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Application of family-involved smart medication management system in rural-dwelling middle-aged and older adult participants with chronic diseases

Management of chronic diseases in rural areas

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Abstract

Management of patients with chronic diseases in rural areas and the use of medications need to be urgently addressed. Therefore, this study aimed to evaluate the efficacy of a family-involved smart medication management system for rural patients with chronic diseases. Between June and August 2021, 82 patients with chronic diseases were selected using convenience sampling from 2 county towns in Hebei Province, China. They were randomly divided into control (41 participants) and experimental (41 participants) groups. The control group was managed using a routine medication management model for chronic diseases. The experimental group was managed using a family-involved smart medication management system, in addition to the control group interventions. The groups were graded using the 8-item Morisky Medication Adherence Scale (MMAS-8), the Self-efficacy for Appropriate Medication Use Scale (SEAMS), the Medication Knowledge Assessment Questionnaire, and the Family Support Scale before the intervention and at 8 and 24 weeks after the intervention. Pre-intervention group differences were not statistically significant. At 8 weeks after the intervention, the control group showed no statistically significant differences in the MMAS-8, SEAMS, and Medication Knowledge Assessment scores pre-and post-intervention. These scores were higher in the experimental group than in the control group, with the post-intervention scores being higher than the pre-intervention scores. The MMAS-8, SEAMS, and Medication Knowledge Assessment scores for the experimental group were higher at 24 weeks than at 8 weeks; these scores were higher in the experimental group than in the control group. The experimental group also had higher family support scores than the control group; these scores were higher pre-intervention than post-intervention. A family-involved smart medication management system can effectively improve medication adherence, self-efficacy for appropriate medication use, medication knowledge assessment scores, and family support for rural middle-aged and older adult patients with chronic diseases.

Abbreviations: IT = information technology, MMAS-8 = 8-item Morisky medication adherence scale, SD = standard deviation, SEAMS = self-efficacy for appropriate medication use scale.

1. Introduction

Chronic diseases constitute a major threat to Chinese residents' health and have become a major public health issue affecting China's economic and social development.[1] The 2019 Global Burden of Disease Study suggested that the burden of chronic diseases accounted for 84.93% of the total burden of diseases in China in 2019.[2] A report on the nutrition and chronic disease status of Chinese residents in 2020 suggested that deaths due to chronic diseases in China accounted for 88.5% of total deaths from all causes in 2019.[3] In clinical practice, most patients with chronic diseases require long-term therapeutic pharmacological interventions or lifelong management.[4] It is essential for patients to strictly adhere to all instructions concerning their medications, as prescribed by their doctor, and not arbitrarily change the medication type and dosage. At present, the medication management system for chronic diseases in China is not without flaws, and relevant guidelines for safe medication management in patients with chronic diseases have not been formulated. Most medical staff use the drug safety management specifications in hospitals as a reference.[5] Most patients with chronic diseases in rural areas have poor awareness of the harm caused by chronic diseases and have limited support from family members, poor medication

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

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adherence, and a low level of self-management efficacy. This results in unsatisfactory control of chronic diseases, further worsening of disease conditions, increased hospitalization rates, and heavy burdens on society and families.[6–8] Hence, the issue of improving medication adherence in patients with chronic diseases in rural areas and the management of their use of medications needs to be urgently addressed. The use of information technology (IT) for medication management in patients with chronic diseases has been increasing gradually. Compared with conventional intervention measures such as home visits and motivational interviewing, IT-based interventions can optimize the costs of healthcare resources and enable the delivery of more timely, high-quality, and convenient services for patients while guaranteeing the safety of medication use.[9–13]

Therefore, this study aimed to develop an approach to smart transitional care for the management of chronic diseases in rural areas on the basis of medication management for chronic diseases, to discuss the effect of this intervention measure on middle-aged and older adult patients with chronic diseases in rural areas, and provide references for medication management among these patients.

2. Methods

2.1. Sample size estimation

The sample size of this study was estimated using a formula to compare the means of the 2 samples: $n1 = n2 = 2*[(Z_{\alpha/2} + Z_{\beta})\sigma/\delta]$.[2] Our preliminary experimental results indicated that the difference in mean medication adherence scores (σ) was 2.52, the standard deviation (SD) (δ) was 2, $a = 0.05$, and $\beta = 0.1$. After substituting these numbers into the formula, we obtained $n1 = n2 = 33$. With a 20% loss to follow-up, the final sample size was 82 patients.

2.2. Study participants

In this interventional study, 82 study participants from 2 rural county towns in Hebei Province, China, were selected using convenience sampling between June and August 2021. Inclusion criteria were participants: aged ≥ 45 years, diagnosed with chronic noninfectious diseases for > 1 year, requiring long-term use of at least 1 medication for > 6 months, and who were prepared to participate voluntarily and provide written informed consent. Exclusion criteria were participants: unable to use smartphones, with a severe hearing impairment, with mental disorders or cognitive impairment, and using other electronic medication reminder devices. Elimination criteria comprised participants who withdrew from the study. This study was reviewed and approved by the Medical Ethics Committee of Hebei Provincial Hospital of Traditional Chinese Medicine. All participants included in the study provided written informed consent.

2.3. Grouping methods

SPSS version 26.0 software was used to generate a table of random numbers, and a concealed random allocation scheme was adopted based on this table. Relevant random numbers, serial numbers, and group names were placed into opaque cowhide envelopes that were then sealed and numbered. The participants were divided into experimental and control groups according to the order of registered visits.

2.4. Intervention methods

2.4..1. Intervention methods for the control group. The control group was managed using a routine medication management model for chronic diseases in rural areas. The investigators explained the characteristics and principles of medication administration, medication storage, and common adverse drug reactions to the participants with chronic diseases and their family members on a regular basis. They also offered encouragement to the participants and responded to questions related to medication administration.

2.4..2. Intervention methods for the experimental group.

2.4..2..1. Establishment of multidisciplinary intervention teams. This study was conducted by graduate student supervisors, village and township doctors, graduate nursing students, graduate clinical medical students, and IT professionals. The graduate student supervisors were responsible for supervising project implementation; the clinical medical graduate students were responsible for the design and application of the system; the nursing graduate students were responsible for pre-intervention training, implementation of intervention measures, data collection, and support management; the village and township doctors were responsible for offering medical care and guidance on medication use; and the IT professionals were responsible for the construction, testing, and maintenance of the system.

2.4..2..2. Design of the sign-in system for medication management. The intervention team collaborated with a Ph.D. graduate in computer science from a university in Wuhan to develop a smart medication management system. This study was led by graduate student supervisors who identified specific requirements and design ideas for consideration by research and development personnel. The nursing graduate students were responsible for retrieving existing literature on in-home chronic disease management in rural areas, providing information and data, and establishing requirements for specific operations. The clinical medical graduate students and nursing graduate students were responsible for seeking advice on the development of the application program from 6 chronic disease management professionals at 2 township-village health centers, and 10 patients with chronic diseases. The smart medication management system was designed and developed based on the results of a preliminary investigation of the current status, a review of relevant literature, and an information-motivation-behavior skills model.[14,15] Older adult-friendly designs and barrier-free operations are integral to an effective user-friendly smart medication management system. The system was divided into a web management support component and a client component, which could involve both participants and family members/guardians. The specific functions of the system are illustrated in Figure 1. The participants and their family members/guardians could engage with the application using the client component to transmit relevant data to the cloud for storage to enable historical data to be reviewed and adjust their medication habits once the system had been used for some time. Users could report any issues with their daily use to the management support administrators who could then provide timely responses via push messages and offer follow-up healthcare services.

2.4..2..3. Pre-intervention preparations. The members of the study team conducted collective training and assessments of the staff members as well as one-on-one training and assessments of the selected study participants. In addition, detailed operational flowcharts were provided to the staff members and the participants.

2.5. Implementation of the intervention measures

2.5..1. Creation of a medication plan. The clinicians created and adjusted the medication plans based on the participants' medical and medication histories. The investigators entered the

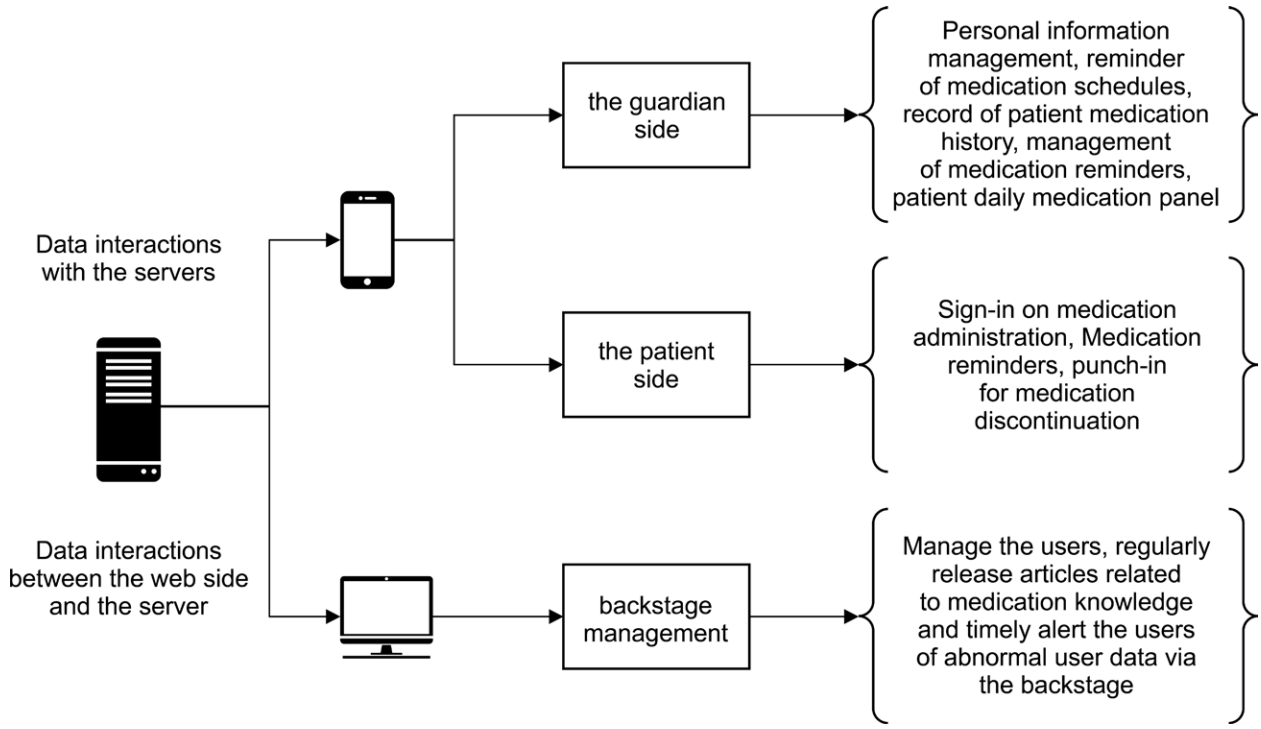

Figure 1. Functional design of the smart medication management system.

participants' medication information into the web management support component to generate the medication plans. The participants signed and alerted the medication administration using the patient component of the application. The sign-in records were then uploaded to the cloud database via the internet and the administered dosage of medications was displayed. In case of special circumstances that required medication discontinuation and reexaminations, the participants signed in to indicate medication discontinuation. Guardians monitored the participants' use of medications. If a patient did not take the medication on time or forgot to register, he/she received a reminder via phone calls or management support.

2.5..2. Management of follow-up. The nursing graduate students updated the computer management system and released content on medical knowledge in the form of pictures, texts, voice messages, and videos at 20:00 hour every Wednesday and Friday. The updated contents included the characteristics and principles of medication administration for chronic diseases, medication storage, and common adverse drug reactions. The township-village doctors were available online from 10:00 hour to 17:00 hour every day to answer questions on the interactive platform. The participants could also exchange ideas and encourage each other, and benefit from a more enriched healthcare experience. The graduate student supervisors reviewed the intervention measures every week, followed up on the implementation process and efficacy, and offered guidance on relevant issues to track the implementation of chronic disease management plans.

The interventions were performed for 8 weeks in both the control and experimental groups.

2.6. Study tools

2.6..1. General information questionnaire. The general information questionnaire was self-designed by the investigators based on the literature review. Items included sex, age, level of educational attainment, monthly household income per capita, type of medications, number of household members, and frequency of medication administration.

2.6..2. The 8-item morisky medication adherence scale (MMAS-8). We used the MMAS-8 in this study.[6] The MMAS-8 has good reliability and validity (Cronbach's alpha = 0.83, intraclass correlation coefficient = 0.87), and contains 8 items in total. The total score is 8 points, and medication adherence is directly proportional to this score.

2.6..3. Self-efficacy for appropriate medication use scale (SEAMS). Risser et al's SEAMS has good reliability and validity (Cronbach's alpha = 0.89, intraclass correlation coefficient = 0.98) and is composed of 13 items divided into 2 domains.[12] Total scores ranged from 13 to 39 points and the scores positively correlated with patients' self-efficacy for medication adherence.

2.6..4. Medication knowledge assessment questionnaire. We used the Medication Safety Knowledge Assessment Questionnaire for older adult patients with chronic diseases designed by Ma in 2015.[16] This questionnaire has good reliability and validity (Cronbach's alpha = 0.860, intraclass correlation coefficient = 0.772), contains 12 items, and the scores of each item are graded from 0 to 3 points. The total scores ranged from 0 to 36 points. Higher scores indicated a better understanding of medication knowledge.

2.6..5. The family support scale. The self-rating Family Support Scale, revised by Procidano et al in 1983,[9] is based on China's national conditions and has a 0.75 reliability and validity index (Cronbach's alpha = 0.75). This scale consists of 15 items, with a maximum possible score of 15. Higher scores indicate stronger family support.

2.7. Data collection methods

General data were collected before the intervention. The MMAS-8, Medication Knowledge Assessment Questionnaire, and the 2

groups' SEAMS scores were determined pre-intervention, and at 8 and 24 weeks. The study participants self-rated all questionnaire items. The investigator explained the survey questions to the participants, one-on-one, and face-to-face, and assisted each participant to complete the questionnaire. Questionnaires were collected and inspected immediately to ensure the integrity of the collected data.

2.8. Statistical analysis

SPSS 26.0 software was used for statistical analysis. Enumeration data were expressed as frequencies and percentages, and intergroup comparisons were performed using the χ^2 test. Normally distributed measurement data were denoted by $\bar{x} \pm$ SD, and intergroup comparisons were performed using 2 independent sample t tests. Non-normally distributed measurement data were denoted using median values and quartiles, and intergroup comparisons were performed using the Mann–Whitney U test. A P value < .05 indicated statistically significant differences. Repeated-measures data were analyzed using repeated-measures analysis of variance. If sphericity was not met ($P < .05$), the Greenhouse-Geisser test was performed to correct the results, and Bonferroni's multiple comparison method was adopted for intragroup pairwise comparisons ($\alpha = 0.05$).

3. Results

3.1. Participant engagement

No study participants withdrew from the study at 8 weeks after intervention. All participants received information concerning the study outcomes, and all 82 participants were included in the study for further analysis.

3.2. Participant baseline data

In terms of baseline data, including sex, age, and level of educational attainment, both groups were found to be comparable, with no statistically significant differences. Participant details are presented in Table 1. Potential confounding factors (e.g., age, sex, number of prescribed medications, and level of educational attainment) did not influence medication adherence. This corresponds with evidence that suggests that reported adherence is not strongly influenced by some patient characteristics.[17]

3.3. Utilization of the family-involved smart medication management system

During the 8-week intervention using the family-involved smart medication management system, the experimental group used the system 5152 times in total: 3879 routine medication administrations (75.3%), 274 medication discontinuations (5.3%), and involving 999 family member reminders (19.4%). The operators used the system to disseminate 12 items of medication safety knowledge, and the doctors offered 17 sessions of online guidance.

3.4. Between-group comparison of outcome measures concerning medication administration

The results of the repeated-measures analysis of variance on the MMAS-8, SEAMS, and Medication Knowledge Assessment scores for the 2 study groups showed statistically significant differences in time effects, between-group effects, and interaction effects between the 2 groups. At 8 weeks of intervention, no statistically significant differences were noted in the pre-and post-intervention scores of the control group.

Table 1

Participants' baseline data.

Items	Experimental group (n = 41)	Control group (n = 41)	Statistical magnitude (χ^2)	*P* value
Sex (participant, %)			0.195	.659
Male	21 (51.2%)	19 (46.3%)		
Female	20 (48.8%)	22 (53.6%)		
Age (participant, %)			–0.109	.913
<55 yrs	20 (48.8%)	20 (48.8%)		
55–75 yrs	18 (43.9%)	19 (46.3%)		
>75 yrs	3 (7.3%)	2 (4.9%)		
Level of educational attainment (participant, %)			–0.418	.676
Elementary school	28 (68.3%)	30 (73.2%)		
Junior high school	8 (19.5%)	6 (14.6%)		
Senior high school	5 (12.2%)	5 (12.2%)		
Junior college and above	0 (0%)	0 (0%)		
Per capita income (participant, %)			–0.278	.781
<500	24 (58.5%)	23 (56.1%)		
500–1000	12 (29.3%)	12 (29.3%)		
>1000	5 (12.2%)	6 (14.6%)		
Number of household members (participant, %)			–0.149	.882
1	13 (31.7%)	11 (26.8%)		
2	16 (39.0%)	19 (46.3%)		
≥3	12 (29.3%)	11 (26.8%)		
Type of medications (participant, %)			–0.857	.391
1 type	10 (24.4%)	13 (31.7%)		
2 types	24 (58.5%)	23 (56.1%)		
≥3 types	7 (17.1%)	5 (12.2%)		
Frequency of medication administration (participant, %)			–0.115	.908
1 per d	8 (19.5%)	7 (17.1%)		
2 per d	15 (36.6%)	16 (39.0%)		
≥3 per d	18 (43.9%)	18 (43.9%)		

The scores were higher in the experimental group than in the control group, with the post-intervention scores being higher than the pre-intervention scores. The scores in the experimental group were higher at 24 weeks of intervention than at 8 weeks of intervention and higher than those in the control group (Tables 2–4).

The results of the family support scale showed that the scores in the experimental group were higher than those in the control group, with the post-intervention scores being higher than pre-intervention scores, and the differences were statistically significant (Table 5).

4. Discussion

In this study, the family-involved smart medication management system was found to improve medication adherence in the rural-dwelling participants with chronic diseases. Administration errors, including dosage discontinuation, missing doses, or wrong medication, have been shown to occur among patients living in rural areas, owing to a lack of healthcare resources and inadequate patient awareness of chronic diseases.[14] Our study findings indicated that the experimental group scored higher than the control group at 8 and 24 weeks of intervention and that the intergroup differences were

Table 2

Medication adherence scores ($\bar{x} \pm S$).

Items	Number of participants	Pre-intervention	8 wks	24 wks	Time effects *F (P)* value	Between-group effects *F (P)* value	Interaction effects *F (P)* value
Control group	41	3.00 ± 0.96	3.14 ± 1.11*	3.17 ± 1.12†	44.953	54.792	54.752
Experimental group	41	2.81 ± 0.93	5.04 ± 0.70‡	5.47 ± 0.95§	(.000)	(.000)	(.000)
T		–0.878	–9.252	–9.970			
P		.383	.000	.000			

*$P > .05$ when compared with the pre-intervention scores of the same group.
†$P > .05$ when compared with the scores at 8 weeks of intervention.
‡$P < .05$ when compared with the pre-intervention scores of the same group.
§$P < .05$ when compared with the scores at 8 weeks of intervention.

Table 3

Self-efficacy score concerning appropriate medication use ($\bar{x} \pm S$).

Items	Number of participants	Pre-intervention	8 wks	24 wks	Time effects *F (P)* value	Between-group effects *F (P)* value	Interaction effects *F (P)* value
Control group	41	22.41 ± 43.39	22.80 ± 3.36[a]	22.26 ± 3.65†	5.248	13.910	10.331
Experimental group	41	22.51 ± 3.19	25.41 ± 4.87‡	26.97 ± 5.84§	(.001)	(.010)	(.000)
t		–0.134	–2.824	–4.375			
P		.894	.006	.000			

*$P > .05$ when compared with the pre-intervention scores of the same group.
†$P > .05$ when compared with the scores at 8 weeks of intervention.
‡$P < .05$ when compared with the pre-intervention scores of the same group.
§$P < .05$ when compared with the scores at 8 weeks of intervention.

Table 4

Medication knowledge assessment score ($\bar{x} \pm S$).

Items	Number of participants	Pre-intervention	8 wks	24 wks	Time effects *F (P)* value	Between-group effects *F (P)* value	Interaction effects *F (P)* value
Control group	41	19.54 ± 2.28	19.56 ± 2.68*	19.70 ± 3.92†	9.655	54.854	15.941
Experimental group	41	20.12 ± 2.44	22.58 ± 4.00‡	24.78 ± 4.49§	(*P* = .00)	(*P* = .00)	(*P* = .00)
t		–1.122	–4.016	–5.472			
P		.265	.000	.000			

*$P > .05$ when compared with the pre-intervention scores of the same group.
†$P > .05$ when compared with the scores at 8 weeks of intervention.
‡$P < .05$ when compared with the pre-intervention scores of the same group.
§$P < .05$ when compared with the scores at 8 weeks of intervention.

Table 5

Family support score M (P_{25}, P_{75}).

Items	Number of participants	Pre-intervention	24 weeks	*Z*	*P*-value
Control group	41	6 [4–7]	6 [5–8]	–1.629	.103
Experimental group	41	6 [5–8]	12 [10–13]	–5.519	.000
Z		–0.953	–7.723		
P		.341	.000		

statistically significant. These findings showed that family-involved medication management improved medication adherence among the participants with chronic diseases who resided in rural areas. These results are consistent with those of Peng et al[18] On the one hand, studies indicate that due to the low educational level and poorer understanding of chronic diseases among rural patients, forgetting to take medication, repeated medication, and overly frequent medication intake often occur.[19] Notably, the intelligent medicine management system not only reminds patients to take their medication regularly but also provides real-time medical staff occupational health education and supervision to ensure adequate medical care and improve medical security for patients. Accordingly, medication compliance is increased by directly reducing skipped, missed, or wrong dose intake. On the other hand, Niriayo et al[20] proved that medication belief is also one of the important influencing factors for medication compliance. Social support can play a role in improving the patient's belief in the treatment. The medication management system compared with conventional management allows families to intuitively participate and provide support to patients. The system allows staff to communicate with the family and patients to provide guidance regarding the disease, extend social and psychological support, and strengthen the awareness of patient and family support to improve positive beliefs regarding treatment and drug compliance.

The family-involved smart medication management system was also found to have improved the self-efficacy of appropriate medication use among the participants with chronic diseases. Self-efficacy for appropriate medication use refers to a patient's confidence in adhering to appropriate medication use. A lack of confidence is an important barrier to behavioral changes.[21] Bandura et al[22] suggested that improving self-efficacy is influenced by personal life experience, the role of peers, verbal persuasion, and social psychological support. The results of this study showed that the experimental group exhibited significantly higher self-efficacy for appropriate medication use than the control group at 8 and 24 weeks of intervention with smart medication management. Possible reasons for this were: team members conducted family-involved smart medication management interventions, the involvement of participants' family members in supervising the participants and correcting their non-adherent behaviors in a timely manner; the intervention team promptly developed or adjusted the medication schedule for the participants as prescribed by the doctor in the management support component of the application, and the participants could avoid uncertainty in medication administration due to adjustment of medication types and dosage through relying on the system's medication reminders; and the participants also received guidance on medication use from the system's staff members, received more education concerning their chronic disease, and became aware of the importance of medication adherence with respect to timing, dosage, and frequency, which boosted their confidence in adhering to appropriate medication use, changing their medication-taking behaviors, and improving their self-efficacy for appropriate medication use.

The family-involved smart medication management system was found to have increased awareness of medication knowledge among the participants by showing that those undergoing interventions with the family-involved smart medication management system exhibited an increasingly higher level of medication knowledge and had a significantly higher level of knowledge than the control group at 8 and 24 weeks of intervention. These results suggest that patient education on medication use via WeChat platforms might be more effective than conventional approaches to patient education, which is consistent with the findings of Liu et al[14] WeChat mini-programs are easy to use and are more widely used.[23] Furthermore, patient medication guidance can be offered on WeChat in different forms including texts, images, and videos. The WeChat platform is beneficial in that WeChat can help deliver health education and knowledge on relevant diseases and medications more intuitively. WeChat's "view chat history" function is not limited in terms of time and space, and past messages can be repeatedly reviewed such that the patients and their family members can receive comprehensive education on diseases and medications; thus, the timeliness, continuity, and sharing nature of health education can be guaranteed. Additionally, a higher level of medication knowledge can lead to higher medication safety. For example, patients with a higher level of medication knowledge have a better understanding of drug incompatibilities, do not arbitrarily increase or decrease medication doses or switch to other medications, and are equipped with basic medication knowledge, including the storage of spare medications.

The family-involved smart medication management system was also found to strengthen family support for the rural-dwelling participants with chronic disease. Patients with chronic diseases have been reported to have poor self-initiative and a sense of inferiority and discomfort. They have been reported to feel less supported, less respected, and less concerned about their chronic diseases, and to receive limited social and family support.[24–28] This study showed that the experimental group exhibited higher scores for family support than the control group at 24 weeks of intervention using the smart medication management system and that the difference was statistically significant. This may be explained by the family-involved smart care that enabled the participants to communicate with staff members on the platform, who were then able to offer psychological counseling to the participants. Therefore, patients were assisted in overcoming their personal problems, had their social skills enhanced, were helped to develop a healthy mentality, and realize the benefits of social support. Thus, this is likely to have enhanced their motivation in terms of medication adherence in anticipation of treatment benefits and social support and helped them to build strong family relationships, which are crucial for stronger family support. A participant's family member could gain better insights into the respective chronic disease via information exchange in the family-involved smart medication management system, develop skills to enhance care, and acquaint themselves with home care caveats, so that trust between the participants and their family members could be fostered and stronger family relationships could be established.

The strength of this study lies in its utility and ability to provide references for future use of IT in transitional care or for medication management for rural patients as well as provide guidance for further recommended long-term, large-sample interventional studies. Our results suggest that medication management for rural patients with chronic diseases should be adopted on a larger scale, application programs should be improved, and users of such platforms should receive appropriate knowledge training.

Although the family-involved intelligent medication management system seems feasible and has the potential to become widely used, it still has some shortcomings. First, the quality of information and the system need to be improved. Second, the system needs to be more flexible and tailored to individuals' specific needs, because at present, the system reminds older adults to take their medication at a fixed time every day, but this occasionally disturbs their resting time. Third, the sample size was small. If a large-sample long-term intervention research is subsequently conducted, the scope of use and influence of medication management for chronic diseases in rural areas should be expanded, related application programs should be improved, and knowledge training should be conducted for users of the platform.

5. Conclusion

Our findings indicated that the family-involved smart medication management system effectively improved the participants'

medication adherence, self-efficacy for appropriate medication use, family support scores, and medication safety, and facilitated the participation of individuals with chronic diseases and their family members in terms of enhancing medication safety management.

Author contributions

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