Development and validation of a mobile health application usability scale for older adults with chronic diseases

Hongyu Yu, Weiyu Qiu, Yanfeng Wang, Qinyang Wu, Ke Hu, Qiuyun Ye, Qiaohong Yang

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Abstract

Background: Chronic diseases are one of the leading causes of disability and death in people over 60 years. Mobile health applications can revolutionize healthcare delivery and management of chronic conditions as well as reduce healthcare costs. Unfortunately, many of these applications are not designed for elderly patients with chronic diseases. Therefore, it is crucial to create a reliable and specialized tool that developers and researchers can use to assess the usability of mobile (mHealth) applications designed specifically for elderly patients.

Objective: To develop and validate a mHealth application usability evaluation scale for elderly patients with chronic diseases.

Methods: We developed the first edition of the scale from March to September 2022 through literature review, interview, team discussion, and the Delphi method. Between October and December 2022, the improved scale after a pilot test was used to conduct surveys in Guangzhou, Guangdong, China, to analyze and screen items using the Item Discrimination Index, Correlation coefficient, Internal consistency test, and exploratory factor analysis. From October 2022 to February 2023, we completed the data collection and evaluation of the reliability and validity of the scale.

Results: The finalized scale included six dimensions and 23 items. Item-level content validity indices and the average scale content validity index ranged from 0.85–1. The validation evaluation showed that the scale has a good fit, with a ?2/df ratio of 1.728 and various fit indices ranging from 0.817–0.928. The AVE and CR values also met the recommended criteria, with a value greater than 0.4 and 0.6, respectively. Additionally, the Cronbach's ? coefficient for the full scale and subscales ranged from 0.758–0.911, indicating good internal consistency.

Conclusions: The mHealth application usability evaluation scale for older adults with chronic disease was developed with rigorous steps, showing good reliability and validity. The scale can be used to evaluate the usability of mHealth among older adults and promote the age-appropriateness of mHealth.

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Keywords: MHealth app, usability, instrument development, validation, older adults, chronic diseases

Introduction

As the world's population ages and chronic diseases continue to be prevalent, the care needs of elderly patients are becoming increasingly important. There were over 700 million older people

worldwide in 2019, which is set to double by 2050 [1]. Older adults are at increased risk of developing chronic diseases and care dependence; chronic diseases are the leading causes of disability and mortality in people over 60 years [1]. Improving symptom management, sleep quality, health education, self-management ability, and information exchange can help promote health, wellbeing, and security while reducing social alienation [2]. Failure to meet these needs can result in reduced physical, psychological, and social functions, increased hospitalization, medication complexity, discomfort, decreased quality of life, and even death [3,4]. Additionally, the ongoing course and high complication rate of chronic diseases significantly increase physical and psychological stress on family caregivers and the economic burden on society [5-7]. It is essential to meet the needs of elderly patients with chronic diseases to promote their health and wellbeing and reduce the burden on caregivers and society.

Mobile health applications (mHealth Apps) have had remarkable effects on the management of chronic diseases, breaking through temporal and spatial barriers of traditional medical service models. These apps support patients through health education, remote monitoring and feedback, and psychosocial interventions, improving medication adherence and lifestyles [8-10]. Patients benefit from improved adherence, promotion of healthy behaviors, enhanced symptom and complication management, better clinical indicators and quality of life, reduced readmissions and mortality, and cost savings on healthcare expenses and trips to the doctor; caregivers also benefit from improved physical and mental health [11-14]. Involving patients with chronic diseases in mHealth is essential.

Although mHealth has notable benefits, elderly patients with chronic diseases often struggle to participate [15-17]. Older patients often reject electronic software due to difficulty adapting to the emerging model and a low sense of benefit: they may believe they cannot learn or are unwilling to learn how to use it. Additionally, the complex operation interface and technical requirements are often challenging for elderly patients. The icons and text within applications often appear too small to discern comfortably, rendering interaction difficult due to visual or auditory impairment. Continuous monitoring may also pose a challenge to patient autonomy and health perceptions, and they may also fear a potential violation of personal privacy. The needs and habits of elderly patients with chronic diseases should be considered to improve the user experience and achieve positive impacts of mHealth.

Without a standardized usability assessment, designing and implementing mHealth apps that meet the needs of elderly individuals with chronic diseases can be challenging. Previously, assessments have relied on interviews and questionnaire surveys. Qualitative data regarding usability can be categorized as positive or negative [18]. Favorable usability encompasses feelings of convenience, usefulness, relaxation, support, and empowerment. In contrast, unfavorable usability is characterized by stress, difficulty, helplessness, mistrust, or a desire to disengage. Questionnaire surveys have

gained prominence due to their ease of implementation and data analysis. However, the existing usability assessment tools do not adequately address the unique requirements of mHealth apps tailored for elderly patients with chronic diseases. The System Usability Scale (SUS) [19] and the Post-Study System Usability Questionnaire (PSSUQ) [20] collect user feedback on system usability, but they do not differentiate mHealth apps from other systems. The MHealth App Usability Questionnaire (MAUQ) [21] was designed to assess mHealth app usability, encompassing aspects like ease of use, efficiency, learnability, and satisfaction. Although the MAUQ has been translated and adapted into various versions [22-24], it still has limitations because individuals over 65 years old or those with limited education were excluded during the development process. Other existing tools also suffer from shortcomings, such as inadequate sampling methods, a lack of a robust theoretical framework, and incomplete evaluations [25, 26]. In order to address these gaps, we aimed to create and validate a usability scale, named the mHealth app usability scale for the elderly with chronic diseases (MAUS-EC), specifically tailored for mHealth apps intended for older adults with chronic diseases.

Methods

Overview

This research project consisted of three parts. In Study 1, literature review, interviews, the Extended Unified Theory of Acceptance and Use of Technology (Extended UTAUT model) [27,28], and research team discussions were used to form a pool of candidate items. After that, in Study 2, the Delphi method [29] were applied to create the dimensions and items of the initial version of MAUS-EC. We conducted Study 3, which involved a process of item analysis and screening, to identify the most informative items for each domain. Additionally, we evaluated the reliability and validity of the instrument we developed in Study 3.

Ethics

As part of a large-scale research project, this series of studies has been approved by the Medical Ethics Committee of our University (JNUKY-2022-038). Participants were informed of the purpose and the process in advance. They participated voluntarily in this project and were allowed to withdraw at any time.

Study 1: Assembling a pool of candidate items

Literature Search

Seven English databases and four Chinese databases were searched to collect published research papers on the attitude and experience of elderly patients with chronic diseases using mHealth. The databases included PubMed, Embase, the Cochrane Library, Web of Science, Scopus, CINAHL, ProQuest, The China National Knowledge Infrastructure (CNKI), Weipu (VIP), Wanfang Data, and the Chinese biomedical literature service system (SinoMed). Eligible studies were as follows: (1) Study participants were aged 60 years or older and diagnosed with at least one chronic disease; (2) Research phenomenon: the experience of using mHealth; (3) Research methods: qualitative studies or mixed-method studies with qualitative results. Methodologies were not limited to descriptive qualitative research, phenomenology, ethnography, and grounded theory. The exclusion criteria were: (1) The full text is unavailable; (2) Mixed-method studies in which qualitative results cannot

("Older adults" OR "Elderly" OR "Senior citizens" OR "Aging population" OR "Older individuals") AND ("Hypertension" OR "Diabetes" OR "Heart disease" OR "Arthritis" OR "Chronic obstructive pulmonary disease" OR "COPD" OR "Osteoporosis") AND ("mHealth" OR "Mobile health" OR "Mobile applications" OR "Smartphone apps" OR "Mobile technology") AND ("Attitude" OR "Perception" OR "Opinion" OR "Viewpoint" OR "Sentiment") AND ("Experience" OR "User experience" OR "Patient experie aphy" OR "Phenomenology" OR "Grounded theory" Thematic analysis")

Identification

Records identified through database searching (n=6093): PubMed (n=1580), Embase (n=1386), The Cochrane Library (n=9), Web of Science (n=1577), Scopus (n=1281), CINAHL (n=112), ProQuest (n=17), CNKI (n=40), Wanfang Data (n=86), VIP (n=5)

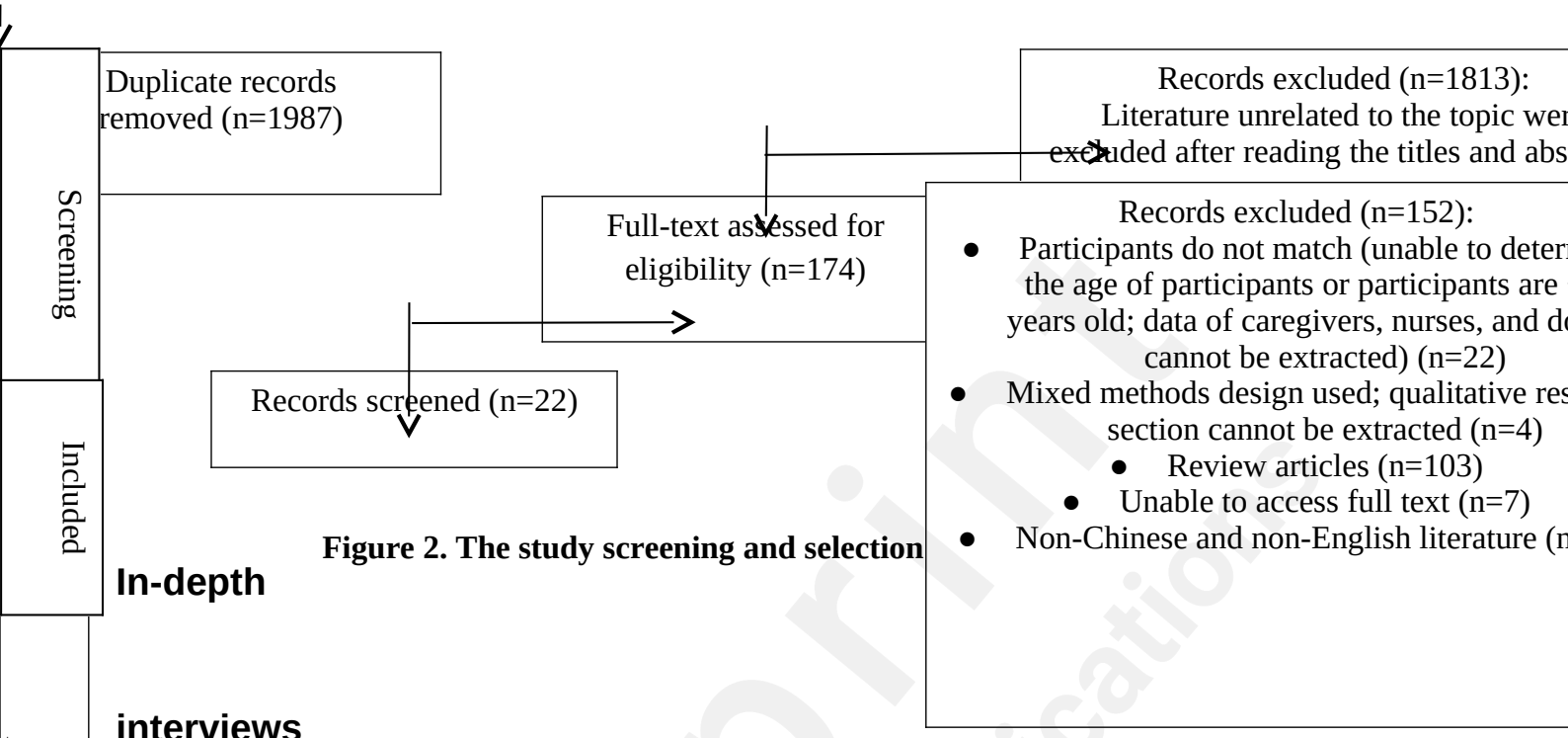

Figure 2. The study screening and selection

In-depth

interviews

We used purposeful sampling to recruit participants from a tertiary hospital in Guangzhou, Guangdong Province, between March and May 2022. To be eligible, participants had to have at least one chronic condition, be 60 years or older, be a current or past user of mHealth, understand and answer the interview questions independently, and provide informed consent. Face-to-face interviews were conducted with patients who provided informed consent. After data collection, the first author supplemented the literature-based items pool.

Research team discussion

A research team consisting of three highly experienced nursing professors specializing in chronic disease management, mHealth, and scale development, two accomplished lecturers with doctorate degrees in Nursing and specialized knowledge in chronic disease care and scale development, one senior clinical nursing expert, and the first author, were assembled to enhance the quality of the items. This team modified items in the pool for Delphi expert review. Furthermore, the team chose potential experts and designed the consultation questionnaire. Following each round of expert consultation, the team discussed the expert opinions and relevant indicators. The team members made appropriate adjustments or deletions and ultimately produced the initial version of the scale.

Study 2: The development of the initial version of MAUS-EC

Recruitment of Experts for the Delphi

An electronic version of the consultation questionnaire for the experts was issued through WeChat and NetEase Email Master to gather expert opinions through the Delphi method [29]. The Delphi method was used to ensure anonymous expression of opinions, with multiple rounds of questionnaire surveys and systematic steps to reach basic unanimous views of the experts consulted. To be considered as an expert, candidates had to meet the following criteria: (1) Possess a master's degree or higher; (2) Have at least five years' experience in the healthcare or research of elderly patients with chronic diseases in tertiary hospitals or institutions of higher education or the field of mHealth; (3) Hold the title of deputy senior or higher, although exceptions were made for those with exceptional knowledge and experience; (4) Took part in this research voluntarily and actively collaborated to complete consultations.

Data Collection and Analysis

The Delphi study was initiated online in August 2022. The objectives of our study were communicated to the experts via email, along with the consultation questionnaire. The questionnaire comprised five sections aimed at gathering expert opinions and information. The first section includes a form with 5-point scales for collecting opinions on the importance of dimensions and suggested revisions. The second part included a form with 5-point scales for evaluating the importance value of items, 4-point scales for evaluating the relevance, and suggested modifications. The third section asked experts to rate their familiarity with the information they provided before, using a 5-point scale. The fourth section featured a table for experts to assess the foundation of the basis of their judgment, including practical experience, theoretical knowledge, references, and personal intuition, graded on a scale of 1–3. Finally, the fifth section was an expert information collection sheet.

The first-round consultation questionnaire was sent out to 27 potential experts who were informed of the study and the participation requirements. Participants were given four weeks to respond and were sent reminders every two weeks. After carefully reviewing the responses, incorporating participants' feedback, and discussing with the research team, the first author made the necessary adjustments by adding, deleting, or modifying the content. In the second round, the first author emailed the results of the first iteration to all experts who responded to the preliminary survey, allowing them to gain insights from all Delphi experts. This round also had a four-week response time. After the second round of Delphi, the first author collated the results and found that expert opinions had converged. The consultation ended in September 2022. The anonymity of experts was

maintained throughout both rounds. The initial version of MAUS-EC was formed after minor revisions following the second round of consultation and research team discussion.

Study 3. Refining and validating MAUS-EC

Participants and setting

From October 2022 to January 2023, trained investigators used convenience sampling to recruit elderly patients with chronic diseases who had experience using smart devices and mobile applications in a tertiary hospital and two residential communities in Guangzhou, Guangdong. The participants were required to rate their agreement with items in MAUS-EC on a scale from 1 (strongly disagree) to 5 (strongly agree). Before the formal investigation, 30 elderly patients with chronic diseases pretested the scale to assess its comprehensibility and testability. According to the recommendation [31], a sample size of at least 100 and 200 is required for the Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA), respectively. Data analysis was conducted using IBM SPSS Statistics 26.0 and IBM SPSS Amos 28.0.

The apps and tasks required to perform

Before the survey, participants were explained the study objective and the MAUS-EC. They were also provided with a basic introduction and brief demonstration of the mHealth application. Participants were asked to use one of the eight corresponding apps from the Data.ai database with a rating of at least 4.5 and complete specific tasks. The database offers free access to current rankings and market data for apps on iOS and Android App Stores. The apps used were Spring Rain Doctor, Xiaohe Health, Gaoxin Health, Diabetes Nurse, Kidney Online, Dongdong Oncology, Lansheng Brain Doctor, and Respiratory Rehabilitation. The tasks included: (1) registering and logging in to the app; (2) completing personal information, settings, and medical history, and adding physiological indicator records; (3) familiarizing themselves with various modules, browsing, and trying to publish text, pictures, or video information; (4) completing monitoring records and physical and mental condition assessments; (5) contacting healthcare personnel using mHealth to check the instructions and messages received.

Item Analyses

A thorough item analysis and screening procedure were performed using the Item Discrimination Index (IDI), Correlation Analysis, Cronbach's α, and EFA [32]. This approach strategically amalgamates the strengths of different methods while circumventing their respective limitations, ultimately enhancing the robustness and consistency of the screening results [32].

(1) Item Discrimination Index

IDI [33] measures an item's ability to distinguish between high- and low-performing individuals. It is calculated by comparing the proportion of high-scoring individuals who answered an item correctly to the proportion of low-scoring individuals who did the same. The 27th percentile score represents the upper bound of the low-scoring group, and the 73rd percentile score represents the lower bound of the high-scoring group. The critical ratio (CR) is the average difference between high- and low-scoring groups for each item. An independent sample t-test was then used to compare the scores of these two groups on each item to determine whether the difference was statistically significant; otherwise, the item was considered for removal [33].

(2) Correlation coefficient

The Item-Total Correlation (ITC) is calculated using Pearson Correlation, which measures the correlation between a specific item's score and the overall test score. The Corrected Item-Total Correlation (CITC) accounts for the contribution of the specific item being analyzed to the total score. CITC = ITC * √(Variance of Total Scores / Variance of Total Scores Excluding the Item). CITC adjusts the correlation to consider the item's variance and its impact on the variance of the total score. Moreover, it provides a more accurate assessment of the item's relationship with the construct being measured. Items with a correlation coefficient above 0.4 are often considered acceptable [33,34].

(3) Internal consistency test

Cronbach's α [32], a classic index for testing internal consistency test, was used for assessing the internal consistency reliability of the scale. If removing an item increases the Cronbach's α, it suggests that the item negatively contributed to the internal consistency of the dimension. This could indicate that the item was not closely related to the other items or that it measured a different aspect of the construct. In this case, removing the item could potentially improve the overall reliability of the dimension.

(4) Exploratory Factor Analysis

EFA [32] is a methodology capable of unveiling latent constructs or dimensions that elucidate the correlations among items. This approach aids in refining the measurement instrument, detecting potential issues with specific items, and acquiring deeper insights into the underlying structure of the phenomenon being measured.

Validity and Reliability assessment

(1) Content validity

Content validity is a fundamental concept that evaluates the extent to which the content of a measurement instrument aligns accurately with the construct it is intended to measure [32]. Two indices are most commonly used to evaluate content validity, including the Item-Level Content

Validity Index (I-CVI) and the Average Scale-Level Content Validity Index (S-CVI/Ave) [35]. The I-CVI, derived from the expert consultation questionnaire, is computed by the experts who rated items 3 or 4 for relevance; this count is then divided by the total number of experts consulted. This index measures the proportion of experts who rate a specific item as relevant or appropriate. The S-CVI/Ave is the average of I-CVI values across all items, reflecting the average agreement among experts regarding the relevance of items within the scale.

(2) Confirmatory Factor Analysis

CFA is a statistical technique employed to evaluate and validate the construct validity of a measurement instrument [32]. Embedded within structural equation modeling (SEM), the primary objective of CFA is to validate whether the hypothesized relationships between the observed items and their latent constructs correspond harmoniously with the theoretical expectations [32]. The Goodness-of-fit Indices used were the Chi-Square divided by Degrees of Freedom (χ^2/df), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), CFI (Comparative Fit Index), Incremental Fit Index (IFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). These Goodness-of-fit Indices help evaluate how well the model aligns with the observed data.

(3) Convergent Validity

Convergent validity [36] measures how well multiple items of the same latent construct or factor in an SEM model are related. It assesses whether different indicators that theoretically are supposed to measure the same construct do so. Standardized factor loadings (SFL) provide insights into how well the indicators measure the underlying constructs. The standard error (SE) reflects the degree of uncertainty in the estimated parameter. Smaller standard errors indicate greater precision in the estimate, while larger standard errors suggest higher uncertainty. Composite reliability (CR) is used to assess the internal consistency or reliability of latent constructs (also known as factors or variables) in an SEM model. The Average Variance Extracted (AVE) was used for measuring the proportion of variance captured by the latent construct about measurement error. Coefficients calculated the correlations between different items measuring the same construct.

(4) Internal Consistency Reliability

We used Cronbach's α to assess how well items in the scale measure the same underlying construct. A higher alpha indicates higher internal consistency.

Results

The pool of candidate items

We developed the pool of candidate items (Table 1) for review by Delphi experts after reviewing 22

original studies, interviewing 19 elderly patients with chronic diseases, and discussing with the research team twice.

Table 1. The pool of candidate items.

Dimension	Item	Source
Perceived Usefulness	1. It is easy for me to reach out to doctors and nurses when needed	Fairbrother [37], interview
	2. I feel secure with the care of doctors and nurses	O'Cathain [38], Bond [39], Korpershoek [40]
	3. I am more receptive to my illness(es)	Selman [41], interview
	4. I feel that I am in control of my health	Sanders [15]
	5. I know more about my illness(es)	Bond [39], Fairbrother [42], Lyngå [43], Chang [44], Huniche [45], interview
	6. I can notice changes in my health	Fairbrother [42], Lyngå [43], Chang [44], interview
	7. MHealth lets me know what to do when my health condition changes	Bond [39], Fairbrother [42], Lyngå [43], Chang [44], Huniche [45], interview
	8. MHealth helps me know fellow patients	Interview
	9. MHealth prevents me from making unnecessary guesses about my health	Fairbrother [42], Huniche [45]
	10. I am more confident in managing my illness(es)	Selman [41], Huniche [45], Hägglund [46]
	11. I realize the importance of continuous disease management	Lyngå [43], Chang [44], Hägglund [46], interview
	12. Managing illness(es) became my daily routine	Lyngå [43], Chang [44], interview
	13. My health issues are overemphasized (-)	Lyngå [43], Fairbrother [47], Huniche [45]
	14.MHealth is not helpful for my health (-)	O'Cathain [38], Chang [44], Ladin [48]
Perceived	15. MHealth offers me easy communication options, e.g., typing, voice call, or video call	Fairbrother [37], Ladin [48], Hanley [49], Lundell [50], interview
	16. Managing my illness(es) with mHealth is not difficult for me	Lyngå [43]
	17. The health education materials on mHealth are hard to understand (-)	Sanders [15], Chunhan [51], interview
	18. It is hard for me to find what I want on mHealth (-)	Chunhan [51], interview
	19. There are too many functions, and I am struggling with them (-)	Cajita [17], Chunhan [51], interview
	20. MHealth is complicated to operate (-)	Chunhan [51], Poppe[52], Vergouw [53] ,

		interview
Ease of Use	21. The font size on it is too small to see (-)	Cajita [17], Chunhan [51], interview
	22. The icons on it are too small to see (-)	Cajita [17], Chunhan[51], interview
	23. The contrast between text and background is not clear, making it hard to see (-)	Cajita [17], interview
	24. It took me a while to figure out how to use mHealth (-)	Interview
	25. Using mHealth for health monitoring is time-consuming (-)	Chunhan [51], Sultan [54], interview
	26. MHealth brings inconvenience due to the lack of synchronization of diagnosis and treatment information in different hospitals (-)	Chang [44], interview
	27. The recent update makes mHealth harder to use (-)	Portz [55]
	28.MHealth frequently lags, making it difficult to use (-)	Lyngå [43], Lundell [50], interview
Social Influence	29. My family approves me to use mHealth	Huniche [45], Hägglund [46], Poppe [52], interview
	30. Seeing friends and colleagues use mHealth, I also started using it	Interview
	31. Fellow patients recommended me to use mHealth	Interview
	32. Other important people in my life approves me to use mHealth	Interview
Facilitating Conditions	33. My family can help me use mHealth	Huniche [45], Hägglund [46], Poppe [52], interview
	34. Medical staff can help me use mHealth	Interview
	35. Lack of technical assistance makes mHealth difficult to use (-)	Interview
	36. Unclear instructions make mHealth inconvenient to use (-)	Vergouw [53], interview
	37. Absence of usage guidelines makes mHealth hard to use (-)	Vergouw [53], interview
	38. Getting help when mHealth malfunctions is inconvenient (-)	Interview
Technology Anxiety	39. I am reluctant to use mHealth due to a lack of familiarity with electronic devices (-)	Bond [39], interview
	40. Using mHealth is challenging for me (-)	Bond [39], interview
	41. I am afraid of accidentally damaging my phone, computer, or tablet while using mHealth	Chang [44]

	(-)	
	42. I fear making mistakes and getting stuck while using mHealth (-)	Lyngå [40], Lundell [50], interview
	43. I had negative experiences with digital technology before, so I resist using mHealth (-)	Portz [51], interview
	44. I am unwilling to invest time and effort in learning to use mHealth (-)	Cajita [17], Chang [44], Lundell [50], interview
Perceived Security	45. I feel like I am being watched (-)	Herrmann [48]
	46. I have privacy concerns with shared health records among fellow patients (-)	Selman [41], interview
	47. I feel insecure about registering health information on mHealth (-)	Interview
	48. MHealth cannot protect my sensitive information (-)	Interview
	49. I worry about being scammed through mHealth (-)	Interview
Professional Trust	50. I trust my doctor and nurse's judgment about using mHealth	Chang [44], interview
	51. I believe in the professionalism of the disease(s) management methods that mHealth offers	Fairbrother [37], Huniche [42], Hägglund[46], interview
	52. I doubt the monitoring results provided by mHealth (-)	Huniche [43], interview
	53. I have no confidence in the advice given by doctors and nurses on mHealth (-)	Huniche [43], Hanley [49], Vergouw [53], Korpershoek [56], interview

Results of two rounds of Delphi expert consultation

Characteristics of the Delphi experts

Twenty experts completed two rounds of consultation. These experts came from 14 universities and six tertiary hospitals located across various regions: Guangdong Province, Anhui Province, Hunan Province, Jiangsu Province, Beijing City, Shanghai City, Zhengzhou City, and Xi'an City. The experts had an average age of 44.55 years (standard deviation [SD] 9.32), with an average relevant research experience of 15 ± 8.5 years. Eleven experts held senior professional titles, and six held deputy senior titles. Furthermore, there were 14 experts with doctoral degrees and six with master's degrees (Table 2).

Table 2. Delphi experts' demographics.

Characteristics		**N** (%)
Age bracket	32–41	9 (45%)

(years)	42–51	5 (25%)
	52–61	6 (30%)
	Master's degree	6 (30%)
Education background	Doctoral degree	14 (70%)
	Medium-grade title	3 (15%)
Professional title	Deputy senior title	6 (30%)
	Senior title	11 (55%)
	≤ 10	4 (20%)
Work experience (years)	11–20	6 (30%)
	21–30	4 (20%)
	31–40	6 (30%)
	Chronic disease management	9 (45%)
Relevant research field	Aging care	6 (30%)
	Mobile health	5 (25%)
	5–9	5 (25%)
Research experience related	10–19	7 (35%)
to this study (years)	20–29	6 (30%)
	≥ 30	2 (10%)

Experts' enthusiasm

The response rate of the expert consultation questionnaires reflects the expert positivity coefficient, with a rate over 70% indicating a high positivity [57]. Twenty-seven inquiry questionnaires were sent in the first round, yielding 20 responses completed with expert opinions and insights, resulting in a commendable positive coefficient of 74.1%. In the second round, 20 consultation questionnaires were issued, and the suggestions and opinions of experts were also obtained. The expert positivity coefficient reached 100%. Both rounds achieved positive coefficients meeting the recommended criteria, demonstrating the active engagement, and significant investment of experts in this research project.

Expert Authority Coefficient

The Expert Authority Coefficient is used to determine experts' level of authority or influence in the context of this study. Cognitive Authority (Ca) was calculated based on experts' self-evaluation judgment. Cr was calculated from (Ca +Cs) / 2. As shown in Table 3, the authority coefficient of both rounds was higher than 0.7, indicating that the degree of authority was good and the consultation results were reliable [33].

Table 3. The Expert Positivity Coefficient.

	Ca	**Cs**	**Combined Rating (**Cr**)**
Round 1	0.84	0.74	0.79
Round 2	0.84	0.86	0.85

Coordination Degree of Experts

The average importance and the full score ratio reflect the concentration of experts' opinions on the article. In the first and second rounds of correspondence, the average importance of each item ranged from 3.37–5 and 4.1–4.9, and the full score ratio ranged from 0.22–1 and 0.45–0.9, respectively.

Expert Opinion Coordination Degree Index

The degree of coordination of experts' opinions is measured by the Coefficient of Variation (CV). In the first and second rounds of consultation, the CV of each item ranged from 0 to 0.5 and 0.063 to 0.37, respectively. The results of these two rounds of inquiry were statistically significant ($P<0.05$).

Initial Version of MAUS-EC

Experts provided their input on dimensions and items. Dimensions and items were deleted or modified based on the experts' feedback, considering three key indicators and our team discussions. As shown in Table 4, items with a Mean Importance Score (MIS) of ≤ 3.50, a Full Scale Ratio (FSR) of ≤ 0.2, or a CV of ≥ 0.25 were subject to modification or removal [33]. Following the initial round of inquiries, 13 items were removed, and 13 were modified. There were suggestions for adding three items. Items 19 and 20 were merged into a single item, as were items 21 and 22, along with items 36 and 37. Based on the feedback and evaluation criteria of the experts and following our group discussions, six items were removed, and four were modified. Items 23 and 26 were merged into a single item, as were items 34 and 35 (Table 4). After two rounds of expert consultation, the initial version of MAUS-EC was constructed to comprise six dimensions and 32 items. These dimensions encompassed nine items for Perceived Usefulness, nine for Perceived Ease of Use, four for Facilitating Conditions, three for Technology Anxiety, three for Perceived Safety, and four for Professional Trust.

Table 4. Indicators of two rounds of Delphi consultation and the screening results.

Delphi consultation	Dimension or item	MIS	FSR	CV	Result
Round 1	Perceived Usefulness	4.95	0.95	0.05	Kept
	1. It is easy for me to reach out to doctors and nurses when needed	4.79	0.79	0.09	Kept
	2. I feel secure with the care of doctors and nurses	4.21	0.53	0.25	Deleted
	3. I am more receptive to my illness(es)	4.11	0.26	0.18	Kept
	4. I feel that I am in control of my health	4.32	0.47	0.17	Kept
	5. I know more about my illness(es)	4.63	0.63	0.11	Kept
	6. I can notice changes in my health	4.58	0.63	0.13	Kept
	7. MHealth lets me know what to do when my health condition changes	4.42	0.74	0.24	Kept
	8. MHealth helps me know fellow patients	3.89	0.37	0.27	Revised
	9. MHealth prevents me from making unnecessary guesses about my health	4.05	0.42	0.25	Deleted
	10. I am more confident in managing my illness(es)	4.53	0.68	0.19	Kept
	11. I realized the importance of continuous disease management	4.47	0.68	0.19	Kept
	12. Managing illness(es) became my daily routine	4.37	0.59	0.19	Revised
	13. My health issues are overemphasized (-)	3.63	0.26	0.33	Deleted
	14. MHealth is not helpful for my health (-)	3.74	0.47	0.39	Deleted
	N/A				
	N/A				
	Perceived Ease of Use	4.84	0.89	0.1	Kept
	15. MHealth offers me easy communication options, e.g., typing, voice call, or video call	5	1	0	Kept
	16. Managing my illness(es) with mHealth is not difficult for me	4.68	0.79	0.16	Kept
	17. The health education materials on	4.74	0.74	0.10	Revised

	mHealth are hard to understand (-)				
	18. It is hard for me to find what I want on mHealth (-)	4.89	0.89	0.06	Kept
	19. There are too many functions, and I am struggling with them (-)	4.47	0.74	0.22	Merged
	20. MHealth is complicated to operate (-)	4.53	0.79	0.23	
	21. The font size on it is too small to see (-)	4.53	0.68	0.19	Merged
	22. The icons on it are too small to see (-)	4.58	0.68	0.15	
	23. The contrast between text and background is not clear, making it hard to see (-)	4.47	0.68	0.20	Revised
	24. It took me a while to figure out how to use mHealth (-)	4.42	0.68	0.25	Deleted
	25. Using mHealth for health monitoring is time-consuming (-)	4.37	0.58	0.23	Kept
	26. MHealth brings inconvenience due to the lack of synchronization of diagnosis and treatment information in different hospitals (-)	4.53	0.68	0.17	Revised
Round 1	27. The recent update makes mHealth harder to use (-)	3.37	0.37	0.50	Deleted
	28. MHealth frequently lags, making it difficult to use (-)	4.21	0.47	0.23	Kept
	Social Influence	4.47	0.63	0.19	Kept
	29. My family approves me to use mHealth	4.47	0.74	0.25	Revised
	30. Seeing friends and colleagues use mHealth, I also started using it	4.63	0.79	0.21	Kept
	31. Fellow patients recommended me to use mHealth	4.53	0.68	0.21	Kept
	32. Other important people in my life approves me to use mHealth	4.32	0.63	0.26	Deleted
	Facilitating Conditions	4.63	0.74	0.15	Kept
	33. My family can help me use mHealth	4.74	0.89	0.20	Revised
	34. Medical staff can help me use mHealth	4.74	0.89	0.20	Kept

	35. Lack of technical assistance makes mHealth difficult to use (-)	4.11	0.53	0.31	Deleted
	36. Unclear instructions make mHealth inconvenient to use (-)	4.32	0.63	0.27	Merged
	37. Absence of usage guidelines makes mHealth hard to use (-)	3.95	0.58	0.38	
	38. Getting help when mHealth malfunctions is inconvenient (-)	4.32	0.63	0.29	Deleted
	Technology Anxiety	4.68	0.89	0.2	Kept
	39. I am reluctant to use mHealth due to a lack of familiarity with electronic devices (-)	4.42	0.79	0.30	Deleted
	40. Using mHealth is challenging for me (-)	4.37	0.63	0.24	Deleted
	41. I am afraid of accidentally damaging my phone, computer, or tablet while using mHealth (-)	3.74	0.47	0.42	Deleted
	42. I fear making mistakes and getting stuck while using mHealth (-)	4.16	0.63	0.33	Revised
	43. I had negative experiences with digital technology before, so I resist using mHealth (-)	4.26	0.63	0.30	Kept
	44. I am unwilling to invest time and effort in learning to use mHealth (-)	3.95	0.58	0.36	Revised
	Perceived Security	4.47	0.68	0.2	Kept
	45. I feel like I am being watched (-)	4.37	0.63	0.24	Revised
	46. I have privacy concerns with shared health records among fellow patients (-)	4.32	0.68	0.30	Deleted
	47. I feel insecure about registering health information on mHealth (-)	4.48	0.74	0.24	Revised
	48. MHealth cannot protect my sensitive information (-)	4.58	0.22	0.22	Revised
Round 1	49. I worry about being scammed through mHealth (-)	4.47	0.25	0.25	Kept
	Professional Trust	4.47	0.68	0.22	Kept
	50. I trust my doctor’s and nurse’s judgment about using mHealth	4.11	0.68	0.36	Kept
	51. I believe in the professionalism of the disease(s) management methods	4.58	0.79	0.22	Revised

	that mHealth offers				
	52. I doubt the monitoring results provided by mHealth (-)	4.53	0.68	0.21	Kept
	53. I have no confidence in the advice given by doctors and nurses on mHealth (-)	4.58	0.84	0.24	Kept
	Perceived Usefulness	4.85	0.85	0.076	Kept
	1. It is easy for me to reach out to doctors and nurses when needed	4.75	0.85	0.134	Kept
	N/A				
	2. I am more receptive to my illness(es)	4.15	0.5	0.274	Deleted
	3. I feel that I am in control of my health	4.1	0.45	0.273	Deleted
	4. I know more about my illness(es)	4.55	0.8	0.242	Kept
	5. I can notice changes in my health	4.75	0.75	0.094	Kept
	6. MHealth lets me know what to do when my health condition changes	4.75	0.75	0.094	Kept
	7. MHealth allows me to get health information and support from fellow patients	4.65	0.7	0.126	Kept
	N/A				
	8. I am more confident in managing my illness(es)	4.75	0.85	0.134	Kept
	9. I realized the importance of continuous disease management	4.4	0.7	0.238	Kept
	10. MHealth is turning managing chronic condition(s) into my routine	4.8	0.8	0.085	Kept
	N/A				
	N/A				
	11. The services provided by mHealth do not match what I need (-)	4.25	0.6	0.294	Deleted
	12. Some important functions require payment to use (-)	4.3	0.55	0.228	Revised[1]
	Perceived Ease of Use	4.85	0.85	0.076	Kept
	13. MHealth offers me easy communication options, e.g., typing, voice call, or video call	4.9	0.9	0.063	Kept
	14. Managing my illness(es) with mHealth is not difficult for me	4.5	0.7	0.197	Kept
	15. The health information on mHealth is hard to understand (-)	4.85	0.85	0.076	Kept
	16. It is hard for me to find what I want on mHealth (-)	4.9	0.9	0.063	Kept
	17. The operation is complicated and	4.25	0.8	0.365	Deleted

	difficult to use (-)				
	18. The font and icons are too small to see (-)	4.4	0.85	0.333	Kept
	19. Sharper contrast in text and background colors is needed (-)	4.45	0.8	0.287	Kept
	N/A				
	20. Using mHealth for health monitoring is time-consuming (-)	4.45	0.7	0.247	Revised[2]
	21. MHealth brings inconvenience due to the lack of synchronization of diagnosis and treatment information in different hospitals (-)	4.65	0.8	0.201	Kept
	N/A				
	22. MHealth frequently lags, making it difficult to use (-)	4.4	0.65	0.238	Kept
	Social Influence	4.35	0.75	0.144	Merged[3]
	23. My family encourages me to use mHealth	4.75	0.85	0.151	Merged[4]
	24. Seeing friends and colleagues use mHealth, I also started using it	4.7	0.75	0.122	Revised[5]
	25. Fellow patients recommended me to use mHealth	4.9	0.9	0.063	Deleted
	N/A				
Round 1	Facilitating Conditions	4.45	0.85	0.134	Merged[3]
	26. My family or friends can help me use mHealth	4.8	0.9	0.145	Merged[4]
	27. Medical staff can help me use mHealth	4.75	0.8	0.116	Kept
	N/A				
	28. Instructions and guidelines cannot help me understand how to use mHealth (-)	4.8	0.9	0.145	Revised[6]
	N/A				
	Technology Anxiety	4.8	0.85	0.109	Kept
	29. I am not familiar with electronic devices, so using mHealth makes me nervous (-)	4.85	0.9	0.101	Kept
	N/A				
	N/A				
	30. I am afraid that if I click something wrong, I will not know how to continue (-)	4.7	0.7	0.100	Deleted

	31. I had negative experiences with digital technology before, so I resist using mHealth (-)	4.7	0.75	0.122	Kept
	32. I do not think I will be able to learn how to use mHealth (-)	4.55	0.75	0.219	Kept
	Perceived Security	4.85	0.85	0.076	Kept
	33. Continuous monitoring and follow-up from the medical team make me feel like I am being watched (-)	4.55	0.75	0.231	Kept
	N/A				
	34. Registering personal information (such as name, phone number, ID) on mHealth makes me feel unsafe (-)	4.65	0.8	0.201	Merged[7]
	35. I worry that mHealth might leak my health information (-)	4.65	0.85	0.212	
	36. I worry about being scammed through mHealth (-)	4.7	0.85	0.196	Kept
	Professional Trust	4.9	0.9	0.063	Kept
	37. I trust my doctor’s and nurse’s judgment about using mHealth	4.65	0.85	0.212	Kept
	38. I believe the disease(s) management methods provided by mHealth are trustworthy	4.7	0.8	0.14	Kept
	39. I doubt the monitoring results provided by mHealth (-)	4.7	0.75	0.122	Kept
Round 1	40. I have no confidence in the advice given by doctors and nurses on mHealth (-)	4.85	0.9	0.101	Kept

Round 2

Round 2

Round 2

Round 2

Note: 1: The item "Some important functions require payment to use (-)" was changed to Item "I cannot use some useful functions without paying (-)."

2: The item "Using mHealth for health monitoring is time-consuming (-)" was changed to "Adding disease measurement results manually on mHealth is annoying (-)."

3: The dimensions "Social Influence" and "Facilitating Conditions" were merged into the dimension "Facilitating Conditions."

4: The items "My family encourages me to use mHealth" and "My family or friends can help me use mHealth" were merged into "My family encourages and teaches me to use."

5: The items "Seeing friends and colleagues use mHealth, I also started using it" and "My family encourages me to use mHealth" were merged into "My friends, coworkers, or fellow patients recommend and teach me to use."

6: The item "User instructions and operation guides can guide me in using (-)" was changed to "Operation guides can guide me in using (-)."

7: The items "Registering personal information (such as name, phone number, ID) on mHealth makes me feel unsafe (-)" and "MHealth may leak my health information" were merged into "MHealth may leak my personal and health information, so I feel it is unsafe (-).

Refinement and Validation of MAUS-E

Polit survey results indicate that the scale items are clearly constructed and easily understandable. However, we have observed that all the items within the same

dimension were either all positive or all negative, with no alternating positive and negative items. This presents a potential risk of response bias. Therefore, we made adjustments to the following items: (1) "MHealth allows me to get health information and support from fellow patients" was modified to "MHealth has not enabled me to obtain health information and support from fellow patients (-)"; (2) "I am more confident in managing my illness" was modified to "I still lack confidence in managing my illness (-)"; (3) "Managing my illness with mHealth is not difficult for me" was modified to "Managing my illness with mHealth is difficult for me (-)"; (4) "MHealth frequently lags, making it difficult to use (-)" was modified to "MHealth is smooth, I find it user-friendly"; (5) "I am not familiar with electronic devices, and using mHealth makes me nervous (-)" was modified to "I am familiar with electronic devices, using mHealth does not make me nervous"; (6) "MHealth may leak my personal and health information, so I think it is unsafe (-)" was modified to "MHealth will not disclose my personal and health information, I feel secure."

Results of Item Analysis and Screening

We collected 175 valid responses during this stage: 109 (62.3%) from males and 66 (37.7%) from females. Among these respondents, 93 (53.1%) in the were between 60–69 years age group, 62 (35.4%) in the 70–79 age group, and the remaining 20 individuals (11.4%) were aged between 80 and 92. One hundred (57.1%) participants resided in urban areas, and 133 (76%) were married. The educational background of the participants was as follows: primary school or below, 78/175 (44.6%); junior high school, 69/175 (39.4%); high school or vocational education, 22/175 (12.6%); and college or above, 6/175 (0.3%). Among all respondents, 32.6% had an average monthly household income of less than 2000 yuan, 60.6% had an income between 2001 and 6000 yuan, and 0.7% had an income exceeding 6000 yuan.

(1) Item Discrimination Index

As depicted in Table 5, the results of the independent sample t-test have revealed that only items 20 and 30 did not display a significant difference ($p > 0.05$). In such a scenario, if the items exhibit a critical ratio (CR value) < 3 [33], it signifies poor discrimination and may be considered for removal. Additionally, all items, except for items 20 and 30, demonstrated effective discrimination.

(2) Correlation coefficient

Table 5 reveals that several items do not meet the thresholds and can be considered for deletion. Specifically, Items 1, 2, 9, 17–22, 26, 28, 29, 31, and 32 did not satisfy

the criteria of ITC ≥ 0.4; they also did not demonstrate a significant difference ($p < 0.05$) or have a CITC ≥ 0.4.

(3) Internal consistency test

Cronbach's α values were computed for each dimension, with the following results: Dimension 1 (Items 1–9), Dimension 2 (Items 10–18), Dimension 3 (Items 19–22), Dimension 4 (Items 23–25), Dimension 5 (Items 26–28), and Dimension 6 (Items 29–32) had a value of 0.712, 0.774, 0.524, 0.817, 0.758, and 0.686, respectively. After removing Items 9, 18, 26, and 29, the Cronbach's α values for the corresponding dimension improved by 0.094, 0.022, 0.034, and 0.072, respectively. Considering other relevant indicators, it was advisable to reconsider the exclusion of Dimension 3 (Item 19–22).

(4) Exploratory factor analysis

After analysis, the Kaiser-Meyer-Olkin (KMO) value was found to be 0.789, and Bartlett's sphericity test was statistically significant ($P < 0.05$), indicating that it was appropriate to conduct EFA [59, 60]. Six factors were extracted based on the criterion of eigenvalues greater than 1. The scree plot in Figure 3 illustrates a transition from steep to stable, indicating a satisfactory factor solution. The cumulative variance contribution rate reached 68.12%, exceeding the 60% threshold, which suggests that the model is acceptable [32]. We eliminated two cross-loaded items, Items 7 and 8, although their factor loadings were more than 0.4.

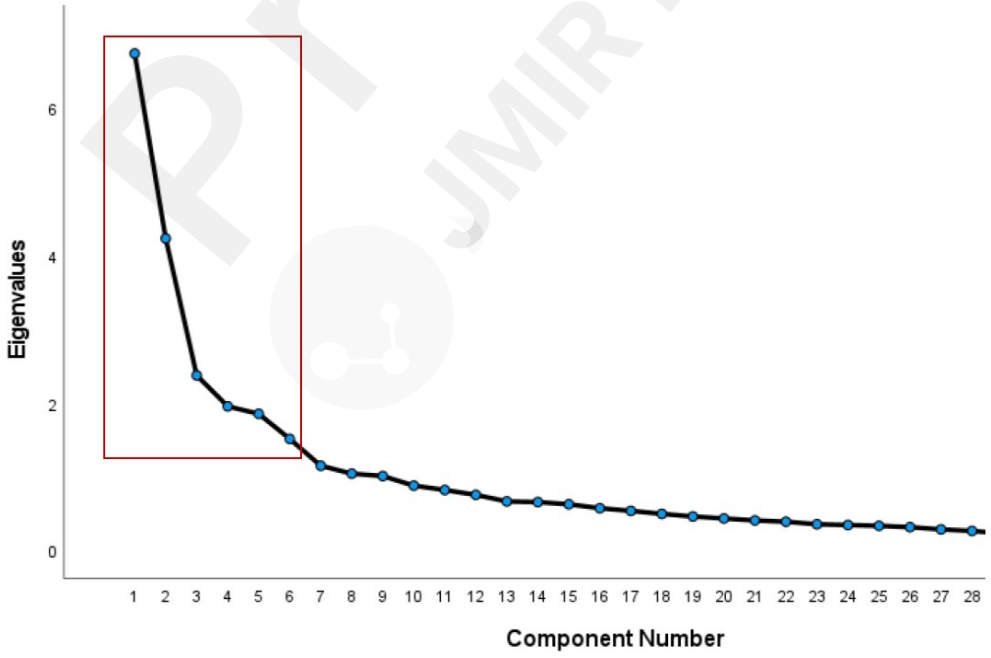

Figure 3. Gravel diagram.

Table 5. Item analysis and screening.

Item No.	IDI		CC		ICT	EFA		Results
	CR	*p-value*	ITC	CITC	Cronbach's α (After deleting the item)	Communality	Factor Loadings	
1	3.314	0.001***	**0.230*** **	**0.313**	0.702	0.61	0.525	Kept
2	4.279	0.000***	**0.385*** **	0.501	0.669	0.553	0.672	Kept
3	5.354	0.000***	0.525***	0.572	0.655	0.588	0.707	Kept
4	8.154	0.000***	0.605***	0.501	0.666	0.584	0.556	Kept
5	5.028	0.000***	0.469***	0.47	0.671	0.616	0.587	Kept
6	6.707	0.000***	0.515***	0.548	0.661	0.658	0.571	Kept
7	7.464	0.000***	0.576***	0.529	0.663	0.592	**N/A**	**Deleted**
8	4.301	0.000***	0.521***	0.541	0.654	0.551	**N/A**	**Deleted**
9	4.519	0.000***	**0.056**	**0.220**	**0.806**	0.619	0.468	**Deleted**
10	5.569	0.000***	0.549***	0.446	0.756	0.735	0.808	Kept
11	3.102	0.003***	0.612***	0.582	0.734	0.703	0.786	Kept
12	3.973	0.000***	0.630***	0.515	0.745	0.697	0.673	Kept
13	4.074	0.000***	0.667***	0.593	0.732	0.776	0.764	Kept
14	5.695	0.000***	0.451***	0.537	0.74	0.684	0.418	Kept
15	6.796	0.000***	0.429***	0.524	0.745	0.696	0.51	Kept
16	7.138	0.000***	0.415***	0.445	0.754	0.664	0.763	Kept
17	7.816	0.000***	**0.391*** **	**0.383**	0.765	0.731	0.812	Kept
18	6.837	0.000***	**0.190***	**0.111**	**0.796**	0.801	0.469	**Deleted**
19	6.547	0.000***	**0.273*** **	**0.292**	0.469	0.722	0.509	**Deleted**
20	**0.445**	**0.657**	**0.326*** **	**0.338**	0.429	0.724	0.763	**Deleted**
21	3.338	0.001***	**0.276*** **	**0.302**	0.462	0.774	0.793	**Deleted**
22	8.226	0.000***	0.529***	**0.32**	0.445	0.729	0.653	**Deleted**
23	8.947	0.000***	0.546***	0.69	0.727	0.682	0.635	Kept
24	9.678	0.000***	0.520***	0.66	0.762	0.682	0.642	Kept
25	9.555	0.000***	0.541***	0.664	0.755	0.743	0.659	Kept
26	6.01	0.000***	**0.333*** **	0.482	**0.792**	0.672	0.754	Kept
27	4.514	0.000***	0.433***	0.72	0.522	0.742	0.728	Kept
28	4.519	0.000***	**0.356*** **	0.576	0.69	0.736	0.608	Kept
29	4.806	0.000***	**0.215*** **	**0.24**	**0.758**	0.63	0.562	**Deleted**
30	**1.444**	**0.152**	0.429***	0.625	0.515	0.696	0.741	Kept
31	3.904	0.000***	**0.381*** **	0.53	0.585	0.708	0.769	Kept
32	4.04	0.000***	**0.377*** **	0.517	0.588	0.7	0.8	Kept

Note: *** indicates < 0.001

In summary, items 7–9, 18–22, and 29 were removed (Table 5). We, therefore, obtained a scale of 23 items in six dimensions and began validation survey and analysis.

Reliability and validity evaluation of MAUS-EC

Two hundred respondents (males: 124/200, 62%; females: 76/200, 36%) completed this validation survey; 107 were aged between 60 and 69 years old (53.5%), 68 participants were aged between 70 and 79, and 25 individuals were aged 80 or above

(12.5%). In total, 155 (77.5%) people resided in urban areas, while 45 (22.5%) lived in rural areas, respectively. The majority of participants were married (185/200). More than half of the respondents (116/200) had at least a junior high school education (junior high school: 63/200, 31.5%; high school or vocational school: 42/200, 21%; college or higher: 11/200, 5.5%). The average monthly family income was stratified as follows: 2000 yuan or less (94/200, 47%), 2001 to 6000 yuan (94/200, 47%), and more than 6000 yuan (12/200, 6%). One yuan is approximately equal to 0.14 US dollars.

Evaluation of scale reliability and validity

(1) Content validity

The I-CVI ranged from 0.85–1, which aligns with the minimum requirement of 0.78 [35]. Furthermore, the average S-CVI was 0.97, exceeding the specified threshold of 0.9 [35].

(2) Structural validity

The model formed by CFA (Figure 4) grouped four items: Item 14—"The font and icons are too small to see (-)"; Item 15—"Sharper contrast in text and background colors is needed (-)"; Item 16—"Adding disease measurement results manually on mHealth is annoying (-)"; and Item 17— "MHealth brings inconvenience due to lack of synchronization of diagnosis and treatment information in different hospitals (-), into a single dimension". Parameter estimates for this model all met the criteria (Table 6), indicating that this new model better aligns with the observed data compared to the initial model. The formed dimension was, therefore, renamed "Access Empowerment".

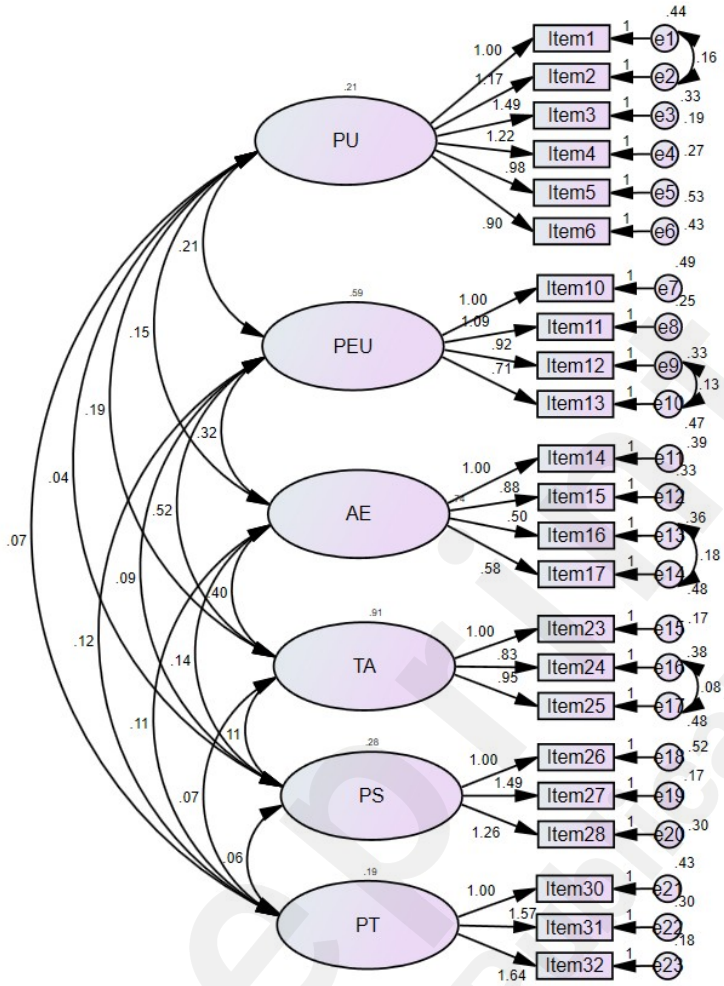

Figure 4. The standardized model.

Abbreviations: PU: Perceived Ease of Use. PEU: Perceived Usefulness. AE: Access Empowerment. TA: Technology Anxiety. PS: Perceived Security. PT: Professional Trust.

Table 6. Fit indices of the structural equation models.

Statistic indices	χ^2/df	GFI	AGFI	CFI	IFI	TLI	RMSEA	SRMR
Observed value	1.728	0.860	0.817	0.927	0.928	0.913	0.060	0.067
Standard	□3 [32]	0.8 [61]	≥0.8 [62]	□0.9 [32]	□0.9 [32]	□0.9 [32]	□0.08 [63]	□0.1 [64]

(3) Convergent Validity

The SFL, AVE, and CR were greater than 0.5, 0.4, and 0.6, respectively (Table 7). These results align with the established standards [65-68].

Table 7. Indicators of convergent validity.

Path			SFL	SE	P	CR	AVE
Item 1	<---	F1	0.572				
Item 2	<---	F1	0.686	0.126	***		
Item 3	<---	F1	0.844	0.188	***	0.8172	0.4347
Item 4	<---	F1	0.733	0.165	***		
Item 5	<---	F1	0.527	0.165	***		
Item 6	<---	F1	0.532	0.15	***		
Item 10	<---	F2	0.739				
Item 11	<---	F2	0.86	0.097	***		
Item 12	<---	F2	0.78	0.089	***	0.8401	0.5709
Item 13	<---	F2	0.624	0.086	***		
Item 14	<---	F3	0.807				
Item 15	<---	F3	0.798	0.09	***		
Item 16	<---	F3	0.583	0.066	***	0.7918	0.4934
Item 17	<---	F3	0.588	0.076	***		
Item 23	<---	F4	0.883				
Item 24	<---	F4	0.82	0.064	***	0.8825	0.7148
Item 25	<---	F4	0.832	0.072	***		
Item 26	<---	F5	0.595				
Item 27	<---	F5	0.886	0.19	***	0.8019	0.5804
Item 28	<---	F5	0.776	0.158	***		
Item 30	<---	F6	0.553				
Item 31	<---	F6	0.778	0.217	***	0.7806	0.5502
Item 32	<---	F6	0.86	0.23	***		

Note: *** indicates < 0.001.

(4) Reliability evaluation

As shown in Table 8, the Cronbach's α of MAUS-EC was 0.85, and the Cronbach's α coefficients for dimensions 1–6 were 0.813, 0.911, 0.854, 0.858, 0.788, and 0.758, respectively. All Cronbach's α coefficients exceeded 0.7 and were in the acceptable range [69].

Table 8. Cronbach's α of MAUS-EC and the subscales.

Dimension No.	Number	Cronbach's α
Perceived Usefulness	6	0.813
Perceived Ease of Use	4	0.911
Access Empowerment	4	0.854
Technology Anxiety	3	0.858
Perceived Security	3	0.788
Professional Trust	3	0.758
Full scale	23	0.850

Discussion

This study reports on the development of a scale (MAUS-EC) to measure the usability of mHealth apps among older adults with chronic diseases and also assessed its psychometric proprieties among a sample of older Chinese adults. This scale has 23 items in six domains to operationalize the usability, providing researchers and stakeholders with a reliable and valid instrument to improve the age-appropriateness of mHealth.

Compared with previous usability testing tools, such as SUS, PSSUQ, and MAUQ [19-21], we adopted a series of organized and standardized empirical studies focused on elderly patients with chronic diseases. The development of scale items is based on a systematic literature review and the existing framework, showing a solid theoretical foundation. In-depth interviews extended information relating to the interactions between the patients and mHealth. Our experienced research team members promoted

the accuracy and readability of the items through discussion. The Delphi method was used to further modify the scale items, conducted among experts from the central, northern, and eastern regions as well as the southern coastal areas of China. Their expertise included chronic disease care, aging care, and mHealth. These observations reflect the geographical and professional representation of the experts. The Delphi survey also gave them sufficient time and energy to consult relevant materials, enrich background knowledge, think more thoroughly, and express their views fully about the scale through "back-to-back" communication [29]. A pilot survey using a small sample strengthened the feasibility of measurement.

In this study, we analyzed the differentiation, representativeness, independence, and internal consistency of all items. We found that the items performed well in terms of differentiation, which may be related to systematic development progress and multiple revisions. The initial version of MAUS-EC formulated after two rounds of expert consultation, consisted of 32 items, each meeting the selection criteria for stability [32]. We referred to relevant indicators and combined expertise during the item screening process. CFA was conducted to examine the factor structure, resulting in six dimensions (perceived usefulness, perceived ease of use, access empowerment, technology anxiety, perceived security, and professional trust) forming the final version of MAUS-EC. The first subdimension (items 1–6) refers to the perceived benefits of using mHealth for elderly patients with chronic diseases. The second subdimension (items 7 and 10) relates to the ease of use of mHealth for older patients. The third subdimension (items 11 and 14) pertains to the technical support mHealth provides for the population. The fourth subdimension (items 15 and 17) addresses the negative emotions that may arise when using mHealth. The fifth subdimension (items 18 and 20) concerns the degree to which patients believe their personal information can be secured when using mHealth. Finally, the sixth subdimension (items 20 and 23) measures the degree of trust in the professionalism of mHealth. These dimensions encompass various aspects of the use of mHealth for elderly patients with chronic diseases, including cognitive, behavioral, physiological, and psychological factors. The comprehensiveness of the scale dimensions ensures that what is measured under each dimension is different.

In summary, MAUS-EC was developed through a theory-driven and evidence-based approach while following the principles of the development process, reflecting good reliability and validity. The qualitative and quantitative evaluation and the screening of the items met the requirements of psychometrics. This feasible scale

helps evaluate the usability of mHealth apps from the perspective of older adults with chronic diseases. The instrument is also easy to understand, without redundant items, and it has a suitable number of items for older adults with chronic diseases to respond to. Future research should focus more on improving the usability of mHealth and enhancing the age-appropriateness of the healthcare delivery model in the evolving digital environment through this tool. Particular attention should be paid to individuals with low scores to reduce digital health inequalities.

Limitations

The elderly patients with chronic diseases surveyed in this study were all from Guangzhou City, Guangdong Province. The mHealth apps involved in this study are some of the existing applications available on the market. Therefore, a wider range of samples and items removed during the development process of our scale still may need to be considered when designing and developing mHealth apps centered on the intended user base.

Conclusions

This study found that MAUS-EC is a reliable and valid tool for assessing mHealth app usability. It was developed using rigorous methods and evaluated with elderly patients suffering from chronic diseases.

Abbreviations

CFA: Confirmatory Factor Analysis
CITC: Corrected Item-Total Correlation
CNKI: China National Knowledge Infrastructure
CV: Coefficient of Variation
EFA: Exploratory Factor Analysis
FSR: Full Scale Ratio
GFI: Goodness-of-Fit Index
IDI: Item Discrimination Index
ITC: Item-Total Correlation
KMO: Kaiser-Meyer-Olkin
MAUQ: MHealth App Usability Questionnaire
MIS: Mean Importance Score

SEM: Structural equation modeling

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Conflicts of Interest

None.

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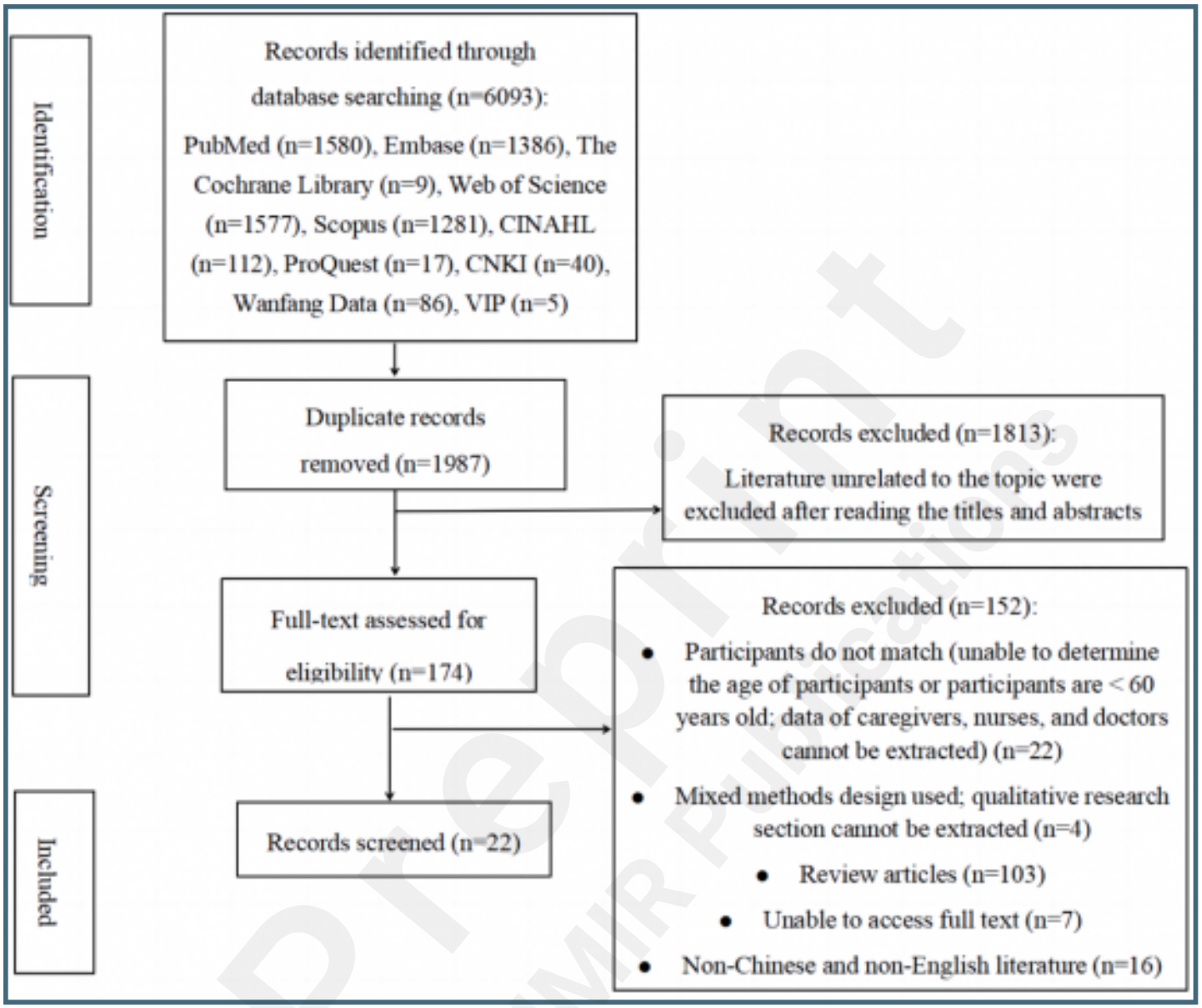
Supplementary Files

Figures

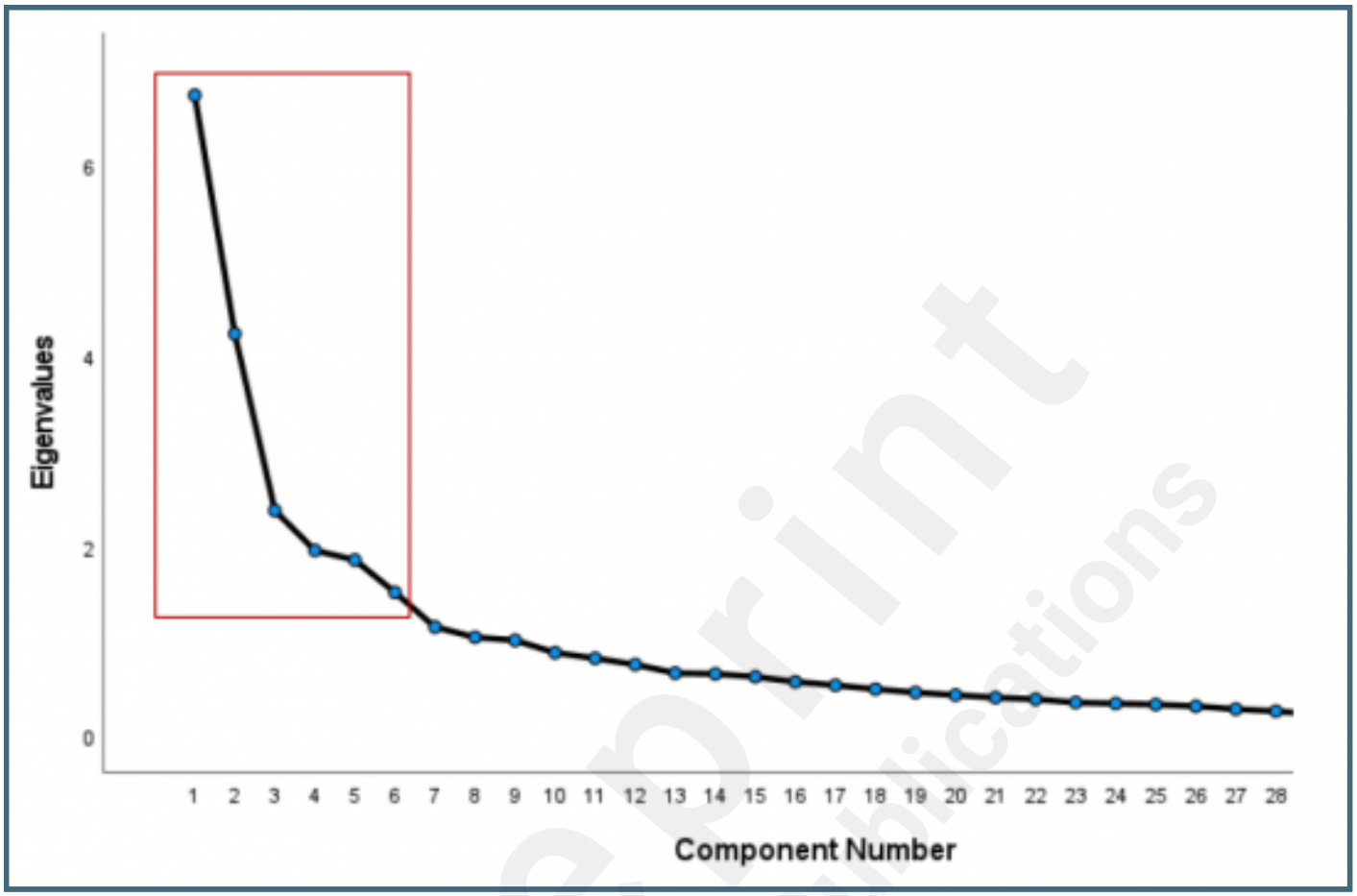
The search strategy used in PubMed.

("Older adults" OR "Elderly" OR "Senior citizens" OR "Aging population" OR "Older individuals") AND ("Hypertension" OR "Diabetes" OR "Heart disease" OR "Arthritis" OR "Chronic obstructive pulmonary disease" OR "COPD" OR "Osteoporosis") AND ("mHealth" OR "Mobile health" OR "Mobile applications" OR "Smartphone apps" OR "Mobile technology") AND ("Attitude" OR "Perception" OR "Opinion" OR "Viewpoint" OR "Sentiment") AND ("Experience" OR "User experience" OR "Patient experience" OR "Lived experience") AND ("Ethnography" OR "Phenomenology" OR "Grounded theory" OR "Narrative analysis" OR "Content analysis" OR "Thematic analysis")

The study screening and selection process.



Gravel diagram.



Multimedia Appendixes

The pool of candidate items.
URL: http://asset.jmir.pub/assets/83f5bf7ca54703d468596b3188f39717.docx

Delphi experts' demographics.
URL: http://asset.jmir.pub/assets/ad8507eeb20e58ca649e4bf2f53cb7e0.docx

The Expert Positivity Coefficient.
URL: http://asset.jmir.pub/assets/d37ae4e732d550c4986119e4fddef488.docx

Indicators of two rounds of Delphi consultation and the screening results.
URL: http://asset.jmir.pub/assets/9552737e7151ad5ef568020937bcfd75.docx

Item analysis and screening.
URL: http://asset.jmir.pub/assets/7e9b19ca5ec84990c6801d472930e410.docx

Fit indices of the structural equation models.
URL: http://asset.jmir.pub/assets/6dcdd3f01b022fd3ea9c7d9b3dba292b.docx

Indicators of convergent validity.
URL: http://asset.jmir.pub/assets/e7a9e377b1da47c3bb2cfe01a90730b7.docx

Cronbach's ? of MAUS-EC and the subscales.
URL: http://asset.jmir.pub/assets/9b6a289155a6916c66c88d49bee3b0b2.docx