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Research Paper

The development and application of the mobile frailty management platform for Chinese community-dwelling older adults

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ABSTRACT

Objectives: This study aimed to develop a mobile frailty management platform for Chinese community-dwelling older adults and evaluate its effectiveness, usability and safety.
Methods: Based on literature research, the research team combined the frailty cycle and integration models, self-determination theory, and technology acceptance models and determined the frailty interventions through expert discussion, then transformed it into multimedia resources, finally, engineers developed the mobile management platform. A cluster sampling, parallel, single-blind, controlled quasi-experimental trial was conducted. Sixty older adults from two community health service centers were recruited from March to August 2023. The control group received routine community care, while the intervention group used the mobile frailty management platform. The incidence of frailty, scores of quality of life, depression, sleep quality, and grip strength within 12 weeks were compared between the two groups, and the availability and safety of the platform were assessed.
Results: A total of 52 participants completed the study, 27 in the intervention group and 25 in the control group. At 12 weeks after the intervention, the frailty state of the intervention group was reversed to pre-frailty. There were no significant differences in the scores of quality of life, depression, sleep quality, and grip strength between the two groups before and 4 weeks after intervention. At 8 weeks and 12 weeks after the intervention, the quality of life, depression, and grip strength of the intervention group were improved with statistical significance ($P < 0.05$). Sleep quality was statistically significant only 12 weeks after the intervention ($P < 0.05$). System Usability Scale score for the platform was (87.96 ± 5.88), indicating a highly satisfactory user experience. Throughout the intervention, no adverse events were reported among the older adults.
Conclusions: The mobile frailty management platform effectively improved frailty status, depressive mood, sleep quality, grip strength, and quality of life for Chinese community-dwelling older adults. It holds clinical application value and is an effective tool for strengthening frailty management among Chinese community-dwelling older adults.

What is known?

- The prevalence of frailty among community-dwelling older adults is substantial, often challenging to diagnose accurately, and leads to severe health outcomes.
- Frailty is a dynamic and reversible condition, multicomponent exercise regimens with nutritional interventions have effectively improved frailty status and quality of life.
- Mobile healthcare provides older adults with valuable opportunities for self-management support, serving as an effective strategy for continuous monitoring and health education.

What is new?

- The mobile frailty management platform was developed and validated for Chinese community-dwelling older adults, demonstrating its usability and effectiveness.
- The mobile frailty management platform exhibited high usage frequency and excellent usability.

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- The mobile frailty management platform effectively improved frailty status, depressive mood, sleep quality, grip strength, and quality of life for Chinese community-dwelling older adults.

1. Introduction

According to WHO, the global population aged 60 and older is projected to increase from one billion in 2020 to 1.4 billion by 2030 [1]. China is currently experiencing rapid population aging, with 18.7% of its population aged 60 years and older and those aged 65 years and older accounting for 13.5% [2]. As the global population ages, frailty-related geriatric syndromes rise [3]. A meta-analysis including 240 studies from 62 countries showed that the pooled prevalence of frailty was 12% [4]. In Germany, the prevalence of frailty among older adults aged 65 and above is 13.7% [5]. In China, the pooled prevalence of frailty and prefrailty among the community-dwelling older adult population is 10.1% and 43.9% respectively [6]. These statistics underscore the growing significance of frailty as a critical public health issue on a global scale.

Frailty is a complex geriatric syndrome characterized by impaired homeostatic regulation across multiple bodily systems, primarily marked by sarcopenia. This condition leads to diminished physiological reserve and an increased vulnerability to adverse events [7]. It is associated with an increased incidence of falls, functional limitations, and heightened risk of hospitalization and mortality [8,9]. Frailty is a dynamic condition that can be mitigated or even reversed through appropriate interventions [10]. Current interventions for frailty predominantly include exercise, nutritional support, and pharmacological treatments, with exercise being widely regarded as one of the most effective approaches [11]. Several studies have substantiated that multicomponent exercise regimens in conjunction with nutritional interventions can significantly ameliorate frailty status while also mitigating depression and enhancing sleep quality in older adults [12–14]. Traditional management models for frail older adults, such as telephone consultations or home visits, have successfully raised awareness and improved self-care abilities within the community. However, these methods are constrained by limited reach, substantial burdens on healthcare providers, and inadequate targeting and interactivity. With the development of technology, many scholars are using mobile health technologies to enhance compliance with traditional intervention measures. Sun et al. [15] developed a health behavioral digital intervention for patients with hypertension based on an intelligent health system and WeChat, which can effectively improve compliance with medication and blood pressure monitoring among older adults. Therefore, there is an urgent need to explore mobile health management platforms specifically tailored to address the needs of frail older adults in the community.

WHO defines mobile health as medical practices and public health services supported by various mobile devices, including smartphones, health monitoring devices, personal digital assistants, and other wireless devices [16]. These services can offer patients various healthcare options such as consultations, diagnoses, monitoring, and health education. Currently, mobile health encompasses applications, informational websites, online platforms, and wearable devices [17]. Studies have demonstrated that mobile health interventions can improve older people's health outcomes and quality of life, alleviate negative emotions, and enhance adherence to healthy behaviors [15,18]. It exhibits greater openness, interactivity, and personalization in disseminating health knowledge. Among health knowledge dissemination platforms, WeChat is the most widely used and trusted platform in China [19]. Surveys show that 68% of older adults aged 60 and above use smartphones and strongly suggest using mobile health applications [20].

Therefore, this study aimed to establish and develop a mobile frailty management platform and evaluate its usability and effectiveness. The platform facilitates low-cost, widely accessible, and personalized frailty management, providing an effective tool and model for screening and managing frailty among Chinese community-dwelling older adults.

2. Methods

2.1. Study design and participants

In accordance with the Consolidated Standards of Reporting Trials (CONSORT) checklist, a cluster sampling, parallel, single-blind, controlled quasi-experimental trial was conducted. Older adults were recruited from two community health service centers in Hangzhou, Zhejiang, China, from March to August 2023. Participants were allocated into two groups based on different communities: the control group received routine community care, and the intervention group used the mobile frailty management platform. This study adopted a single-blind method where participants were unaware of the group allocation. The inclusion criteria were as follows: 1) 60 years or older; 2) be diagnosed as frail or pre-frail according to the FRAIL scale; 3) participate voluntarily and without any language communication barriers; 4) be proficient in using mobile phones and WeChat applications and have the ability to read and understand Chinese information independently; 5) not have severe cardiovascular, pulmonary, hepatic, renal, or other significant illnesses. The exclusion criteria were: 1) presence of cognitive disorders or psychiatric conditions; 2) visual and hearing impairments; 3) physical condition unsuitable for exercise. The dropout criteria were: 1) voluntary withdrawal during the study period; 2) failure to enter health data for two consecutive weeks during the intervention period.

2.2. Sample size

The sample size was calculated using the formula: $2\times[(\mu_\alpha+\mu_\beta)\times(\sigma/\delta)]^2$ [21]. Based on relevant literature [22,23], the standard deviation (σ) was determined to be 1.30, and the effect size (δ) was set at 1.40. With $\alpha = 0.05$ and $\beta = 0.10$, the critical values obtained from the standard regular distribution table were $\mu_\alpha = 1.96$ and $\mu_\beta = 1.65$. To account for potential dropouts and other unforeseen factors, the sample size was inflated by 25%, requiring 30 valid samples per group. Consequently, 60 older adults were recruited in this study.

2.3. Procedures

2.3.1. Establishing the research and implementation teams

The research team comprised six members: one chief nurse, one computer software engineer, and four master's degree students specializing in geriatrics. The team's primary responsibilities encompassed designing the platform's architecture and functional modules, developing a management plan, selecting pertinent experts, organizing expert panel meetings, and refining and finalizing the platform's contents based on expert feedback and recommendations. The implementation team, consisting of two trained graduate students and four nurses from the community health service center, was primarily responsible for recruiting study participants, providing guidance on platform usage, managing the platform's notifications, supervising activities, conducting regular follow-ups, and giving feedback.

2.3.2. Establishment and development of the mobile frailty management platform

The research team conducted an extensive literature review in both Chinese and English databases, using search terms such as "frailty," "frail," "frailty syndrome," "assessment," "management," "intervention," "nutrition," "exercise," "identification," etc. Guidelines, expert consensuses, and evidence summaries of frailty risk screening, assessment, intervention, and management were included. After literature screening, quality evaluation, and evidence extraction, a draft of a comprehensive frailty management program was formed, which included frailty assessment, multicomponent exercise interventions, nutritional interventions, and health education. Several theoretical models were used to guide the program's formulation. Assessment tools were set based on the frailty cycle model [24], and measures for improving frail older adults' physical and nutritional state were developed. The frailty integration model framework [25] was used to comprehensively consider multiple factors for dynamic management. Based on the self-determination theory [26], health education interventions and a platform integrated with an incentive mechanism were designed to stimulate the motivation of older people. In line with the technology acceptance model [27], the platform was user-friendly, with diverse content for older people.

The research team transformed the frailty management program into multimedia resources, including assessment questionnaires, instructional videos, and articles. Additionally, we explored existing chronic disease or frailty management platforms available in app stores such as the App Store and WeChat mini-programs and searched for relevant literature to analyze their modules and functions. Based on this analysis, the team identified key platform modules and functions that align with clinical needs. Subsequently, the research team convened an expert panel comprising four geriatric nursing experts, two rehabilitation medicine specialists, two nutritionists, and two computer software experts to review and optimize the frailty management platform's modules, functions, and overall program, ensuring its scientific validity, reliability, and usability. After the discussion, it was recommended that the nutritional intervention method be changed, on-site exercise guidance for the first session be added, the reminder items and the presentation form of health outcomes be adjusted, and the communication module on the patient end be simplified. The individual authority coefficients of the 10 experts ranged from 0.8 to 1.0, and the average authority coefficient of the expert group was 0.93, indicating a high level of authority among the experts and reliable results.

An information engineer subsequently integrated multimedia resources into a mobile frailty management platform. The platform, finalized in December 2022, comprises two main components. The healthcare provider end (Appendix A) includes a personal center, knowledge management, patient management, and message management. The patient end (Appendix A) includes frailty assessment, reminders, task push, task check-ins, points mall, and data analysis. Specifically, the reminder function prompts the older adults via the platform to record their daily diet and exercise and update their general information and the frailty scale every four weeks. As for the task push and check-in functions, the platform dispatches exercise videos, recommended recipes, and health education videos according to the plan. After completing these, the older adults can click the check-in button and earn corresponding points based on the content of their check-ins. The points mall function lets older adults to view the weekly points ranking list and redeem prizes with the accumulated points. Following the development, three research team members conducted a pretest to ensure the platform's stability and reliability. By carefully using platform functions, they hunted for program bugs and areas where development deviated from expected requirements or had flaws. Then, they compiled reports on each test result and gave feedback to software engineers for debugging and fixing. An information engineer is also responsible for routine maintenance and management to ensure continuous, stable operation. The platform has been awarded computer software copyright with registration number (10480621) and copyright certificate number (2022SR1526422).

2.3.3. Determination of the platform intervention program

The platform-based intervention program includes four components, the duration of which is set for 12 weeks (Appendix A).

Health assessment: the FRAIL scale is utilized to evaluate the frailty status of older adults, documenting general information such as weight, medication usage, and chronic disease conditions. The platform prompts patients to update their health information every four weeks. Frailty assessment scores are visualized in a line graph format, allowing healthcare providers to review detailed patient assessments through the healthcare provider end and provide timely feedback.

Health education: it integrates various video and article materials, addressing frailty content and introducing common diseases that affect frailty. The health education videos are provided according to the plan, and the educational articles are posted on the platform for older adults to read anytime.

Multicomponent exercise guidance: in the form of exercise videos, older adults can access the WeChat mini-program at any time to watch the exercise videos pushed for that day. After following the videos for exercise, they can click the check-in button. Multicomponent exercise program, including aerobic exercise, resistance training, balance training, and stretching exercises. During weeks 1–2, the focus is on lighter exercises, while from weeks 3–12, resistance training with elastic bands is combined. Exercise guidance is scheduled for Mondays, Wednesdays, and Fridays.

Nutritional guidance: the platform reminds older adults to record their daily diet and exercise. Older adults are advised to ensure that their daily energy intake meets or exceeds their energy expenditure and to consume protein at a rate of 1.2 g per kilogram of body weight. The platform offers daily recommended recipes for dietary guidance, allowing older adults to upload photos or text descriptions of their meals. Additionally, the platform generates pie charts comparing energy intake to daily expenditure and bar charts illustrating protein intake, facilitating a clear understanding for older adults.

2.3.4. The intervention group

The older adults in the intervention group received mobile frailty management platform interventions and routine community care. The implementation team facilitated participant enrollment by sharing the WeChat mini-program link. They distributed an operation manual for the mini-program and guided logging in and using the platform. Upon their first login, older adults were required to complete an automatically generated assessment before accessing the mini-program. The first exercise guidance was provided on-site by nurses, while subsequent sessions could be followed via exercise videos available on the platform. Nurses monitored platform usage through the backend, recorded statistics, and provided timely feedback. A reminder SMS was sent if an older adult had not checked in by 5 p.m. on any given day. If participants had not used the platform for more than two days, they were reminded through a phone call or home visit. Older adults could seek online consultations if they encounter any issues, with healthcare providers responding daily.

2.3.5. The control group

The older adults in the control group underwent routine community care. Voluntarily, they attended monthly on-site health education activities organized by the community nurses. The curriculum encompassed fundamental knowledge on frailty, self-screening, dietary habits, and physical exercise guidance.

2.4. Measures

2.4.1. Sociodemographic data

Sociodemographic data include sex, age, BMI, education level, marital status, residence, number of chronic diseases, average monthly income, and medical payment methods.

2.4.2. Frailty

The FRAIL Scale was developed by Morley et al. [28] and culturally adapted for Chinese populations by Jing et al. [29]. It includes five components: fatigue, resistance, ambulation, illnesses, and loss of weight. The total scores range from 0 to 5, with 0 representing robust, 1 to 2 pre-frail, and 3 to 5 frail status. The Cronbach's α coefficient of this scale is 0.705, and the structural validity ranges from 0.538 to 0.656 [29].

2.4.3. Quality of life

The quality of life was assessed using the Short Form 36-Item Health Survey Questionnaire (SF-36), developed by an American research group [30] and culturally adapted for Chinese populations by Li et al. [31]. It is composed of eight dimensions and a non-scored health transition item. The dimensions include physical functioning (ten items), role-physical (four items), bodily pain (two items), general health (five items), vitality (four items), social functioning (two items), role-emotional (three items), and mental health (five items). The actual scores of each dimension need to be converted through a calculation formula into standard scores ranging from 0 to 100: the standard score of each dimension = (the calculated actual score - the minimum score)/(the maximum score - the minimum score)×100%. The total scores range from 0 to 800. Higher total scores indicate better quality of life. The Cronbach's α coefficient for the scale is between 0.70 and 0.91, indicating satisfactory internal consistency.

2.4.4. Depression

The Geriatric Depression Scale (GDS), initially developed by Yesavage et al. [32] and subsequently culturally adapted for Chinese populations by Liu et al. [33], is a screening tool designed to assess depression for older adults. For each item, the answers are "yes" and "no," with 0 and 1 point, respectively. It comprises 30 items, with total scores ranging from 0 to 30. 0–10 indicates no depressive symptoms, 11–20 indicates mild depressive symptoms, and 21–30 indicates moderate to severe depressive symptoms. The scale demonstrates good internal consistency, with a Cronbach's α coefficient of 0.846.

2.4.5. Sleep quality

The Pittsburgh Sleep Quality Index (PSQI), developed by Buysse et al. [34] and culturally adapted for Chinese populations by Liu et al. [35], is an assessment tool that evaluates sleep quality over one month. It consists of 18 self-rating items and five observer-rating items. The 18 self-rating items involved in scoring are divided into seven dimensions: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. Each dimension is scored on a scale from 0 to 3 points, with the total score ranging from 0 to 21, where a score greater than 7 indicates the presence of sleep problems. Higher total scores indicate poorer sleep quality. The internal consistency reliability of the PSQI, as measured by Cronbach's α coefficient, is 0.842.

2.4.6. Grip strength

Grip strength was measured using the Xiangshan electronic dynamometer. Participants were instructed to sit with their elbow flexed at 90°, upper arm adducted and pressed against the torso and forearm in a neutral position, and wrist extended between 0° and 30°. Subsequently, they were asked to grip the handle with maximal force for 3 s. The final measurement reported was the average of three consecutive trials.

2.4.7. Usage and usability evaluation

The platform's effectiveness was assessed based on participants' task check-ins, diet and exercise records, reading educational articles, and health consultations. The Chinese version of the System Usability Scale (SUS) was used to evaluate their satisfaction with the platform [36]. The scale includes two dimensions, usability, and learnability, with 10 items. Items 1, 3, 5, 7, and 9 are positive-worded questions, while items 2, 4, 6, 8, and 10 are negative. A five-point Likert scale is used for scoring, where 1 point represents "strongly disagree" and 5 points represents "strongly agree". The scale scores need to be converted into a percentage-based score. For positive-worded questions, subtract one from the original score; for negative-worded questions, subtract the original score from 5. Then, multiply the sum of these adjusted scores by 2.5 to obtain the total score. The total score ranges from 0 to 100. Higher scores indicate superior usability. The Cronbach's α coefficient for this scale is 0.785, indicating acceptable internal consistency.

2.4.8. Safety evaluation

During the intervention, palpitations, fractures, falls, and hospitalizations related to the use of the platform are systematically recorded for participants.

2.5. Data collection

At baseline, demographic data were collected, and various indicators were assessed through on-site measurements at four time periods: pre-intervention, 4 weeks, 8 weeks, and 12 weeks post-intervention. Before distributing the questionnaires, the study objectives were explained to the participants, and informed consent was obtained. Questionnaires were administered and collected on-site.

2.6. Data analysis

Data were entered into EpiData 3.1 and analyzed using SPSS 26.0. Continuous variables were summarized using means and standard deviations (*SD*), while categorical variables were described using frequencies and percentages (%). For continuous data, normally distributed variables were analyzed using independent *t*-tests or Fisher exact test, whereas non-normally distributed variables were assessed using rank-sum tests. Categorical data were analyzed using chi-square tests. Repeated-measures ANOVA was employed for multivariate normally distributed data. A significance level of $P < 0.05$ was used to determine statistical significance.

2.7. Ethical considerations

The study received approval from the Ethics Committee of Zhejiang Chinese Medical University (No. 20220426-1) and all participants provided informed consent before involvement.

3. Results

3.1. Characteristics of the participants

During the study, eight older adults (3 in the intervention and 5 in the control group) dropped out of the study (Appendix B), and 27 older adults in the intervention group and 25 in the control group were included in the final analysis. In the intervention group, there were six males (22.2%) and 21 females (77.8%), with an average age of 81.30 ± 5.19. In the control group, there were 10 males (40.0%) and 15 females (60.0%), with an average age of 78.92 ± 8.67. A comparison of the baseline demographic characteristics between the two groups revealed no statistically significant differences ($P > 0.05$), indicating that the groups were well-balanced in terms of these characteristics, as detailed in Table 1.

3.2. Comparison of frailty status between two groups

There were no statistically significant differences in the frailty status in the pre-intervention ($\chi^2 = 1.36$, $P = 0.244$), 4 weeks post-intervention ($\chi^2 = 0.64$, $P = 0.432$), and 8 weeks post-intervention ($\chi^2 = 0.02$, $P = 0.899$) between the older adults in both groups. However, after 12 weeks of intervention, the difference between the two groups of older adults was statistically significant ($P = 0.020$). Additionally, after 12 weeks of intervention, all frail older adults in the intervention group reversed to pre-frail status, while the proportion of frailty in the control group increased. The detailed data are presented in Table 2.

3.3. Comparison of quality of life, depression, sleep quality, and grip strength between two groups

Before the intervention, there was no statistically significant difference in quality of life scores ($t = 0.004$, $P = 0.997$), depressive mood scores ($t = 0.05$, $P = 0.958$), sleep quality scores ($t = 0.21$, $P = 0.832$), and grip strength scores ($t = -1.02$, $P = 0.311$) between two groups. Repeated measures ANOVA showed that the interaction effects on quality of life, depressed mood, sleep quality, and grip strength were statistically significant in both groups ($P < 0.05$). Within the intervention group, statistically significant differences were observed in quality of life scores, depressive mood scores, and grip strength at 8 weeks and 12 weeks. These differences were significant relative to the control group ($P < 0.05$). Additionally, at 12 weeks of intervention, the sleep quality score in the intervention group was significantly different from that of the control group ($P < 0.05$). The detailed data are presented in Table 3.

3.4. Platform usage, usability, and safety evaluation

The older adults in the intervention group had a cumulative total of 3,426 task check-ins. Among these, 1,561 were related to recommended recipes, 1,545 involved exercise videos, and 320 were for health education videos. The cumulative pageviews of the educational articles reached 451 times, with an average of 56.37 views per article. The average proportion of diet and exercise records per person was 70.76%, and the average number of days using the platform per week was 4.95 days. Healthcare providers received a total of 25 consultations from participants. The SUS score was 87.96 ± 5.88, indicating high overall satisfaction with the platform. The utilization pattern of the platform by older adult users was characterized by an initial low frequency of use, a peak during the mid-intervention period, and a subsequent decline toward the end of the intervention. Throughout the intervention, no adverse events were reported among the older adults.

4. Discussion

This study introduced the establishment and development process of a mobile frailty management platform for Chinese community-dwelling older adults and evaluated its usability and effectiveness. The platform demonstrated good usability and effectiveness. The frailty management platform is developed based on an evidence-based program constructed by a multidisciplinary team. It utilizes a WeChat mini-program to realize home-based frailty management for the older adults in the community, thereby breaking through the limitations of time and space. It greatly enhances the accessibility of frailty management. This platform allows older adults to conduct exercise training and nutritional monitoring at home, acquire relevant knowledge for repeated learning, and carry out self-management by comparing

Table 1
Comparison of baseline demographic characteristics between the two groups ($n = 52$).

Characteristics	Intervention group ($n = 27$)	Control group ($n = 25$)	χ^2/t	P
Sex				
Male	6 (22.2)	10 (40.0)	1.93	0.165
Female	21 (77.8)	15 (60.0)		
Age (years)	81.30 ± 5.19	78.92 ± 8.67	1.22	0.233
BMI (kg/m^2)	22.72 ± 3.34	22.79 ± 1.65	0.88	0.930
Educational level				
Primary school	6 (22.2)	4 (16.0)	1.33	0.857
Junior high school	5 (18.5)	5 (20.0)		
High school or junior college	7 (26.0)	7 (28.0)		
College	2 (7.4)	4 (16.0)		
Bachelor's degree or above	7 (25.9)	5 (20.0)		
Marital status				
Married	14 (51.9)	19 (76.0)	3.26	0.089
Widowed	13 (48.1)	6 (24.0)		
Residence				
With spouse	14 (51.9)	19 (76.0)	3.26	0.089
Living alone	13 (48.1)	6 (24.0)		
Number of chronic diseases	4.56 ± 1.38	4.11 ± 1.05	1.32	0.192
Average monthly income (yuan)	6,011.11 ± 2,120.29	6,158.00 ± 2,432.08	0.23	0.486
Medical payment methods				
Medical insurance	18 (66.7)	17 (68.0)	0.01	0.918
Self-pay	9 (33.3)	8 (32.0)		

Note: Data are *n* (%) or *Mean* ± *SD*.

Table 2
Comparison of frailty status between two groups ($n = 52$).

Variables	Pre-intervention		Post-intervention					
			4 weeks		8 weeks		12 weeks	
	Pre-frail	Frail	Pre-frail	Frail	Pre-frail	Frail	Pre-frail	Frail
Intervention group	19 (70.4)	8 (29.6)	19 (70.4)	8 (29.6)	23 (85.2)	4 (14.8)	27 (100.0)	0 (0)
Control group	21 (84.0)	4 (16.0)	20 (80.0)	5 (20.0)	20 (80.0)	5 (20.0)	20 (80.0)	5 (20.0)
χ^2	1.36		0.64		0.02		–	
P	0.244		0.423		0.899		0.020[a]	

Note: Data are *n* (%). [a] Fisher exact test.

Table 3
Comparison of quality of life, depression, sleep quality, and grip strength between two groups ($n = 52$).

Variables	Pre-intervention	Post-intervention			Time		Group		Time×Group	
		4 weeks	8 weeks	12 weeks	*F*	*P*	*F*	*P*	*F*	*P*
Quality of life										
Intervention group	461.94 ± 81.03	498.31 ± 81.03	527.71 ± 70.01	557.15 ± 67.57	11.41	<0.001	6.76	0.008	33.66	<0.001
Control group	461.87 ± 49.41	463.22 ± 53.51	462.23 ± 53.76	463.54 ± 53.66						
t	0.004	1.86	3.76	5.50						
P	0.997	0.068	<0.001	<0.001						
Depression										
Intervention group	8.96 ± 3.51	8.37 ± 3.20	7.20 ± 3.05	7.40 ± 3.36	63.33	<0.001	0.30	0.74	9.06	<0.001
Control group	8.92 ± 2.10	8.80 ± 2.41	9.12 ± 2.28	9.04 ± 2.26						
t	0.05	−0.54	−2.52	−2.04						
P	0.958	0.590	0.015	0.047						
Sleep quality										
Intervention group	9.26 ± 4.44	8.27 ± 3.23	7.48 ± 2.50	6.79 ± 1.67	2.58	0.086	8.67	0.001	8.02	0.001
Control group	9.00 ± 4.32	8.96 ± 4.01	9.04 ± 3.87	8.96 ± 3.68						
t	0.21	0.04	1.74	2.79						
P	0.832	0.490	0.088	0.007						
Grip strength (°)										
Intervention group	20.34 ± 5.95	23.04 ± 5.72	25.37 ± 4.68	26.60 ± 5.06	7.54	0.001	5.05	0.001	3.20	0.050
Control group	22.13 ± 6.64	21.60 ± 6.04	21.52 ± 5.82	21.66 ± 4.74						
t	−1.02	0.88	2.64	3.63						
P	0.311	0.388	0.011	<0.001						

Note: Data are *Mean* ± *SD*.

with their own assessments. Additionally, since frailty is a dynamic process, nurses, with the platform's assistance, conduct regular standardized health assessments on older adults, facilitating the monitoring and management of frail older adult individuals and enabling early detection and intervention.

This study conducted a clinical validation of the platform among community-dwelling older adults, and the results show that it effectively improves the frailty status of older adults, consistent with findings from previous studies [37]. Given that frail older adults frequently experience fatigue and muscle weakness, multicomponent exercise interventions, including resistance, aerobic, and balance training, are considered optimal strategies for improving frailty. These interventions enhance muscle strength, coordination, and flexibility [38]. The multicomponent exercise program implemented in this study offers diverse activities, thereby preventing monotony and increasing participant engagement. Additionally, reminders, task check-ins, and points mall promote adherence and extrinsic motivation, fostering healthier behaviours and improving frailty status.

This platform in the present study effectively improved sleep quality, reduced depressive mood, and enhanced the quality of life among older adults, consistent with the findings from other studies [39,40]. Numerous studies have demonstrated that exercise and a healthy diet play crucial roles in preventing and treating depression and anxiety [14,41]. Low-intensity exercise may increase cerebral blood flow, improve neuronal function, and promote deep sleep, thus enhancing sleep quality [42]. Quality of life, an essential measure of an individual's health status, is influenced by factors like sleep quality, functional capacity, physical health, and mental health [43]. In this study, the frailty management platform provided comprehensive knowledge on frailty, exercise, and nutrition. Through task management on the platform, older adults engaged in regular physical activity and improved their daily dietary intake, indirectly enhancing their overall quality of life. Nonetheless, as this study utilized an online-based intervention, older adults had limited opportunities for social interaction. Future optimizations of the platform should consider integrating functions facilitating communication and feedback to support robust social functioning among older adults.

Grip strength is an indicator of skeletal muscle mass and a crucial metric in assessing frailty phenotypes. This study demonstrated that the platform significantly enhanced grip strength, which aligns with the findings of Llurda-Almuzara et al. [44]. Previous research has shown that combining exercise with appropriate protein intake can improve muscle mass and strength, as protein provides the necessary substrates for increased muscle protein synthesis induced by exercise [12]. In China, the dietary structure predominantly consists of grains and tubers, leading to insufficient protein intake among many residents. High-quality protein constitutes only a tiny proportion of the diet, and many individuals fail to meet the daily requirement of 1.2g of protein per kilogram of body weight. Therefore, the platform's food record feature visually reflects older adults' daily protein intake. It offers timely and accurate nutritional guidance, helping them understand their dietary

issues and ensure adequate nutrient intake. The combination of multicomponent exercise guidance and nutritional recommendations to increase protein intake resulted in improved grip strength among older adults. This highlights the superiority of multidimensional interventions over single-dimensional approaches. Future research should focus on strengthening interdisciplinary collaboration and innovating comprehensive frailty management strategies to improve health management for frail older adults.

The frailty management platform developed in this study achieved a score of 87.96 ± 5.88 on the SUS, exceeding the threshold of 85 points for an excellent platform [45], indicating that the platform exhibits superior usability. The platform was used frequently, with an average usage rate of 70.76%, and participants utilized it for an average of 4.95 days per week, significantly higher than the average frequency of 2.2 times per week reported by Dekker-van Weering et al. [46]. Given that older adults often have diminished learning capabilities and require more time and effort to adapt to new technologies, age-friendly design is crucial for the management platform. Considering the physiological characteristics of older adults, the platform was designed to be user-friendly, featuring large, easily distinguishable fonts. Additionally, as a WeChat mini-program, the platform eliminates the need for older adult users to download a separate app, aligning with their habitual technology use patterns. Moreover, during the entire intervention period, no adverse events occurred due to platform use, possibly because the communication function of the platform and regular follow-up by nurses strengthened the connection between older adults and medical staff, preventing adverse events. The platform also prioritizes data security and privacy protection. Older adult users can only access it via shared links and must enter a password upon login, with backend management personnel overseeing platform maintenance. However, a decrease in usage frequency was observed in later stages, potentially due to inadequate incentive and reminder mechanisms, underscoring the necessity for enhancements.

In conclusion, the evidence-based, comprehensive management program for frailty among community-dwelling older adults provides a robust foundation for evidence dissemination and community practice. This enhances the reliability and scientific integrity of the platform's content. The platform offers sustained health education, frailty assessment, exercise guidance, and nutritional guidance specifically tailored for older adults who are frail or prefrail. Consequently, this improves their health status and quality of life. The positive evaluations from older adult users underscore the platform's potential as an effective tool for screening and managing frailty within the community. Moreover, the xperiences gained from constructing and applying this platform can serve as valuable references for managing other chronic conditions.

However, this study has several limitations that warrant attention. As the system is in its preliminary application phase, future research should aim to expand the sample size and conduct long-term intervention studies to validate the sustained effectiveness of the application. This study introduces a universal intervention measure designed for frail older adults, and subsequent research could explore developing tailored intervention programs based on the specific characteristics of different diseases. Furthermore, future evaluations should focus on the platform's usability, gaining deeper insights into patient and healthcare provider experiences with the platform and their suggestions to refine the functionalities and content of the frailty management platform according to user needs.

5. Conclusions

The mobile frailty management platform developed in this study positively impacts the frailty status, depressive mood, sleep quality, grip strength, and quality of life of Chinese community-dwelling older adults. It holds clinical application value and is an effective tool for strengthening frailty management among these adults. However, the platform's long-term effects require further exploration, and continuous optimization of its functions is recommended to improve overall functionality.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Jiayi Hou: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Supervision, Project administration. **Xinrui Wan:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - review & editing, Supervision, Project administration. **Mengjie Li:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing - review & editing. **Guijuan He:** Conceptualization, Methodology, Validation, Formal analysis, Resources, Writing - review & editing.

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Declaration of competing interest

The authors declare that they have no competing interests.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2025.02.005.

References

[1] World Health Organization (WHO). Ageing and Health. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.
[2] National Bureau of Statistics of China. Main Data of the Seventh National Population Census. https://www.stats.gov.cn/english/PressRelease/202105/t20210510_1817185.html.
[3] Allison 2nd R, Assadzandi S, Adelman M. Frailty: evaluation and management. Am Fam Physician 2021;103(4):219–26.
[4] O'Caoimh R, Sezgin D, O'Donovan MR, William Molloy D, Clegg A, Rockwood K, et al. Prevalence of frailty in 62 countries across the world: a systematic review and meta-analysis of population-level studies. Age Ageing 2021;50(1):96–104. https://doi.org/10.1093/ageing/afaa219.
[5] Hajek A, Kretzler B, König HH. Prevalence of prefrailty and frailty among older adults in Germany: a systematic review, meta-analysis and meta-regression. Front Med 2022;9:870714. https://doi.org/10.3389/fmed.2022.870714.
[6] Zhou Q, Li Y, Gao Q, Yuan HP, Sun L, Xi H, et al. Prevalence of frailty among Chinese community-dwelling older adults: a systematic review and meta-analysis. Int J Publ Health 2023;68:1605964. https://doi.org/10.3389/ijph.2023.1605964.
[7] Chinese Society of Geriatrics. Chinese expert consensus on frailty prevention in the elderly. Chin J Geriatr 2022;41(5):503–11 [in Chinese].
[8] Li XP, Li XG, Sun L, Yang L, Wang CZ, Yuan T, et al. The bidirectional relationship between activities of daily living and frailty during short-and long-term follow-up period among the middle-aged and older population: findings from the Chinese nationwide cohort study. Front Public Health 2024;12:

1382384. https://doi.org/10.3389/fpubh.2024.1382384.
[9] Fan JN, Yu CQ, Guo Y, Bian Z, Sun ZJ, Yang L, et al. Frailty index and all-cause and cause-specific mortality in Chinese adults: a prospective cohort study. Lancet Public Health 2020;5(12):e650–60. https://doi.org/10.1016/S2468-2667(20)30113-4.
[10] Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. Lancet 2013;381(9868):752–62. https://doi.org/10.1016/S0140-6736(12)62167-9.
[11] Peng N., Chen J., Bao Z.J., Chen G.B., Gao J.L. Expert consensus on exercise rehabilitation intervention for elderly frailty Geriatr Health Care, vol. 30; 2024. p. 909–914. 04. [in Chinese].
[12] Sirikul W, Buawangpong N, Pinyopornpanish K, Siviroj P. Impact of multicomponent exercise and nutritional supplement interventions for improving physical frailty in community-dwelling older adults: a systematic review and meta-analysis. BMC Geriatr 2024;24(1):958. https://doi.org/10.1186/s12877-024-05551-8.
[13] Han CY, Miller M, Yaxley A, Baldwin C, Woodman R, Sharma Y. Effectiveness of combined exercise and nutrition interventions in prefrail or frail older hospitalized patients: a systematic review and meta-analysis. BMJ Open 2020;10(12):e040146. https://doi.org/10.1136/bmjopen-2020-040146.
[14] Liang W, Wang YP, Huang Q, Shang BR, Su N, Zhou L, et al. Adherence to 24-hour movement guidelines among Chinese older adults: prevalence, correlates, and associations with physical and mental health outcomes. JMIR Public Health Surveill 2024;10:e46072. https://doi.org/10.2196/46072.
[15] Sun T, Xu XJ, Ding ZH, Xie H, Ma LL, Zhang J, et al. Development of a health behavioral digital intervention for patients with hypertension based on an intelligent health promotion system and WeChat: randomized controlled trial. JMIR Mhealth Uhealth 2024;12:e53006. https://doi.org/10.2196/53006.
[16] World Health Organization (WHO). mHealth programmes are sponsored by government. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/4774. [Accessed 5 June 2024].
[17] Linn N, Goetzinger C, Regnaux JP, Schmitz S, Dessenne C, Fagherazzi G, et al. Digital health interventions among people living with frailty: a scoping review. J Am Med Dir Assoc 2021;22(9):1802-12.e21. https://doi.org/10.1016/j.jamda.2021.04.012.
[18] Wong AKC, Wong FKY, Chow KKS, Wong SM, Bayuo J, Ho AKY. Effect of a mobile health application with nurse support on quality of life among community-dwelling older adults in Hong Kong: a randomized clinical trial. JAMA Netw Open 2022;5(11):e2241137. https://doi.org/10.1001/jamanetworkopen.2022.41137.
[19] Liu LX. Research on elderly health communication in the era of new media. Sci Res Aging 2021;9(11):68–77. https://doi.org/10.3969/j.issn.2095-5898.2021.11.007.
[20] Leigh JW, Gerber BS, Gans CP, Kansal MM, Kitsiou S. Smartphone ownership and interest in mobile health technologies for self-care among patients with chronic heart failure: cross-sectional survey study. JMIR Cardio 2022;6(1):e31982. https://doi.org/10.2196/31982.
[21] Dai Y.Q., Shao T., Yao L.F., Hu F., Jia Q. Construction and application of a spinal cord injury rehabilitation care platform based on patient portrait. Chin J Nurs 2024;59(22):2693–2699. [in Chinese].
[22] Dong LJ, Qiao XX, Tian XY, Liu N, Jin YR, Si HX, et al. Cross-cultural adaptation and validation of the FRAIL scale in Chinese community-dwelling older adults. J Am Med Dir Assoc 2018;19(1):12–7. https://doi.org/10.1016/j.jamda.2017.06.011.
[23] Yu R, Tong C, Ho F, Woo J. Effects of a multicomponent frailty prevention program in prefrail community-dwelling older persons: a randomized controlled trial. J Am Med Dir Assoc 2020;21(2):294.e1–294.e10. https://doi.org/10.1016/j.jamda.2019.08.024.
[24] Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001;56(3):M146–56. https://doi.org/10.1093/gerona/56.3.m146.
[25] Gobbens RJ, Luijkx KG, Wijnen-Sponselee MT, Schols JA. Towards an integral conceptual model of frailty. J Nutr Health Aging 2010;14(3):175–81. https://doi.org/10.1007/s12603-010-0045-6.
[26] Scott Rigby C, Deci EL, Patrick BC, Ryan RM. Beyond the intrinsic-extrinsic dichotomy: self-determination in motivation and learning. Motiv Emot 1992;16(3):165–85. https://doi.org/10.1007/BF00991650.
[27] Holden RJ, Karsh BT. The technology acceptance model: its past and its future in health care. J Biomed Inf 2010;43(1):159–72. https://doi.org/10.1016/j.jbi.2009.07.002.
[28] Morley JE, Malmstrom TK, Miller DK. A simple frailty questionnaire (FRAIL) predicts outcomes in middle aged African Americans. J Nutr Health Aging 2012;16(7):601–8. https://doi.org/10.1007/s12603-012-0084-2.
[29] Jing DM, Shen C, Mo YZ, Wang J. Study on the reliability and validity of frail in the evaluation of senile debilitation. J Nurs Train 2021;36(9):784–8. https://doi.org/10.16821/j.cnki.hsjx.2021.09.004 [in Chinese].
[30] Ware JE, Snoww KK, Kosinski MA, Gandek BG, SF-36. Health survey: manual and interpretation guide. Boston: The Health Institute, New England Medical Center; 1993.
[31] Li L, Wang HM, Shen Y. Development and psychometric tests of a Chinese version of the SF-36 health survey scales. Chin J Prev Med 2002;(2):38–42 [in Chinese].
[32] Yesavage JA, Brink TL, Rose TL, Lum O, Huang V, Adey M, et al. Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res 1982;17(1):37–49. https://doi.org/10.1016/0022-3956(82)90033-4.
[33] Liu J, Wang Y, Wang XH, Song RH, Yi XH. Reliability and validity of the Chinese version of geriatric depression scale among Chinese urban community-dwelling elderly population. Chin J Clin Psychol 2013;21(1):39–41. https://doi.org/10.16128/j.cnki.1005-3611.2013.01.041 [in Chinese].
[34] Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28(2):193–213. https://doi.org/10.1016/0165-1781(89)90047-4.
[35] Liu XC, Tang MQ, Hu L, Wang AZ, Wu HX, Gao CN, Li WS. Reliability and validity of the Pittsburgh sleep quality index. Chin J Psychol 1996;29(2):103–7 [in Chinese].
[36] Wang YH, Lei T, Liu X. Chinese System Usability Scale: Translation, Revision, Psychological Measurement. Int J Hum Comput Interact 2020;36(10):953–63. https://doi.org/10.1080/10447318.2019.1700644.
[37] Carnavale BF, da Silva Santos VR, Farche ACS, Rossi PG, Fiogbé E, de Souza Buto MS, et al. Effects of a multicomponent training and detraining on frailty status, physical activity level, sedentary behavior patterns and physical performance of pre-frail older adults: a randomized controlled trial. Eur Geriatr Med 2024;15(6):1701–12. https://doi.org/10.1007/s41999-024-01052-4.
[38] Izquierdo M, Merchant RA, Morley JE, Anker SD, Aprahamian I, Arai H, et al. International exercise recommendations in older adults (ICFSR): expert consensus guidelines. J Nutr Health Aging 2021;25(7):824–53. https://doi.org/10.1007/s12603-021-1665-8.
[39] Fang J, Ren JP, Wang JJ, Qiu XT, Zhang SY, Yuan S, et al. Combining motivational and exercise intervention components to reverse pre-frailty and promote self-efficacy among community-dwelling pre-frail older adults: a randomized controlled trial. BMC Geriatr 2024;24(1):896. https://doi.org/10.1186/s12877-024-05464-6.
[40] Casas-Herrero Á, Sáez de Asteasu ML, Antón-Rodrigo I, Sánchez-Sánchez JL, Montero-Odasso M, Marín-Epelde I, et al. Effects of Vivifrail multicomponent intervention on functional capacity: a multicentre, randomized controlled trial. J Cachexia Sarcopeni 2022;13(2):884–93. https://doi.org/10.1002/jcsm.12925.
[41] Carcelén-Fraile MDC, Déniz-Ramírez NDP, Sabina-Campos J, Aibar-Almazán A, Rivas-Campo Y, González-Martín AM, et al. Exercise and nutrition in the mental health of the older adult population: a randomized controlled clinical trial. Nutrients 2024;16(11):1741. https://doi.org/10.3390/nu16111741.
[42] Seol J, Lee J, Park I, Tokuyama K, Fukusumi S, Kokubo T, et al. Bidirectional associations between physical activity and sleep in older adults: a multilevel analysis using polysomnography. Sci Rep 2022;12(1):15399. https://doi.org/10.1038/s41598-022-19841-x.
[43] Marzo RR, Khanal P, Shrestha S, Mohan D, Myint PK, Su TT. Determinants of active aging and quality of life among older adults: systematic review. Front Public Health 2023;11:1193789. https://doi.org/10.3389/fpubh.2023.1193789.
[44] Llurda-Almuzara L, Rodríguez-Sanz J, López-de-Celis C, Aiguadé-Aiguadé R, Arán-Jové R, Labata-Lezaun N, et al. Effects of adding an online exercise program on physical function in individuals hospitalized by COVID-19: a randomized controlled trial. Int J Environ Res Publ Health 2022;19(24):16619. https://doi.org/10.3390/ijerph192416619.
[45] Bangor A, Kortum P, Miller J. Determining what individual SUS scores mean: adding an adjective rating scale. J Usability Stud 2009;4(3):114–23. https://doi.org/10.5555/2835587.2835589.
[46] Dekker-van Weering M, Jansen-Kosterink S, Frazer S, Vollenbroek-Hutten M. User experience, actual use, and effectiveness of an information communication technology-supported home exercise program for pre-frail older adults. Front Med 2017;4:208. https://doi.org/10.3389/fmed.2017.00208.