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

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