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Identifying User-Centered Mobile Rehabilitation Needs After Total Knee Arthroplasty in Older Adults: An Exploratory Sequential Mixed-Methods Study Using the Technology Acceptance Model and Kano Model

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Abstract

Aims With the widespread implementation of enhanced recovery after surgery, postoperative rehabilitation following total knee arthroplasty (TKA) is increasingly extending from hospital to home. Mobile health technologies offer new opportunities to support continuous home-based rehabilitation; however, older adults have specific needs related to technology acceptance, age-friendly usability, safety management, and family involvement. This study aimed to identify postoperative mobile rehabilitation needs from the perspectives of older adults undergoing TKA, primary caregivers, and healthcare professionals, and to further evaluate how different functional requirements influence user satisfaction and dissatisfaction, thereby informing the design of patient-centered mobile rehabilitation solutions.

Methods and results An exploratory sequential mixed-methods design was employed at a tertiary hospital in southwestern China from September to December 2025. In the qualitative phase, semi-structured interviews were conducted with 10 older adults undergoing TKA, 7 primary caregivers, and 2 healthcare professionals, guided by the Technology Acceptance Model (TAM), and the data were analyzed using thematic analysis. Five themes were identified: individualized and phase-specific rehabilitation management; age-friendly interaction and intuitive operation; safety monitoring and continuous professional support; family collaboration and caregiving support; and a trustworthy, secure, and low-interference digital rehabilitation environment. These themes informed 17 functional requirements for mobile rehabilitation. In the quantitative phase, a paper-based Kano survey was conducted using convenience sampling. A total of 216 complete questionnaires were obtained; 208 were included in the main analysis and all 216 were used for sensitivity analysis. The Kano model, Better-Worse coefficients, and requirement sensitivity score (RS) were used for analysis. The Better-Worse matrix classified 4 requirements as one-dimensional, 6 as attractive, 5 as indifferent, and 2 as must-be. Fall-risk warning and video-guided rehabilitation exercises had the highest RS values (both 0.860), followed by online doctor consultation (0.832), personalized rehabilitation planning (0.824), and caregiver-side synchronization of the rehabilitation plan (0.817). System stability and privacy and security design were located in the must-be quadrant, whereas voice assistance and caregiver-side synchronization functions were mainly located in the attractive quadrant. Sensitivity analysis showed that the quadrant positions and RS rankings of all functions remained stable. Overall, the qualitative and quantitative findings were convergent and complementary: safety support, intuitive exercise guidance, personalized rehabilitation planning, and continuous professional support represented core rehabilitation needs; system stability, privacy and security, and age-friendly design served as foundational safeguards; and voice assistance and family collaboration had the potential to further improve the user experience.

Conclusion Mobile rehabilitation needs after TKA in older adults were hierarchical and context dependent. Future mobile rehabilitation programs should first ensure system stability, privacy and security, and age-friendly usability; prioritize safety support, intuitive exercise guidance, personalized rehabilitation planning, and continuous professional support; and configure voice assistance and caregiver collaboration according to patients' digital capabilities and available family support. Combining TAM-guided qualitative needs identification with Kano and Better-Worse analyses can provide a patient-centered basis for tiered configuration of mobile rehabilitation functions. These proposed configurations require further validation through prototype usability testing, multicenter

studies, and prospective interventions to establish their implementation feasibility and clinical effectiveness.

Keywords Total knee arthroplasty; Older adults; Mobile rehabilitation; Mobile health; Mixed methods; Kano model; Technology acceptance model

1 Introduction

Knee osteoarthritis is a common degenerative musculoskeletal disorder among older adults, and its burden continues to increase with population aging. The Global Burden of Disease study estimated that approximately 595 million people worldwide had osteoarthritis in 2020 and projected that the number of knee osteoarthritis cases would increase by approximately 74.9% by 2050 compared with 2020 [1]. Total knee arthroplasty (TKA) is an important treatment for end-stage knee osteoarthritis, but sustained postoperative rehabilitation remains necessary to restore joint function and mobility. With the widespread adoption of enhanced recovery after surgery (ERAS), the postoperative length of stay after TKA has shortened substantially [2]. Earlier discharge requires patients to assume responsibility for self-exercise and home care sooner; qualitative evidence indicates that patients following fast-track pathways may still experience concerns about symptoms, difficulties with rehabilitation, and ongoing care needs during discharge preparation [3]. A systematic review by Konnyu et al. [4] found that different rehabilitation approaches after TKA generally produced similar improvements in pain, range of motion, and activities of daily living, although the strength of the available evidence remained limited. A systematic review and meta-analysis by Zhao et al. [5] further found no significant differences between home-based and outpatient rehabilitation in major functional outcomes or safety, with comparable quality of life and patient satisfaction, while home-based rehabilitation was more cost-effective. Therefore, maintaining continuity between in-hospital and home-based rehabilitation while shortening hospital stays remains an important issue in postoperative TKA rehabilitation management.

The development of mobile health (mHealth) and telerehabilitation provides new opportunities to extend postoperative TKA rehabilitation from hospital to home. Digital health technologies can support remote health management, home monitoring, and personalized feedback and have considerable potential for home-based health management in older adults [6]. A systematic review by Raje et al. [7] found that digital technologies can support exercise interventions and both objective and subjective rehabilitation assessments after TKA, although the overall quality of evidence remains low to moderate. A meta-analysis by Tsang et al. [8] found that telerehabilitation achieved pain and physical function outcomes comparable to conventional face-to-face rehabilitation while reducing healthcare resource use and related costs. A systematic review and meta-analysis by Özden and Sarı [9] further suggested that mobile application-supported rehabilitation may offer benefits for pain, knee range of motion, and functional recovery. In addition, a randomized controlled trial by Zhao et al. [10] found that smartphone application-supported telerehabilitation was superior to conventional home rehabilitation combined with outpatient guidance for some short-term range-of-motion and functional

outcomes. A multicenter randomized trial by Crawford et al. [11] showed that rehabilitation management based on smartphones and smartwatches could serve as a feasible alternative to traditional face-to-face physical therapy. Shim et al. [12] further showed that digital rehabilitation using augmented reality and real-time feedback achieved overall improvements in function, pain, and quality of life comparable to conventional rehabilitation. Jung et al. [13] reported that home-based rehabilitation combining wearable motion tracking with smartphone application feedback improved early postoperative pain, stiffness, function, and quality of life. A systematic review of randomized controlled studies by Gordon et al. [14] also found that smartphone applications and wearable devices may improve adherence, functional recovery, and patient satisfaction after TKA and may offer potential cost savings. Collectively, these studies suggest that digital rehabilitation may not only maintain or improve postoperative clinical outcomes but may also reduce healthcare resource use and improve patient engagement and access to rehabilitation. However, clinical feasibility or effectiveness does not necessarily ensure that patients are willing to adopt and continue using digital rehabilitation, nor does it directly indicate how individual functions should be configured.

Accordingly, recent research has increasingly examined the practical needs for mobile rehabilitation after joint arthroplasty from the patient perspective. Qualitative studies have shown that patients expect mobile applications to support rehabilitation self-management, facilitate contact with healthcare professionals and peers, and provide emotional support [15]. Patients who completed mobile application-based rehabilitation programs after joint arthroplasty also reported that mobile rehabilitation could improve access to healthcare, support postoperative recovery, foster supportive relationships, and facilitate rehabilitation learning, while longer-term implementation still requires further optimization [16]. A 2024 qualitative systematic review synthesized the experiences of patients undergoing telerehabilitation after hip or knee arthroplasty into needs for knowledge and communication, accessible and high-quality rehabilitation services, positive psychological experiences, and practical challenges encountered during telerehabilitation [17]. A multistakeholder study of a smartphone-based telerehabilitation tool for TKA likewise found that both patients and physiotherapists valued ease of use, intuitive exercise guidance, recovery tracking, timely feedback, and access to professional support when needed [18]. Booth et al. [19] reported that most patients undergoing joint arthroplasty perceived remote monitoring and app-based rehabilitation as easy to use and motivating, and most preferred technology-assisted rehabilitation combined with face-to-face care rather than complete replacement of conventional rehabilitation. During development of a mobile rehabilitation tool after knee arthroplasty, Pritwani et al. [20] further found that patients and family caregivers placed high value on exercise videos, rehabilitation information, video consultations, caregiver support, and personalized treatment plans; limited digital literacy and lack of family

assistance remained important barriers to actual use. At the same time, electronic health literacy among older adults is highly heterogeneous and is influenced by demographic and social factors [21]. Research on mobile application design for older adults also emphasizes simplified navigation, larger interactive controls, optimized visual presentation, and the provision of assistance and training [22]. Therefore, designing mobile rehabilitation for older adults after TKA requires not only identification of specific rehabilitation support needs but also an understanding of how users perceive digital functions, whether they are willing to adopt them, and what conditions support sustained use.

The Technology Acceptance Model (TAM) proposes that perceived usefulness and perceived ease of use are central determinants of technology acceptance and behavioral intention [23]. A meta-analysis of healthcare technology acceptance among older adults further showed that perceived usefulness, perceived ease of use, and social influence were significantly associated with intention to use, with perceived usefulness and perceived ease of use playing particularly important roles in explaining technology acceptance [24]. A systematic scoping review of digital health technology acceptance among older adults also identified perceived value, ease of use, social support, health status, and previous digital experience as factors influencing adoption [25]. A systematic review by Kiani et al. [26] found that age, educational level, self-efficacy, social support, previous use experience, and usability barriers were associated with technophobia among older adults, suggesting that simply providing digital functions is insufficient to ensure sustained use. Therefore, using TAM to guide semi-structured interviews allows the inquiry to move beyond asking only what functions patients need and to explore why those functions are perceived as useful, whether they are easy to operate, and which factors may facilitate or hinder continued use. Given that home-based rehabilitation after TKA in older adults often requires both family assistance and professional support, the qualitative phase of this study included patients, primary caregivers, and healthcare professionals and developed interview guides around perceived usefulness, perceived ease of use, intention to use, and practical rehabilitation support needs.

However, TAM primarily explains the process of technology acceptance and does not itself determine the requirement attributes of different mobile rehabilitation functions or their asymmetric effects on satisfaction and dissatisfaction. The Kano model compares users' responses when a function is present versus absent and classifies requirements as must-be, one-dimensional, attractive, indifferent, reverse, or questionable [27]. Based on Kano classification, Better-Worse coefficients can separately quantify the increase in satisfaction when a function is provided and the increase in dissatisfaction when it is absent, while a two-dimensional matrix can further describe the position of each requirement [28]. To capture the overall sensitivity of satisfaction and dissatisfaction responses

to a requirement, this study further used the requirement sensitivity score (RS), calculated from Better and |Worse|; RS was used throughout to avoid confusion with the Kano reverse category (R) [29]. The Kano model has been applied to studies of telenursing needs among older adults [30] and healthcare service needs in nursing-related populations [31]. A recent mixed-methods study in BMC Nursing also showed that combining qualitative interviews with Kano and Better-Worse analyses can simultaneously identify need content, effects on satisfaction, and implications for service configuration [28]. Accordingly, the present study linked TAM-guided qualitative needs identification with Kano and Better-Worse analyses to address two complementary questions: why users may be willing or unwilling to use mobile rehabilitation, and how different mobile rehabilitation functions should be classified and configured.

On this basis, an exploratory sequential mixed-methods design was used. First, semi-structured interviews guided by TAM were conducted with older adults undergoing TKA, primary caregivers, and healthcare professionals to identify needs that could be translated into mobile rehabilitation functions, with attention to perceived usefulness, perceived ease of use, intention to use, and practical rehabilitation support. The functional items generated in the qualitative phase were then incorporated into a Kano questionnaire, and Better-Worse coefficients, two-dimensional quadrant analysis, and RS were used to evaluate requirement attributes, effects on satisfaction, and relative sensitivity. The study aimed to: (1) explore the practical needs, user experiences, and potential barriers related to postoperative mobile rehabilitation among older adults undergoing TKA from the perspectives of patients, primary caregivers, and healthcare professionals; (2) develop mobile rehabilitation functional items from the qualitative findings and classify and evaluate these needs using the Kano model and Better-Worse coefficients; and (3) integrate the qualitative and quantitative findings to inform a mobile rehabilitation approach that considers clinical value, age-friendly usability, and patient preferences.

2 Methods

2.1 Study design and setting

An exploratory sequential mixed-methods design was used [32]. Data were collected from September to December 2025 in the Department of Orthopedics at the Affiliated Hospital of North Sichuan Medical College in southwestern China. The study began with a qualitative phase in which semi-structured interviews, guided by TAM, were conducted with older adults undergoing TKA, primary caregivers, and healthcare professionals to identify practical mobile rehabilitation needs, experiences of technology acceptance, and implementation-related issues. Needs that could be translated into digital functions were then consolidated into Kano questionnaire items for the

quantitative survey. The Kano model and Better-Worse coefficients were used to evaluate the attributes of each functional requirement, its effects on satisfaction, and requirement sensitivity. Finally, qualitative themes and Kano/Better-Worse findings were integrated during the interpretation phase to develop a comprehensive needs framework for mobile rehabilitation function design.

2.2 Qualitative phase

2.2.1 Participants

Purposive sampling was used to recruit participants who could provide information from different rehabilitation and use contexts, including older adults undergoing TKA, primary caregivers, and healthcare professionals. Patient inclusion criteria were: (1) age ≥60 years; (2) primary unilateral TKA; (3) within 4 weeks after surgery; (4) clear consciousness and basic verbal communication ability; and (5) willingness to participate. Patients with severe cognitive impairment or mental disorders, or with serious postoperative complications requiring reoperation, were excluded. Primary caregivers were eligible if they were: (1) aged ≥18 years; (2) primarily responsible for care during the patient's first 4 postoperative weeks; and (3) willing to participate. Healthcare professionals were eligible if they had ≥5 years of clinical experience in orthopedics or rehabilitation. Data from patients and primary caregivers were used mainly to identify direct needs during home-based rehabilitation, while healthcare professionals contributed perspectives on professional support, clinical coordination, and implementation feasibility.

2.2.2 Development of the interview guides

Separate semi-structured interview guides were developed specifically for this study for patients, primary caregivers, and healthcare professionals according to their roles; these guides had not been published elsewhere. Guided by TAM [23], the interview guides included core questions on perceived usefulness, perceived ease of use, and intention to use, together with open-ended questions to identify support needs during postoperative home rehabilitation. Patient interviews focused on previous rehabilitation and digital tool use, expected mobile rehabilitation functions, preferred ways of learning exercises, needs for reminders and professional support, interface and operation preferences, willingness to continue using the tool, and other rehabilitation support needs. Primary caregiver interviews focused on difficulties in home care, ways of helping patients use digital tools, and desired collaborative support. Healthcare professionals were asked about the clinical value of mobile rehabilitation, age-friendly design requirements, risk management, professional feedback, and implementation workload. The full English versions of the three interview guides are provided in Supplementary File 1.

2.2.3 Data collection

Before the interviews, all participants received information about the study purpose, interview content, privacy protection, the right to withdraw, and audio-recording arrangements. Written informed consent was obtained, including consent for audio recording. Interviews were conducted by researchers trained in qualitative methods and were performed either face to face or remotely according to participant circumstances, with each interview lasting approximately 30-40 min. The semi-structured guide provided the overall framework, and follow-up questions were used to clarify specific use contexts, functional preferences, and the reasons underlying particular needs. Data collection and preliminary analysis proceeded concurrently. Data saturation was considered reached when subsequent interviews generated no new codes or categories and no longer provided substantive additions to the meaning, boundaries, or relationships of existing themes [33]. All data were anonymized, and patients, primary caregivers, and healthcare professionals were coded as P, F, and N, respectively, followed by a number. After the audio recordings were transcribed, the research team checked each transcript against the original recording and corrected unclear wording or possible transcription errors to ensure consistency with participants' original accounts.

2.2.4 Data analysis

Thematic analysis was conducted [34], with NVivo 15.3 (Lumivero) used to support data management, coding, and theme development. Two researchers trained in qualitative methods repeatedly read all transcripts and independently generated initial codes after becoming familiar with the data while retaining the original context. Coding results were then compared, and disagreements were resolved through discussion. Related codes were grouped into categories and candidate themes, with repeated return to the source data to verify consistency between the themes and participants' accounts. Throughout the analysis, similarities, complementary perspectives, and contrasting views among patients, primary caregivers, and healthcare professionals were compared. Divergent evaluations of the same function were retained, including differences in views on follow-up reminders, dietary guidance, and willingness to use digital tools. Coding, category development, and theme generation were supervised and regularly reviewed by the research team to enhance credibility and auditability. The primary purpose of the qualitative analysis was to identify real-world needs and provide a content basis for generating subsequent functional items.

2.2.5 Development of functional items for the Kano questionnaire

Specific needs that recurred in the qualitative data and could be translated into mobile rehabilitation functions were consolidated, with similar expressions merged and converted into functional items. This process generated 17 functional requirements corresponding to five qualitative themes: individualized and phase-specific rehabilitation management; age-friendly interaction and

intuitive operation; safety monitoring and continuous professional support; family collaboration and caregiving support; and a trustworthy, secure, and low-interference digital rehabilitation environment. Before the formal survey, a small pilot test was conducted to assess older participants' understanding of the functional descriptions, item logic, and response burden. Wording and examples were refined according to their feedback. The five qualitative themes and their corresponding functional items are summarized in Table 1.

Table 1 Qualitative themes and functional items in the Kano questionnaire

No.	Qualitative theme	Functional requirement
1	Age-friendly interaction and intuitive operation	Simple operation
2	Age-friendly interaction and intuitive operation	Font adjustment
3	Age-friendly interaction and intuitive operation	Visual accessibility design
4	Trustworthy, secure, and low-interference digital rehabilitation environment	Advertising
5	Trustworthy, secure, and low-interference digital rehabilitation environment	Privacy and security design
6	Trustworthy, secure, and low-interference digital rehabilitation environment	System stability
7	Individualized and phase-specific rehabilitation management	Personalized rehabilitation plan
8	Individualized and phase-specific rehabilitation management	Personal rehabilitation exercise record
9	Individualized and phase-specific rehabilitation management	Video-guided rehabilitation exercises
10	Family collaboration and caregiving support	Dietary recommendations
11	Age-friendly interaction and intuitive operation	Voice assistance
12	Safety monitoring and continuous professional support	Online doctor consultation
13	Safety monitoring and continuous professional support	Fall-risk warning
14	Safety monitoring and continuous professional support	Follow-up reminder
15	Individualized and phase-specific rehabilitation management	Postoperative rehabilitation exercise information
16	Family collaboration and caregiving support	Caregiver-side synchronization of the rehabilitation plan
17	Family collaboration and caregiving support	Caregiver-side synchronization of rehabilitation exercise progress

2.3 Quantitative phase

2.3.1 Participants and sample size

The quantitative phase used a cross-sectional, paper-based questionnaire survey. Convenience sampling was used to recruit older adults undergoing TKA who met the patient criteria described above and their primary caregivers at the study site. Primary caregivers were required to be aged ≥18 years and to have been actively involved in the patient's postoperative care. All respondents had to be able to understand the questionnaire and participate voluntarily. Patients and primary caregivers were enrolled as independent respondents; each participant completed only one questionnaire, and no patient-caregiver paired data were collected. Because no prior estimate of the proportion of participants with a given requirement was available for sample-size calculation, a single-population

proportion formula was used with p=0.50, α=0.05, and allowable error d=0.080, yielding a theoretical sample size of approximately 150. Allowing for approximately 10% invalid questionnaires, the minimum planned sample size was approximately 167. In total, 216 complete questionnaires were obtained.

2.3.2 Survey instrument and data collection

The study-specific questionnaire was developed for the present study and had not been published elsewhere. It consisted of two sections: general characteristics and the Kano functional requirements questionnaire. The general-characteristics section collected respondent role, sex, residence, age, marital status, occupation, living arrangement, educational level, monthly per capita household income, self-rated functional status, daily internet use, and familiarity with smartphones. The Kano section contained 17 functional requirements generated from the qualitative findings, each assessed with one functional and one dysfunctional question, for a total of 34 questions. For example, for personalized rehabilitation planning, participants were asked, “How would you feel if the mobile rehabilitation tool provided this function?” and “How would you feel if the mobile rehabilitation tool did not provide this function?” Each question used the standard five Kano response options: “I like it that way”, “It must be that way”, “I am neutral”, “I can live with it that way”, and “I dislike it that way” [27]. Before the formal survey, researchers used a standardized explanation to introduce the basic concept of a mobile rehabilitation tool and how to answer the Kano questions. For older patients with reading difficulties, researchers explained only the literal meaning of the question and did not suggest or induce any particular response. The full English version of the questionnaire is provided in Supplementary File 2.

2.3.3 Data quality control and sensitivity analysis

Paper questionnaires were first checked for completeness at the time of collection. After data entry, response patterns and internal logical consistency were reviewed according to a standardized data-quality procedure, with particular attention to repeated selection of the same response option, mechanically identical patterns across functional and dysfunctional items, and other response patterns lacking reasonable differentiation. A single irregular feature was not used as a direct exclusion criterion. A questionnaire was excluded only when multiple clearly abnormal response patterns were present simultaneously and the research team, after review, judged the response to be of low quality. Eight questionnaires were ultimately excluded because of clear multiple abnormal response patterns, leaving 208 for the main analysis. To assess robustness, all 216 complete questionnaires were included in a sensitivity analysis, and the Kano model and Better-Worse coefficient analyses were repeated to determine whether quadrant positions or RS rankings changed.

2.3.4 Kano and Better-Worse coefficient analysis

First, according to the standard Kano evaluation matrix, each pair of functional and dysfunctional responses was classified as must-be (M), one-dimensional (O), attractive (A), indifferent (I), reverse (R), or questionable (Q) [27], and the frequency of each attribute was calculated. Better and Worse coefficients were then calculated as Better=(A+O)/(A+O+M+I) and Worse=-(O+M)/(A+O+M+I), respectively; R and Q responses were excluded from these calculations [28]. A Better-Worse four-quadrant plot was constructed with |Worse| on the x-axis and Better on the y-axis, using the mean |Worse| and mean Better values across the 17 functions as the dividing lines. High Better and high |Worse| indicated the one-dimensional quadrant; high Better and low |Worse|, the attractive quadrant; low Better and low |Worse|, the indifferent quadrant; and low Better and high |Worse|, the must-be quadrant [28]. The requirement sensitivity score was further calculated as $RS=\sqrt{[Better^2+|Worse|^2]}$ to summarize the overall sensitivity of user experience when a requirement was present or absent [29]. A higher RS indicated greater combined sensitivity of satisfaction and dissatisfaction responses to that requirement. RS values and rankings were used only as supplementary indicators for functional configuration and were not interpreted independently of Kano attributes, Better-Worse quadrant positions, or the qualitative context.

2.4 Integration of mixed-methods findings

Qualitative and quantitative findings were integrated during the interpretation phase using a joint display [35]. First, the five qualitative themes were mapped to the 17 functional requirements derived from them. The Better-Worse quadrant, Better value, Worse value, and RS for each function were then displayed alongside the corresponding qualitative theme to compare convergence, complementarity, or divergence across the two phases and to generate mixed-methods meta-inferences. When a need was repeatedly emphasized in the qualitative interviews but appeared in the indifferent quadrant or received reverse evaluations in the Better-Worse matrix, its contextual interpretation was retained rather than being dismissed solely on the basis of the quantitative classification.

2.5 Ethical considerations

The study was approved by the Medical Ethics Committee of the Affiliated Hospital of North Sichuan Medical College (approval no. 2025ER297-1). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, and all participants provided written informed consent before participation.

3 Results

3.1 Qualitative findings

3.1.1 Participant characteristics

Nineteen participants took part in the semi-structured interviews, including 10 older adults undergoing TKA, 7 primary caregivers, and 2 healthcare professionals. Patients and primary caregivers provided direct information on experiences and needs during home-based rehabilitation, while healthcare professionals contributed perspectives on professional support, clinical coordination, and implementation feasibility. Coding and thematic analysis generated five major need themes.

3.1.2 Key themes

The qualitative analysis identified five themes related to postoperative mobile rehabilitation needs among older adults undergoing TKA: (1) individualized and phase-specific rehabilitation management; (2) age-friendly interaction and intuitive operation; (3) safety monitoring and continuous professional support; (4) family collaboration and caregiving support; and (5) a trustworthy, secure, and low-interference digital rehabilitation environment. These themes were subsequently translated into 17 functional requirements for the Kano questionnaire.

Theme 1: Individualized and phase-specific rehabilitation management

Patients, primary caregivers, and healthcare professionals repeatedly described the lack of a clear, specific training schedule that could change with the stage of recovery as one of the most immediate challenges of home-based rehabilitation. Patients wanted to know what exercises to perform each day, how much to do, how long to exercise, and when activity levels could be increased. Caregivers wanted to reduce the pressure of relying on their own judgment to determine exercise dosage. For learning exercises, most patients preferred videos demonstrating real people or clear visual materials and wanted to record daily exercise completion and changes in recovery.

> *"What I want most is a clear plan! Tell us what to practice each day and for how long, instead of leaving us to figure it out ourselves. At our age, we are afraid of doing it wrong!" (P1)*
>
> *"Each older patient needs an individualized rehabilitation plan that is adjusted dynamically according to feedback—but that would also substantially increase the clinical workload!" (N2)*

These findings generated functional requirements for personalized rehabilitation planning, a personal rehabilitation exercise record, video-guided rehabilitation exercises, and postoperative rehabilitation exercise information.

Theme 2: Age-friendly interaction and intuitive operation

Older patients varied considerably in their ability to use smartphones, vision, and operational proficiency. Participants generally wanted fewer operational steps, larger text and icons, a clear interface, and voice assistance. Some patients showed limited interest in mobile applications or video-

assisted functions or were unfamiliar with how to use them, indicating individual differences in acceptance of digital rehabilitation.

> *"The simpler the better! Ideally, I could tap an icon and the video would play straight away, without having to search around." (P1)*
>
> *"It has to be foolproof. One tap should start it directly—do not make them choose through multiple steps. Keep the interface to no more than three buttons, and make the text much larger." (N1)*

These findings generated functional requirements for simple operation, font adjustment, visual accessibility design, and voice assistance.

Theme 3: Safety monitoring and continuous professional support

Exercise safety was a central concern for both patients and caregivers. Patients worried about performing movements incorrectly, exercising excessively, or falling, while caregivers were concerned about their ability to determine whether pain, swelling, or restricted movement represented normal recovery. Participants wanted the mobile rehabilitation tool to provide safety prompts and alerts for abnormal situations and to facilitate contact with professionals when necessary. Preferences for follow-up reminders varied across patients.

> *"If I am doing a movement wrong, it needs to tell me!" (P1)*
>
> *"But the app is only an aid; it must never replace face-to-face consultation. Patients still need regular follow-up." (N2)*

These findings generated functional requirements for online doctor consultation, fall-risk warning, and follow-up reminders.

Theme 4: Family collaboration and caregiving support

Family members played an important role in home-based rehabilitation for older patients. Some patients needed family assistance to open the mini-program and to record or upload exercise videos. Caregivers wanted synchronized access to the patient's daily rehabilitation plan, completion status, and recovery progress. Some caregivers also requested professional guidance on diet, nutrition, and daily care. Healthcare professionals likewise considered coordination between patient- and caregiver-facing functions helpful for improving the practical usability of digital tools among older adults with limited digital skills.

> *"It would be best to have two interfaces: a caregiver side for remote monitoring and a simplified patient side." (N2)*

These findings generated functional requirements for dietary recommendations, caregiver-side synchronization of the patient's rehabilitation plan, and caregiver-side synchronization of the patient's rehabilitation exercise progress.

Theme 5: A trustworthy, secure, and low-interference digital rehabilitation environment

Participants considered long-term use of a mobile rehabilitation tool to depend on whether its content was professionally trustworthy, the system was stable, advertising was nonintrusive, and patients' health information was protected. Patients and caregivers generally preferred tools provided by hospitals or healthcare professionals and wanted smooth system performance, ongoing maintenance, and minimal commercial interference. Healthcare professionals were also concerned about the additional workload associated with backend feedback, content updates, and management of abnormal information.

> *"Data security and privacy are also important for older adults. Patients' health information should not be disclosed casually." (F4)*
>
> *"No ads!" (F2)*

These findings generated functional requirements related to advertising, privacy and security design, and system stability.

3.1.3 Development of Kano questionnaire items from the qualitative findings

Across the five themes, specific needs that recurred in the interviews and could be translated into mobile rehabilitation functions were consolidated and standardized, resulting in 17 Kano functional items. Each function was assessed using a functional and a dysfunctional question for Kano attribute classification, Better-Worse analysis, and requirement sensitivity assessment in the quantitative phase. Thus, the qualitative phase primarily served to identify needs and generate items, providing the content basis for subsequent quantitative evaluation.

3.2 Results of the Kano model and Better-Worse coefficient analyses

3.2.1 Participant characteristics and data quality

A total of 216 complete Kano questionnaires were obtained. After review of completeness and response quality, 8 questionnaires were classified as low quality because they simultaneously showed multiple clear abnormal response patterns and were excluded, leaving 208 questionnaires for the main analysis. The main-analysis sample included 63 patients (30.3%) and 145 family members or caregivers (69.7%); 81 participants were male (38.9%) and 127 were female (61.1%). Patients and family members/caregivers were treated as independent respondents and did not constitute patient-caregiver pairs. The median age of the main-analysis sample was 52 years (P25=37, P75=66; range 21-82 years). The median age was 72 years (P25=66, P75=76) among patients and 44 years (P25=35, P75=53) among family members/caregivers. Nine patients (14.3%) lived alone, and the median smartphone familiarity score was 4 (P25=3, P75=4). Thus, the quantitative findings reflect the

combined evaluation of mobile rehabilitation functions by two independent groups: patients and family members/caregivers.

All 34 functional and dysfunctional Kano items across the 17 requirement pairs were completed in the main-analysis sample. All 216 complete questionnaires were included in the sensitivity analysis to assess whether exclusion of the 8 low-quality questionnaires affected Better-Worse quadrant positions or RS rankings. The characteristics of the Kano questionnaire respondents included in the main analysis are summarized in Table 2.

Table 2 Characteristics of Kano questionnaire respondents (n=208)

Variable	Category or statistic	n (%) or statistic
Respondent role	Patient	63 (30.3)
	Family member or caregiver	145 (69.7)
Sex	Male	81 (38.9)
	Female	127 (61.1)
Age	Median (years; P25, P75)	52 (37, 66)
	Range	21-82
	<60 years	137 (65.9)
	≥60 years	71 (34.1)
Patient age	Median (years; P25, P75)	72 (66, 76)
Family member or caregiver age	Median (years; P25, P75)	44 (35, 53)
Living alone (patients, n=63)	Yes	9 (14.3)
	No	54 (85.7)
Smartphone familiarity (1-5 points)	Median (P25, P75)	4 (3, 4)

3.2.2 Better-Worse quadrant classification and requirement sensitivity

The mean Better value (0.718) and mean |Worse| value (0.266) across the 17 requirements were used as the four-quadrant cutoffs. The one-dimensional quadrant (O) included personalized rehabilitation planning, video-guided rehabilitation exercises, fall-risk warning, and follow-up reminders (4 requirements). The attractive quadrant (A) included dietary recommendations, voice assistance, online doctor consultation, postoperative rehabilitation exercise information, caregiver-side synchronization of the patient's rehabilitation plan, and caregiver-side synchronization of rehabilitation exercise progress (6 requirements). The indifferent quadrant (I) included simple operation, font adjustment, visual accessibility design, advertising, and a personal rehabilitation exercise record (5 requirements). The must-be quadrant (M) included privacy and security design and system stability (2 requirements).

Fall-risk warning and video-guided rehabilitation exercises had the highest RS values (both 0.860), followed by online doctor consultation (0.832), personalized rehabilitation planning (0.824), and caregiver-side synchronization of the patient's rehabilitation plan (0.817). System stability (0.807) and caregiver-side synchronization of rehabilitation exercise progress (0.806) also had relatively high RS values, whereas advertising had the lowest RS value (0.526). It should be noted that O/A/I/M in

the table denote quadrant positions in the two-dimensional Better-Worse matrix and are not equivalent to classifications based solely on the most frequent standard Kano attribute. In the standard Kano evaluation, advertising received 113 reverse (R) responses (54.3%), suggesting that the presence of advertising may reduce user experience; no questionable (Q) responses were recorded for any function. Accordingly, RS values should be interpreted together with Better-Worse quadrant positions and the qualitative findings when considering functional configuration. The complete Kano and Better-Worse results are presented in Table 3, and the distribution of the 17 functional requirements across the four quadrants is illustrated in Fig. 1.

Table 3 Kano model and Better-Worse analysis of mobile rehabilitation functional requirements (n=208)

No.	Functional requirement	M	O	A	I	R	Q	B-W quadrant	Better	Worse	RS	Rank
1	Simple operation	14	39	91	64	0	0	I	0.625	-0.255	0.675	16
2	Font adjustment	11	34	103	59	1	0	I	0.662	-0.217	0.697	15
3	Visual accessibility design	4	32	113	55	4	0	I	0.711	-0.176	0.732	14
4	Advertising	2	12	36	45	113	0	I	0.505	-0.147	0.526	17
5	Privacy and security design	8	67	71	58	4	0	M	0.676	-0.368	0.770	10
6	System stability	25	62	74	39	8	0	M	0.680	-0.435	0.807	6
7	Personalized rehabilitation plan	3	57	101	44	3	0	O	0.771	-0.293	0.824	4
8	Personal rehabilitation exercise record	3	49	94	60	2	0	I	0.694	-0.252	0.739	13
9	Video-guided rehabilitation exercises	6	58	109	35	0	0	O	0.803	-0.308	0.860	1
10	Dietary recommendations	4	48	103	53	0	0	A	0.726	-0.250	0.768	12
11	Voice assistance	1	45	112	49	1	0	A	0.758	-0.222	0.790	8
12	Online doctor consultation	3	52	112	41	0	0	A	0.788	-0.264	0.832	3
13	Fall-risk warning	5	62	103	37	1	0	O	0.797	-0.324	0.860	1
14	Follow-up reminder	6	51	100	50	1	0	O	0.729	-0.275	0.780	9
15	Postoperative rehabilitation exercise information	2	49	102	54	1	0	A	0.729	-0.246	0.770	10
16	Caregiver-side synchronization of the rehabilitation plan	3	49	111	43	2	0	A	0.777	-0.252	0.817	5
17	Caregiver-side synchronization of rehabilitation exercise progress	1	47	111	46	3	0	A	0.771	-0.234	0.806	7

Note. M = must-be; O = one-dimensional; A = attractive; I = indifferent; R = reverse; Q = questionable; B-W = Better-Worse; RS = requirement sensitivity score. The B-W quadrant indicates the position based on the mean Better and |Worse| cutoffs.

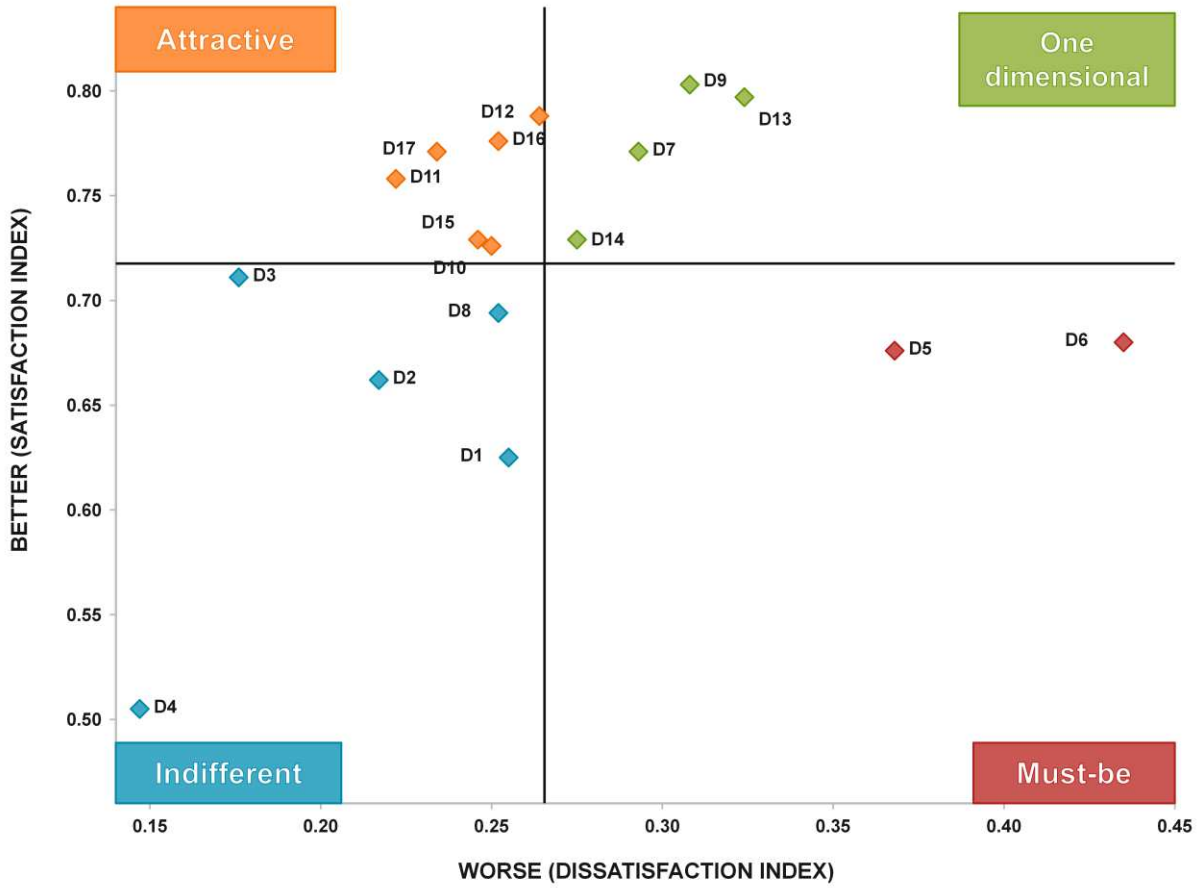


Fig. 1 Better-Worse four-quadrant plot of mobile rehabilitation functional requirements

Note. Numbers in the figure correspond to the functional requirement numbers in Table 3; dashed lines indicate the mean Better value of 0.718 and mean |Worse| value of 0.266.

3.2.3 Sensitivity analysis

After the 8 questionnaires excluded from the main analysis because of multiple abnormal response patterns were reintroduced, the Kano model and Better-Worse coefficient analyses were repeated using all 216 complete questionnaires. The mean Better value across the 17 requirements was 0.690 and the mean |Worse| value was 0.256. The Better-Worse quadrant positions of all 17 functions were identical to those in the main analysis of 208 questionnaires, with 4 one-dimensional, 6 attractive, 5 indifferent, and 2 must-be requirements. RS rankings were also unchanged (Spearman ρ=1.000). In the complete sample of 216 respondents, fall-risk warning (RS=0.828), video-guided rehabilitation exercises (RS=0.828), online doctor consultation (RS=0.801), personalized rehabilitation planning (RS=0.793), and caregiver-side synchronization of the patient's rehabilitation plan (RS=0.786) remained the top five requirements. These findings indicate that reintroducing the 8

low-quality questionnaires did not change the key quadrant classifications or requirement sensitivity rankings.

3.3 Integration of qualitative interviews with Kano and Better-Worse findings

The joint display integrating the qualitative findings with the Kano and Better-Worse results is presented in Table 4. Overall, the two phases were mainly convergent for core rehabilitation support and platform assurance. For age-friendly usability and family collaboration, the Better-Worse results expanded the qualitative findings. For follow-up reminders and dietary recommendations, the qualitative data revealed individual preference variation underlying the group-level quadrant classifications.

Table 4. Joint display integrating qualitative findings and Kano/Better-Worse results

Integrated domain	Qualitative findings	Kano and Better-Worse results	Meta-inference
Core rehabilitation support	• Phase-specific rehabilitation planning • Visual exercise instruction • Error correction and safety reminders • Continuous professional support	O: Personalized rehabilitation plan; video-guided rehabilitation exercise; fall-risk warning; follow-up reminder A: Online doctor consultation Highest RS: fall-risk warning 0.860; video-guided rehabilitation exercise 0.860; online doctor consultation 0.832	**Convergence:** Safety support, visual guidance, personalized planning, and professional support should be prioritized.
Age-friendly usability and family collaboration	• Simple operation • Large fonts and clear icons • Voice assistance • Family assistance and synchronization	**I:** Simple operation; font adjustment; visual accessibility design **A:** Voice assistance; caregiver-side synchronization	**Expansion:** Age-friendly interface features are foundational accessibility conditions despite an indifferent Kano classification; voice and family functions add value.
Platform assurance	• System stability • Professional and trustworthy content • Privacy and safety protection • Reduced advertising interference	M: System stability (RS=0.807); privacy and safety (RS=0.770) Advertising: lowest RS=0.526; reverse responses in standard Kano 54.3%	**Convergence:** System stability and privacy/security are basic safeguards; advertising interference should be minimized.
Preference heterogeneity	• Different views on follow-	**O:** Follow-up reminder **A:** Dietary recommendation	Complementarity: Group-level Better-Worse classification

Integrated domain	Qualitative findings	Kano and Better-Worse results	Meta-inference
	up reminders • Different views on dietary guidance		does not eliminate individual preference variation; optional or configurable delivery may be appropriate.

Note. O = one-dimensional; A = attractive; I = indifferent; M = must-be; R = reverse; Q = questionable; RS = requirement sensitivity score. "Convergence," "Expansion," and "Complementarity" indicate the mixed-methods relationship between qualitative and quantitative findings.

Taken together, the Kano and Better-Worse analyses complemented the qualitative findings by quantitatively distinguishing how different requirements were associated with satisfaction and dissatisfaction, while RS provided additional information on overall sensitivity. The two phases were complementary and together provided a basis for distinguishing core functions, foundational safeguards, and optional value-added functions.

4 Discussion

4.1 Main findings

This exploratory sequential mixed-methods study identified mobile rehabilitation needs from the perspectives of older adults undergoing TKA, primary caregivers, and healthcare professionals and further evaluated the relative effects of different functions on satisfaction and dissatisfaction using Kano and Better-Worse analyses. Three main findings emerged. First, safety support, intuitive exercise guidance, personalized rehabilitation planning, and continuous professional support represented core postoperative mobile rehabilitation needs. Fall-risk warning and video-guided rehabilitation exercises had the highest RS values, while online doctor consultation and personalized rehabilitation planning also had relatively high RS values. Second, age-friendly design and family collaboration showed different patterns in their relationship with satisfaction: simple operation, font adjustment, and visual accessibility design were located in the indifferent quadrant, whereas voice assistance and caregiver-side synchronization functions were located in the attractive quadrant. Third, system stability and privacy and security design were located in the must-be quadrant, indicating that platform reliability and data protection are foundational conditions that need to be secured in mobile rehabilitation design. Overall, the qualitative and quantitative findings were convergent and complementary and further revealed individual preference variation underlying group-level classifications.

4.2 Core rehabilitation support: moving from access to safe, clear, and sustained home rehabilitation

In this study, fall-risk warning and video-guided rehabilitation exercises had the joint highest RS values, while personalized rehabilitation planning and online doctor consultation also had relatively high RS values. These findings suggest that participants' needs for mobile rehabilitation after TKA were concentrated less on increasing the number of digital functions and more on receiving clear training content, easy-to-understand exercise demonstrations, safety feedback, and professional support when needed. In a randomized controlled trial among patients undergoing TKA, Nuevo et al. [36] found that a telerehabilitation system with real-time exercise feedback and communication functions improved exercise adherence and quadriceps strength and received favorable usability ratings, consistent with the "video-guided exercise-safety reminder-professional support" chain of needs identified in the present study. Other recent digital rehabilitation trials show a similar direction: Shim et al. [12] used augmented reality and real-time feedback for home training, while Jung et al. [13] combined wearable motion tracking with smartphone application feedback. Both studies suggest that digital feedback can provide an important complement to conventional home-based rehabilitation.

From the Better-Worse quadrants, personalized rehabilitation planning, video-guided rehabilitation exercises, and fall-risk warning were all located in the one-dimensional quadrant, suggesting a more direct relationship between adequate provision of these functions and higher user satisfaction. Online doctor consultation was located in the attractive quadrant and therefore appeared to provide added value beyond basic rehabilitation services. A systematic review by Song et al. [37] on mHealth adoption among older adults with hip fractures similarly found that patients, family caregivers, and healthcare professionals recognized the value of mHealth for rehabilitation guidance and professional communication, while limited technological literacy, functional constraints, and resource limitations could hinder actual use. Mobile rehabilitation tools for older adults after TKA may therefore place greater emphasis on training plans, intuitive demonstrations, safety feedback, and professional support rather than simply expanding the number of functions. Booth et al. [19] also found that although patients undergoing TKA or unicompartmental knee arthroplasty generally considered digital rehabilitation easy to use and motivating, most preferred technology-assisted rehabilitation combined with face-to-face services, further supporting the view that ongoing professional support should not be completely replaced by digital tools.

4.3 Age-friendly design and family collaboration: "indifferent" does not mean "unimportant"

Simplified operation, larger text, clear icons, and voice assistance were repeatedly mentioned in the qualitative interviews. However, in the Better-Worse analysis, simple operation, font adjustment, and visual accessibility design were located in the indifferent quadrant, whereas voice assistance was

located in the attractive quadrant. It is important to distinguish between drivers of satisfaction and basic conditions for usability. An indifferent classification indicates only that the presence or absence of these functions produced relatively limited changes in satisfaction in the current sample; it does not imply that they lack value for older users. A systematic review by van Acker et al. [38] summarized key influences on older adults' engagement with mHealth as capability limitations, motivation to use the technology, and social support and recommended design adaptation and blended online-offline approaches to improve engagement. Amouzadeh et al. [39] further identified simplified navigation, larger text and touch targets, voice interaction, and error-tolerant design as relatively consistent age-friendly design elements for mobile applications used by older adults. Accordingly, simple operation, font adjustment, and visual accessibility design in the present study are better interpreted as baseline conditions for access to mobile rehabilitation rather than low-priority functions that can be omitted.

Family collaboration showed a clearer value-added pattern. Caregiver-side synchronization of rehabilitation plans and rehabilitation exercise progress were both located in the attractive quadrant, and caregiver-side synchronization of the rehabilitation plan had an RS of 0.817. A scoping review by Lee et al. [40] found that caregiver-focused mHealth tools for community-dwelling older adults were mainly used for health monitoring, home-care education, emergency alerts, and communication between family members and healthcare professionals. Kelley et al. [41] further reported that family caregivers have clear needs for information access, support, and care coordination and that mobile applications can connect patients, caregivers, and clinical teams. In the context of Chinese older adults, Leung et al. [42] found that family or peer support, guidance from healthcare professionals, and timely technical support facilitated mHealth use. Ruan et al. [43] showed that home-dwelling older adults and their caregivers do not experience digital health services in the same way: older adults are more constrained by complex operations and limited digital literacy, whereas caregivers additionally consider service integration, time burden, and privacy and security. Thus, the patient-facing interface should remain as simple as possible, while caregiver-facing functions may support plan viewing, progress synchronization, and necessary reminders without transferring responsibility for clinical judgment to family caregivers.

4.4 Platform safeguards: stability, privacy, security, and low interference as prerequisites for sustained use

System stability and privacy and security design were both located in the must-be quadrant, indicating that their absence is more likely to generate user dissatisfaction, whereas their adequate provision may not produce a comparable increase in additional satisfaction. A systematic review by Alhammad et al. [44] showed that patient concerns about mHealth data confidentiality, privacy, and

security continue to affect application adoption and that stronger protection of personal data and clear privacy safeguards may improve acceptance. From the perspective of mobile device use among older adults, Gupta et al. [45] further noted that privacy and security concerns are closely related to system design, support approaches, and user knowledge and that mismatches between age-related capability changes and design may increase security risks and barriers to use. An updated systematic review by Hepburn et al. [46] identified privacy concerns, lack of trust, usability problems, and limited digital literacy as important barriers to digital health technology adoption among older adults with chronic diseases and suggested that accessible design, support from healthcare professionals, and blended online-offline models may facilitate adoption. These findings support treating system stability, privacy protection, and age-friendly design as foundational platform safeguards rather than optional add-on functions.

Advertising showed a different and noteworthy pattern: it had the lowest RS value, and 54.3% of responses for this function were classified as reverse in the standard Kano evaluation. This suggests that advertising is not simply a low-priority requirement but may negatively affect the user experience. In mobile rehabilitation platforms designed for older postoperative patients, commercial information, pop-up advertisements, and rehabilitation-irrelevant notifications should be minimized. If commercial operation is considered in the future, professionally trustworthy clinical content, data security, and interface stability should remain prerequisites.

4.5 Clinical and design implications of integrating qualitative and Kano/Better-Worse findings

Compared with a simple importance ranking, the mixed-methods integration in this study provided information at two levels: why a need arises and how that need influences satisfaction. The qualitative interviews explained the contexts and reasons underlying different functional requirements, whereas Kano and Better-Worse analyses further distinguished their effects on satisfaction and dissatisfaction. Mobile rehabilitation functions should therefore not be configured mechanically according to RS ranking alone; standard Kano attribute frequencies, Better-Worse quadrant positions, RS values, and qualitative context should be considered together. Based on the joint display, future functional design can be conceptualized in three tiers. The first tier comprises foundational safeguards, including system stability, privacy and security, and an age-friendly interface. The second tier comprises core rehabilitation functions, including phase-specific personalized planning, video-guided exercises, fall-risk and safety alerts, and follow-up management. The third tier comprises value-added support, including online doctor consultation, voice assistance, rehabilitation information, and caregiver collaboration. In the TReAT project, Pritwani et al. [20] used a user-centered development process involving patients, family members, and healthcare professionals and ultimately integrated

education, exercise training, goal management, bidirectional communication, caregiver-facing functions, and individualized treatment plans into a single platform, broadly consistent with the tiered functional structure derived in the present study.

Whether digital rehabilitation can be implemented in practice also depends on its fit with existing clinical workflows and organizational contexts. A systematic review by van Tilburg et al. [47] on implementation of digital health services for musculoskeletal conditions found that barriers and facilitators span multiple levels, including technological usability and privacy/security, stakeholder acceptance, changes in treatment workflows, organizational support, healthcare professional attitudes, and division of responsibilities. Future product development should therefore address not only patient-facing functions but also the frequency with which healthcare professionals review data, workflows for responding to abnormal information, boundaries of responsibility, and offline referral pathways, while using automated summaries and graded alerts to minimize additional workload. Before formal implementation, prototype usability testing and real-world pilot studies should be conducted, followed by prospective intervention studies evaluating user adherence, rehabilitation outcomes, healthcare professional workload, and cost-effectiveness. Subsequent development should also incorporate co-design or co-creation strategies. A realist review by Høiseth and Nakrem [48] indicated that co-creation of digital health services with older adults requires sustained interaction, clear roles, and trusting relationships. An umbrella review by Kilfoy et al. [49] likewise emphasized that early involvement of patients, caregivers, and healthcare professionals helps incorporate real-world needs, value preferences, and implementation barriers into the design of digital interventions.

To illustrate how the identified needs may be translated into subsequent functional design, Fig. 2 presents an example interface and core functions of the mobile rehabilitation mini-program, including assessment management, personalized training plans, exercise demonstrations, abnormality alerts, and family collaboration. The figure is intended to illustrate the mapping between identified needs and functional modules and should not be interpreted as evidence of clinical or implementation effectiveness.

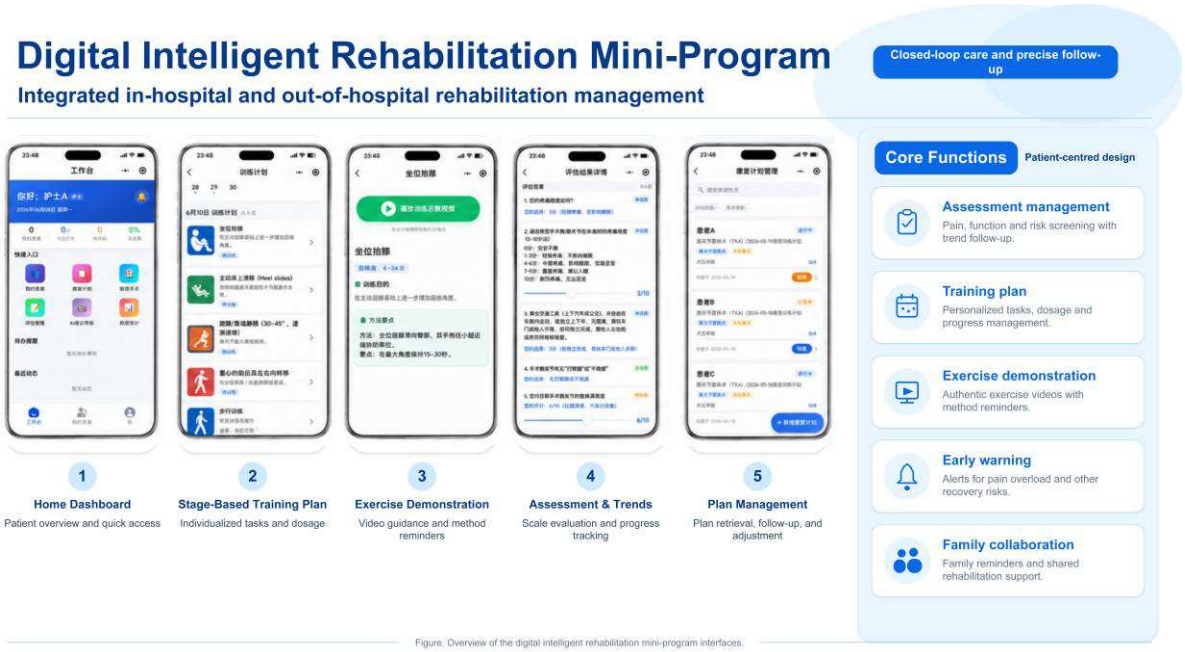


Fig. 2 Example interface and core functions of the mobile rehabilitation mini-program

4.6 Strengths, limitations, and future research

A key strength of this study is that the mobile rehabilitation functional items were not predetermined by the researchers. Instead, needs were first identified from multiple perspectives—patients, primary caregivers, and healthcare professionals—through TAM-guided qualitative interviews and were then evaluated quantitatively using Kano and Better-Worse analyses. This enabled the content of the needs and judgments about functional configuration to be linked within the same study framework. In addition, the study retained standard Kano attribute frequency distributions, Better-Worse coefficients, Better-Worse quadrants, and RS rankings and conducted a sensitivity analysis using all 216 complete questionnaires. The identical quadrant classifications and RS rankings in the main and sensitivity analyses strengthen the robustness of the findings.

Several limitations should also be considered. First, this was a single-center study conducted in southwestern China, and convenience sampling was used in the quantitative phase. Regional differences in digital infrastructure, family caregiving patterns, and rehabilitation resources, together with possible selection bias, may influence the observed needs structure; multicenter studies are therefore needed to assess generalizability. Second, family members or caregivers accounted for 69.7% of respondents in the quantitative phase. The Kano and Better-Worse results consequently reflect functional preferences formed jointly by two independent respondent groups—patients and family caregivers—and cannot be interpreted as a ranking from the perspective of older patients alone. Future studies could recruit a larger patient sample and conduct stratified patient-caregiver

comparisons. Third, the 17 functional requirements were developed primarily for needs identification and functional decision-making and do not constitute a unidimensional scale developed through a full psychometric process. Fourth, Kano attributes represent preferences at a particular time point and may change with postoperative stage, digital-use experience, and health status. Fifth, a complete mobile rehabilitation system was not actually deployed in this study; therefore, the findings cannot establish that these functions improve adherence, functional recovery, or other clinical outcomes. Future research should combine co-design, prototype testing, and prospective clinical validation to further evaluate usability, implementation feasibility, and clinical effectiveness.

5 Conclusions

This study systematically identified postoperative mobile rehabilitation needs among older adults undergoing TKA from the perspectives of patients, primary caregivers, and healthcare professionals and further described the effects and relative sensitivity of different functions on satisfaction and dissatisfaction using the Kano model and Better-Worse coefficients. Fall-risk warning, video-guided rehabilitation exercises, personalized rehabilitation planning, and continuous professional support emerged as core functions warranting priority attention. System stability and privacy and security should serve as foundational safeguards, while age-friendly features such as simple operation, adjustable font size, and visual accessibility should be treated as basic usability conditions. Voice assistance, online doctor consultation, and caregiver-side collaboration may provide additional value for the user experience. Future mobile rehabilitation programs should strengthen personalized exercise guidance, professional feedback, and family collaboration while ensuring safety, reliability, and age-friendly usability and should be integrated with existing clinical workflows. Nurses can play a coordinating role in rehabilitation education, identification of abnormal information, professional feedback, and family collaboration. Because this study remains at the stage of needs identification and functional configuration assessment, these proposed configurations require further validation through prototype usability testing, multicenter studies, and prospective interventions.

Declarations

Ethics approval and consent to participate

This study was reviewed and approved by the Medical Ethics Committee of the Affiliated Hospital of North Sichuan Medical College (approval no. 2025ER297-1). All participants provided written informed consent before participation. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available because of participant privacy and ethical restrictions.

Competing interests

The authors declare that they have no competing interests.

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No funding was received for this study.

Authors' contributions

YG: Conceptualization, Methodology, Formal analysis, Data curation, and Writing – original draft. MY: Investigation, Data curation, and Writing – review and editing. QS: Investigation, Data curation, and Validation. YC: Investigation, Resources, and Project administration. KG: Methodology, Validation, Visualization, and Writing – review and editing. HZ: Investigation, Resources, Validation, and Writing – review and editing. MT: Conceptualization, Supervision, Project administration and Writing – review and editing. YG and MY contributed equally to this work. All authors read and approved the final manuscript.

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