The Impact of Mobile Health on Blood Pressure and Health Literacy in Chronic Kidney Disease: Randomized Open-Label Clinical Trial

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[1]Kaohsiung Medical University Chung-Ho Memorial Hospital Kaohsiung City TW
[2]Taipei Medical University-Shuang Ho Hospital Taipei TW
[3]Kaohsiung Municipal CiJin Hospital Kaohsiung TW
[*]these authors contributed equally

Corresponding Author:
Yi-Wen Chiu
Kaohsiung Medical University Chung-Ho Memorial Hospital
No.100 , Tzyou 1st Road
Kaohsiung City
TW

Abstract

Background: Mobile health (mHealth) management is an emerging therapeutic strategy for chronic diseases. Although it has been shown to improve self-care management and assist in the early detection of a worsening health status. Its effect on blood pressure (BP) control and health literacy (HL) in patients with chronic kidney disease (CKD) has not been well-studied.

Objective: This randomized open-label clinical trial aimed to examine the effectiveness of mHealth on BP control and HL in CKD.

Methods: We designed and developed a new mHealth, called iCKD. The application has several major features, including BP monitoring, alarms and a warning system. We randomly assigned 122 CKD patients (stages 1-3a: 28, stage 3b: 46, stage 4-5: 48) to use iCKD or paper-based education (placebo) to monitor office BP. Trained nurses interviewed the patients using structured questionnaires to evaluate HL. The primary and secondary efficacy endpoints were office BP less than 130/80 mmHg and total HL score after 6 months, respectively.

Results: In the intention-to-treat analysis, baseline kidney function and office BP were not significantly different between the iCKD and placebo groups at enrollment. At the end of the 6-month study period, 21 participants had withdrawn, and 22 of 52 participants (42.3%) in the iCKD group and 11 of 49 participants (22.4%) in the placebo group reached the optimal office BP of 130/80 mmHg (p=0.03). The patients who reached the BP target had higher total HL score than those who did not, and the iCKD group had a greater increase in total HL score than the placebo group (p=0.01).

Conclusions: A higher proportion of the iCKD group reached the target BP value and had better HL scores than the placebo group. Our findings demonstrate that mHealth can improve HL and BP status in CKD patients, suggesting its potential application in clinical CKD care. Clinical Trial: NCT03649516

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[1]Department of Nephrology, Department of Internal Medicine, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Kaohsiung, Taiwan

[2]Division of General Medicine, Department of Internal Medicine, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Kaohsiung, Taiwan

[3]Kaohsiung Municipal CiJin Hospital, Kaohsiung, Taiwan

[4]School of Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan

[5]Center for Long-Term Care Research, Kaohsiung Medical University, Kaohsiung, Taiwan.

[6]Center for Liquid Biopsy and Cohort Research, Kaohsiung Medical University, Kaohsiung, Taiwan.

[7]Department of Nursing, Kaohsiung Medical University Hospital, Kaohsiung Medical University

[8]Clinical Research Center, Taipei Medical University-Shuang Ho Hospital, New Taipei, Taiwan

[#]The contributions of authors are equal.

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[*]Corresponding author:

Yi-Wen Chiu M.D.

Department of Nephrology, Department of Internal Medicine, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Taiwan

100 TzYou 1st Road, Kaohsiung 807, TAIWAN

E-mail address: chiuyiwen@gmail.com

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Keywords: office blood pressure, mobile health, health literacy, chronic kidney disease

Introduction

Chronic kidney disease (CKD) is a global public health issue associated with high rates of morbidity and mortality. CKD has been reported to affect 14% of the US population and 12% of the Taiwanese population, contributing to a high burden on health-care systems [1, 2]. Hypertension is very common and remains difficult to control in patients with CKD. A bidirectional relationship between hypertension and CKD has been well-established with the progressive elevation of blood pressure (BP) often culminating in kidney failure [3]. Persistently high BP accelerates the progression of CKD, and the progressive decline in kidney function conversely interferes with achieving adequate BP control [4]. The coexistence of uncontrolled hypertension and CKD substantially augments the risk of cardiovascular morbidity and mortality [4].

Owing to the complexity of health recommendations in CKD management, patients should have an adequate level of health literacy (HL). HL has been shown to be a significant social determinant of health, defined as the ability to access, understand, appraise, and apply health-related information across healthcare, disease prevention, and health promotion [5, 6]. Sufficient HL has been shown to improve self-care behavior to maintain health and assist in disease management and making decisions regarding the therapeutic strategy [7]. However, CKD patients commonly have low HL [8, 9], and low HL is associated with increased morbidity and mortality [10]. In addition, hypertensive patients with limited HL tend to have poor hypertension knowledge [11], and HL has been correlated with better BP control in hypertensive patients [6, 12]

Mobile health (mHealth), is an emerging strategy of care for patients with chronic diseases such as diabetes mellitus, hypertension, heart disease, stroke and asthma, and it is accessed via mobile devices such as smartphones, tablets, or web-based portals [13]. mHealth has been shown to improve communication between healthcare professionals and patients facilitate monitoring of bio-information at home, improve health behavior management, and further promote the early detection of a worsening health status [14]. The efficiency of mHealth for the treatment of chronic diseases may depend on the characteristics of the users. In the Chronic Renal Insufficiency Cohort (CRIC) Study, Schrauben et al. identified the characteristics of CKD patient who used digital and mHealth technologies, including age, HL, annual income, and education level [15]. How to identify and overcome the limitations of mHealth are crucial issues for clinical care givers.

The management of co-existing between BP and CKD is challenging. One meta-analysis indicated that mHealth may have the potential to improve BP levels in the general population [16]. However, the effect of mHealth on BP management in CKD patients has not been well-explored. Therefore, the aim of this study was to investigate the impact of the iCKD Healthcare Technology Platform, a digital mHealth service, on achieving BP goals and HL compared to traditional health education (paper-based) in patients with CKD.

Methods

Study setting and design

This study was a single-center, open-blind, placebo-controlled trial designed to evaluate the efficacy of iCKD compared to paper-based health education on BP control and HL at Kaohsiung Medical University Hospital (KMUH). This trial is registered at ClinicalTrials.gov, with registration number NCT03649516. The inclusion criteria included age > 20 years-old, communicative, having smart phone, tablet or computer, the diagnosis of CKD without receiving renal replacement therapy and receiving anti-hypertensive medications and CKD care program that was conducted by a cross-disciplinary team, including clinical physicians, nursing staff, pharmacists, and nutritionists > 3 months. We screened 672 patients who CKD was newly diagnosed from August 2018 to January 2020, and 405 were eligible. Then, we invited 405 patients, but excluded 274 patients because of smart cellphone without internet connection (n=52), no regular follow-up (n=20), subjects in other clinical trials (n=12) or unwillingness (n=190). One hundred thirty-one patients agreed and entered screen phase but nine had withdrawal. Finally, 122 patients were randomized to use the iCKD app (iCKD group) or receive traditional paper-based health education (non-iCKD group) for 6 months in an open-blinded manner (**Figure 1**). The frequency of paper-based health education depended on CKD stage (once every 6 months for CKD stages 1-2, once every 3 months for CKD stages 3-4, and once every month for CKD stage 5). The stages of CKD were defined according to the Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines. Estimated glomerular filtration rate (eGFR) was calculated using the four-variable Modification of Diet in Renal Disease Study equation, and graded as follows: stage 1 ≥ 90 ml/min/1.73m^2; stage 2 = 60-89 ml/min/1.73m^2; stage 3a = 45-59 ml/min/1.73m^2; stage 3b 30-44 ml/min/1.73m^2; stage 4 = 15-29 ml/min/1.73m^2; and stage 5 < 15 ml/min/1.73m^2 [17]. During the intervention period of 6 months, 15 participants had withdrawal, 5 entered commencing dialysis, and one had death. The study protocol was approved by the Institutional Review Board of KMUH (KMUHIRB-F(II)-2018005). Written informed consent was obtained from all patients, and all clinical investigations were conducted according to the principles expressed in the Declaration of Helsinki.

mHealth-iCKD

KMUH designed and developed the iCKD Healthcare Technology Platform, a digital learning and information service, in April 2013. The platform includes the iCKD health management application (iCKD app) and a collaborative management platform. The iCKD platform has 10 major features: alert tracking, outpatient visit status reminder, mobile health management, interpretation of examination results, tailored health education videos, nutritional feedback and analysis, care and treatment notifications, audio responses, personalized dashboard, and integrated care quality analysis. Clinical physicians can use the collaborative management platform to remotely analyze and monitor a patient’s health status with self-recorded data via the personal dashboard. The healthcare quality indicators allow the related healthcare teams to assess the current disease status and provide timely feedback with online reminders.

Clinical measurements

Information on socio-demographic and clinical characteristics such as age, sex, tobacco smoking (yes *v.s.* no), alcohol consumption (yes *v.s.* no), marital status, education level, current occupation, and co-morbidities were obtained from interviews with the patients and medical records at study interview. Data on marital status (married, single, divorced or widowed), and working status (currently working, no job or retirement) were also recorded. Hypertension was defined as having a history of the disease and taking antihypertensive medications including angiotensin-converting enzyme inhibitors/angiotensin receptor blockers, β-blocker, calcium channel blocker, central alpha blocker. We also record any change in antihypertensive medications during study period. Cardiovascular disease was defined as having a history of congestive heart failure, myocardial infarction, or ischemic heart disease. Diabetes mellitus was defined as having a history of the disease, the use of anti-diabetic medications, or blood glucose values as defined in the American

Diabetes Association criteria. The duration of CKD was calculated from self-reports and the initial diagnosis of CKD. The number of health education sessions was calculated between enrollment into the multidisciplinary CKD program and study interview. Blood and urine samples were taken after a 12-hour fast for biochemistry studies on the same day as the study interview. Urine protein levels were measured using urine protein-creatinine ratio.

HL measurement

HL was measured at study interview using a multidimensional HL questionnaire which has been validated among adults in Taiwan [18]. The questionnaire covers the following five dimensions: accessing, understanding, appraising, applying health information, and communication and interaction. The total HL score was calculated as (the average scores of the sum of the 5 dimensions - 1)*50/3.

Statistical analysis

Data were expressed as mean±SD or median (25^{th}, 75^{th} percentiles) for continuous variables, and percentages for categorical variables. Non-normally distributed continuous variables were log-transformed to approximate normal distribution. The independent *t*-test or Mann-Whitney U test was used to compare two groups of continuous variables, and the chi-square test was used to evaluate differences in the distribution of categorical variables. The paired t-test was used to analyze BP and HL after using iCKD or paper-based health education for 6 months. Statistical analyses were conducted using SPSS version 22.0 for Windows (IBM Inc., Armonk, NY). Graphs were drawn using Graph Pad Prism 8.0 (GraphPad Software Inc., San Diego CA, USA). Statistical significance was set at a two-sided p-value of ≤ 0.05.

Results

Clinical characteristics of the study participants

Comparisons of the clinical characteristics of the iCKD and non-iCKD groups in intention-to-treat (ITT) analysis are shown in Table 1. The mean age of all patients was 66.9 ± 12.3 years, 63.1% were male, and 95.0%, 47.9%, 15.3%, and 39.3% had hypertension, diabetes, cardiovascular disease, and hyperlipidemia, respectively. In addition, 84.4% were married, 26.2% were economically independent, and 68.0% had graduated from senior high school or above. The mean eGFR was 36.0±21.0 ml/min/1.73m^2, and the median of urinary protein-creatinine ratio was 0.74 (0.19, 2.02) g/g. Among all participants, 10.7% did not use medication for BP control, 42.6% used angiotensin-converting enzyme inhibitors/angiotensin receptor blockers, 20.5% used beta blockers, and 30.3% used calcium channel blockers. During the study period, the kind or dose of anti-hypertensive agents were modified among 46.7% of the participants.

Comparison of office BP between the iCKD and non-iCKD groups

BP levels between two groups were shown in Figure S1. There was no different in the distribution of frequency of BP measurement (Table S1). In ITT analysis, the proportion of those who reached a BP of 140/90 mmHg after 6 months increased from 54.1% to 76.9% (p<0.001) in the iCKD group, compared to 49.2% to 59.2% (p=0.041) in the non-iCKD group (Table 2). There was no significant difference between the two groups. The proportion of those who reached a BP of 130/80 mmHg after 6 months increased from 31.1% to 42.3% (p=0.019) in the iCKD group and from 19.7% to 22.4% in the non-iCKD group (p=0.012). In per-protocol (PP) analysis (Table S2), the proportion of those who reached a BP of 140/90 mmHg after 6 months increased from 57.7% to 76.9% (p=0.008); however, there was no significant increase in the proportion of those reaching a BP of 140/90 mmHg in non-iCKD group. In summary, a higher proportion of the CKD patients who used iCKD reached the BP therapeutic goal of 130/80 mmHg than those who received traditional medical education in both ITT and PP analyses (42.3% *v.s.* 22.4%, p=0.033).

Comparison of HL between the iCKD and non-iCKD groups

The mean HL score at baseline was 29.8 ± 6.4, and the scores for accessing, understanding, appraising, and applying health information and communication/interaction dimensions were 27.0 ± 9.2, 34.8 ± 6.6, 26.0 ± 8.8, 29.4 ± 7.8, and 32.0 ± 7.6, respectively. At the end of the 6-month study period, significant improvements in total HL score in both the iCKD group (from 30.38±6.33 to 32.55±6.65, p=0.015) and non-iCKD group (from 29.32±6.65 to 31.34±7.12, p=0.01) were noted compared to enrollment (Table 3). Among the five domains of HL, a significant increase in accessing health education score was found in both the iCKD (from 28.13±8.88 to 31.33±8.79, p=0.007) and non-iCKD (from 25.85±9.62 to 29.25±9.45, p=0.003) groups. An increase in appraising health information score was found in the iCKD group (from 26.84±8.55 to 29.33±8.41, p=0.031), but not in the non-iCKD group. There were no significant increases in the scores of understanding and applying health information, and communication/interaction dimensions in the two groups.

HL among CKD patients who did and did not reach the BP therapeutic target

After the 6-month intervention period, increases in total HL score (p<0.001) and accessing (p<0.001), appraising (p=0.003), and applying health information (p=0.003), and communication/interaction (p=0.001) scores were found in the patients who reached the BP therapeutic goal (Table 4). In addition, the patients who reached the BP therapeutic goal had significantly greater increases in accessing (p=0.029) and applying (p=0.041) health information, and communication/interaction (p=0.022) scores compared to those who did not reach the BP therapeutic goal.

Interactions between using iCKD and reaching the BP therapeutic target in HL in CKD patients

The patients who reached the BP goal had significant increases in total HL score of and accessing health information score independently of using iCKD (Table 5). Significant increases in the scores of appraising (p=0.007), and applying health information (p=0.007), and communication/interaction (p=0.003) dimensions were only found in the patients in the iCKD group who reached the BP goal, but not in those in the non-iCKD group who reached the BP goal.

Discussion

This study investigated the influence of the mHealth iCKD Healthcare Technology Platform on achieving BP goals and HL compared to traditional health education (paper-based) in CKD patients. After 6 months of the intervention, a higher proportion of the patients using iCKD reached the BP target of 130/80 mmHg compared to those receiving traditional health education (non-iCKD group). In addition, patients in both the iCKD and non-iCKD groups had increases in total HL score and accessing health education score after the intervention. Of the five domains of HL, an increase in appraising health information score was found in the iCKD group but not in non-iCKD group. In addition, the patients who reached the BP goal had significant increases in total HL and accessing health information scores independently of using iCKD. Among those who reached the BP goal, the iCKD group had significant increases in the scores of appraising, and applying health information, and communication/interaction dimensions compared to the non-iCKD group. Our results provide insights into the impact of using mHealth on BP control and HL in CKD patients.

Regarding the higher proportion of the iCKD group reaching the BP target of 130/80 mmHg, we previously reported that CKD patients who used iCKD had better BP monitoring behavior than those who did not [1]. Patients can view their home-recorded BP measurements and submit them to health-care providers via the iCKD app. Several other studies have also shown a reduction in home-recorded BP in patients with cardiovascular disease or advanced CKD patients using mHealth applications compared to those receiving usual care [19, 20]. Previous meta-analysis studies have also reported the impact of mHealth on BP control [21, 22]; although, the results were inconsistent. Zhou et al. found that mHealth could significantly improve the uncontrolled hypertension control rate [21]. Conversely, Khoong et al found that although mHealth could reduce systolic BP at 6 months, there was no significant difference in change in systolic BP between the mHealth and control groups. The inconsistent effect of mHealth on BP control may be related to age, education level, or economic status [22]. Therefore, personalized mHealth applications should be considered for different populations.

Uncontrolled hypertension in CKD patients may be caused by low medication adherence, patient misconceptions, misunderstanding about their care, polypharmacy, affordability, limited access to medications due to excessive cost, and low HL levels [23]. CKD care programs can assist CKD patients in learning about the potential risk factors for kidney injury such as BP and glucose control, and the diagnosis and treatment of CKD [24]. Compared with mHealth, paper-based or face-to-face traditional education is limited by the availability of providers. The mobile iCKD app can deliver knowledge and health information anywhere and at any time through visual and audio formats, and we previously found that this could help patients engage with and reinforce their understanding of kidney care [1], along with help in understanding and inspiring subsequent behavior changes [25]. In addition, mHealth devices can provide real-time feedback regarding warnings and brief educational reminders to patients, encouraging them to monitor their home BP, recognize biochemical risks, and revisit previously learned materials. The iCKD app allows the patients to view their recorded BP data, complete with alert tracking and audio prompts, which can help them to establish regular monitoring habits and stay aware of their BP goals.

Improving awareness of diseases and HL may improve self-care behavior and clinical prognosis [26]. Our previous results demonstrated a significant and positive relationship between HL and self-care behavior [27]. In the current randomized controlled trial, we evaluated the effect of mHealth on the multidimensionality of HL in CKD patients. Of the five HL domains, an increase in appraising health information score was found in the iCKD group compared to the traditional health education group. In addition, the patients who reached the BP goal in the iCKD group had significant increases in appraising, and applying health information, and communication/interaction score. There are several possible explanations for the increases after using iCKD [13, 28]. mHealth devices provide immediate access to a wealth of health information, further empowering users to critically evaluate and apply the information to their own health situations. This immediate feedback helps users to better understand their health status and increase their ability to appraise and apply relevant information effectively. In addition, interactive features such as chatbots, forums, and community support facilitate communication between users and healthcare providers, enhancing the ability to share experiences and information, which can lead to better application of health concepts. This personalized approach can lead to higher engagement and motivation, enabling users to appraise and apply medical information confidently.

In conclusion, a higher proportion of the patients who used the iCKD app reached the optimal BP value and had better HL than those who received traditional medical education. This study demonstrates that mHealth can improve HL and BP status in patients with CKD, and the potential role of mHealth applications in clinical CKD care.

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Abbreviations

BP: blood pressure

CKD: chronic kidney disease

CKDSC: CKD Self-Care

eGFR: estimated glomerular filtration rate

HL: health literacy

iCKD app: iCKD health management application

K/DOQI: Kidney Disease Outcomes Quality Initiative

KMUH: Kaohsiung medical university hospital

mHealth: mobile health

Supplemental data

Table S1. The distribution of frequency of blood pressure measurement

Table S2. Office blood pressure among participants with or without iCKD usage in PP analysis

Figure S1. Continue blood pressure levels during intervention period between two groups

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Table 1. Clinical characteristics of enrolled participants in ITT analysis

	All participants (N=122)	iCKD group (N=61)	Non-iCKD group (N=61)	*P-value*
Demographic data				
Age	66.9±12.3)	66.5±11.8)	67.4±12.8)	0.68
Sex (male), n(%)	77 (63.11%)	43 (70.5%)	34 (55.7%)	0.09
Marriage, n(%)				0.78
Never	7 (5.74%)	3 (4.9%)	4 (6.6%)	
Married	103 (84.43%)	51 (83.6%)	52 (85.3%)	
Divorced/Widowed	12 (9.84%)	7 (11.5%)	5 (8.2%)	
Education, n(%)				0.24
Below senior high school	39 (31.97%)	19 (31.2%)	20 (32.8%)	
Senior high school or above	83 (68.03%)	42 (68.8%)	41 (67.2%)	
Economic source, n(%)				0.38
Independent	32 (26.23%)	14 (23.0%)	18 (29.5%)	
Dependent	89 (72.95%)	47 (77.1%)	42 (68.9%)	
Comorbidity, n(%)				0.09
Diabetes mellitus	58 (47.9%)	24 (19.8%)	34 (28.1%)	0.083
Hypertension	115 (95.0%)	58 (47.9%)	57 (47.1%)	0.680
Cardiovascular disease	18 (15.3%)	9 (7.6%)	9 (7.6%)	0.938
Hyperlipidemia	46 (39.3%)	18 (15.4%)	28 (23.9%)	0.069
CKD stage, n(%)				0.97
Stage 1-3a	28 (23.0)	14(22.9)	14(23.0)	
Stage 3b	46 (37.7)	22(36.0)	24(39.3)	
Stage 4-5	48(39.3)	25(41.1)	23(37.7)	
Anti-hypertensive agents				
Baseline medications (visit 1)				
Alpha blocker	2 (1.6%)	1 (1.6%)	1 (1.6%)	1.00
β-blocker	25 (20.5%)	17 (27.9%)	8 (13.1%)	0.05
Calcium channel blocker	37 (30.3%)	18 (29.5%)	19 (31.1%)	0.79
ACEI/ARB	64 (52.4%)	31 (50.8%)	33 (54.1%)	0.63
Central alpha blocker	5 (4.1%)	3 (4.9%)	2 (3.3%)	1.00

Changing medication during study period (yes)	57 (46.72%)	30 (49.18%)	27 (44.26%)	0.86
Laboratory data				
Estimated GFR, ml/1.73m2/yr	36.0 (21.0)	35.9 (20.8)	36.2 (21.4)	0.93
Blood urea nitrogen, mg/dl	32.0 (16.3)	32.2 (16.7)	31.9 (16.0)	0.92
Hemoglobin, g/dl	12.1 (2.2)	12.1 (2.2)	12.2 (2.2)	0.87
Uric acid, mg/dl	6.8 (1.9)	6.6 (2.0)	6.9 (1.8)	0.33
Total Calcium, g/dl	9.1 (0.6)	9.0 (0.6)	9.2 (0.5)	0.03
Phosphorus, g/dl	3.8 (0.7)	3.9 (0.7)	3.8 (0.7)	0.33
Albumin, g/dl	4.3 (0.5)	4.2 (0.5)	4.3 (0.5)	0.14
Cholesterol, mg/dl	179.2 (52.5)	178.4 (48.4)	180.0 (56.5)	0.87
Triglyceride, mg/dl	133.6 (73.1)	124.7 (71.7)	142.0 (74.1)	0.21
Glycated hemoglobin, %	6.5 (1.5)	6.3 (1.3)	6.7 (1.6)	0.23
Urine PCR, g/g	0.7 (0.2, 2.0)	0.7 (0.2, 1.9)	0.7 (0.2, 2.2)	0.91

Abbreviations: CKD: chronic kidney disease; GFR: established glomerular filtration rate; ACEI/ARB: angiotensin-converting enzyme inhibitors/angiotensin receptor blockers; glomerular filtration rate; PCR: protein-creatinine ratio

Table 2. Office blood pressure between participants with or without using iCKD

	Intention-to-treat analysis			
	All participants (N=122)	**iCKD group (N=61)**	**Non-iCKD group (N=61)**	***P-value***
Rate of reaching blood pressure target (140/90 mmHg)				
Baseline (n=122)	63 (51.6%)	33 (54.1%)	30 (49.2%)	0.587
Post 3M (n=112)	67 (59.8%)	37 (63.8%)	30 (55.6%)	0.374
Post 6M (n=101)	69 (68.3%)	40 (76.9%)	29 (59.2%)	0.056
p-value for post 6M *v.s.* baseline	<0.001	<0.001	0.041	
Rate of reaching blood pressure target (130/80 mmHg)				
Baseline (n=122)	31 (25.4%)	19 (31.1%)	12 (19.7%)	0.146
Post 3M (n=112)	32 (28.6%)	17 (29.3%)	15 (27.8%)	0.858
Post 6M (n=101)	33 (32.7%)	22 (42.3%)	11 (22.4%)	0.033
p-value for post 6M *v.s.* baseline	0.001	0.019	0.012	

Abbreviations: CKD: chronic kidney disease

Table 3. Health literacy between participants with or without using iCKD

Scores	All participants (N=101)	iCKD group (N=52)	Non-iCKD group (N=49)	*P-value*
Accessing				
Baseline	27.02±9.27	28.13±8.88	25.85±9.62	0.220
Post 3M	30.61±9.40	32.21±10.01	28.91±8.48	0.078
Post 6M	30.32±9.13	31.33±8.79	29.25±9.45	0.255
Post 6M-baseline	3.30±7.93	3.21±8.28	3.40±7.64	0.902
p-value for post 6M *v.s.* baseline	<0.001	0.007	0.003	
Understanding				
Baseline	34.82±6.68	34.78±6.85	34.86±6.57	0.947
Post 3M	35.73±6.80	35.90±6.56	35.54±7.12	0.796
Post 6M	36.01±6.20	35.74±6.25	36.31±6.19	0.645
Post 6M-baseline	1.20±6.91	0.96±7.13	1.45±6.73	0.727
p-value for post 6M *v.s.* baseline	0.085	0.335	0.139	
Appraising				
Baseline	26.03±8.81	26.84±8.55	25.17±9.08	0.343
Post 3M	28.88±8.86	29.65±9.75	28.06±7.83	0.371
Post 6M	28.30±9.08	29.33±8.41	27.21±9.70	0.244
Post 6M-baseline	2.27±8.09	2.48±8.10	2.04±8.16	0.785
p-value for post 6M *v.s.* baseline	0.006	0.031	0.087	
Applying				
Baseline	29.46±7.80	30.37±8.51	28.49±6.93	0.227
Post 3M	31.35±8.07	32.05±8.68	30.61±7.39	0.373
Post 6M	31.35±8.35	32.37±7.55	30.27±9.07	0.208
Post 6M-baseline	1.90±8.55	2.00±8.94	1.79±8.20	0.899
p-value for post 6M *v.s.* baseline	0.028	0.113	0.134	
Communication/Interaction				
Baseline	32.01±7.61	31.81±6.90	32.23±8.37	0.785
Post 3M	33.66±6.03	34.46±6.61	32.82±5.29	0.175
Post 6M	33.83±7.30	33.97±6.57	33.67±8.06	0.837
Post 6M-baseline	1.82±7.78	2.16±7.98	1.45±7.63	0.645
p-value for post 6M *v.s.* baseline	0.021	0.056	0.191	
Health Literacy				
Baseline	29.87±6.48	30.38±6.33	29.32±6.65	0.412
Post 3M	32.05±6.60	32.85±7.08	31.19±6.00	0.208
Post 6M	31.96±6.87	32.55±6.65	31.34±7.12	0.381

Post 6M-baseline	2.10±5.74	2.16±6.18	2.02±5.30	0.903
p-value for post 6M *v.s.* baseline	<0.001	0.015	0.010	

Abbreviations: CKD: chronic kidney disease

Table 4. Health literacy between participants with and without reaching blood pressure (BP) target of 130/80 mmHG after intervention

	Reaching BP goal (N=33)	Without reaching BP goal (N=68)	*P-value*
Accessing			
Baseline	26.4±9.1	28.4±9.7	0.316
Post 3M	30.0±9.3	31.9±9.6	0.350
Post 6M	30.9±9.3	29.2±8.9	0.389
Post 6M-baseline	4.5±7.0	0.8±9.3	0.029
p-value for post 6M *v.s.* baseline	<0.001	0.636	
Understanding			
Baseline	34.4±6.6	35.7±6.9	0.382
Post 3M	35.3±6.4	36.7±7.6	0.321
Post 6M	35.7±6.0	36.7±6.7	0.440
Post 6M-baseline	1.3±7.0	1.0±6.8	0.879
p-value for post 6M *v.s.* baseline	0.138	0.391	
Appraising			
Baseline	25.5±8.4	27.2±9.8	0.361
Post 3M	29.2±9.2	28.3±8.3	0.633
Post 6M	28.4±9.4	28.1±8.5	0.896
Post 6M-baseline	2.9±7.9	0.9±8.5	0.253
p-value for post 6M *v.s.* baseline	0.003	0.546	
Applying			
Baseline	28.7±7.4	31.1±8.5	0.145
Post 3M	31.3±8.0	31.5±8.3	0.895
Post 6M	31.8±8.8	30.5±7.4	0.471
Post 6M-baseline	3.1±8.2	-0.7±8.9	0.041
p-value for post 6M *v.s.* baseline	0.003	0.681	
Communication/Interaction			
Baseline	30.7±6.7	34.8±8.8	0.013
Post 3M	33.3±4.7	34.4±8.3	0.510
Post 6M	33.8±6.7	34.0±8.6)	0.885
Post 6M-baseline	3.0±6.9	-0.8±9.1	0.022
p-value for post 6M *v.s.* baseline	0.001	0.630	
Total score			
Baseline	29.1±6.2	31.4±7.0	0.099
Post 3M	31.8±6.4	32.6±7.1	0.602

Post 6M	32.1±7.1	31.7±6.4	0.789
Post 6M-baseline	3.0±5.0	0.3±6.8	0.052
p-value for post 6M *v.s.* baseline	<0.001	0.8305	

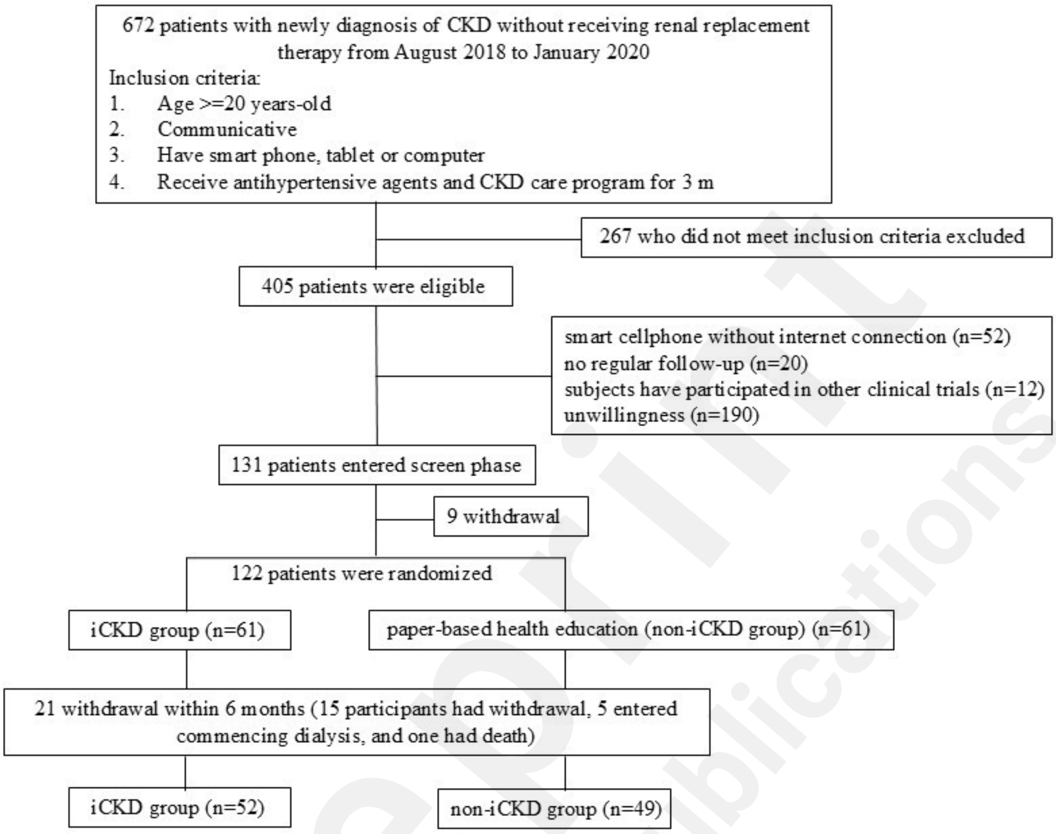
Table 5. Health literacy among participants with or without iCKD usage or reaching blood pressure target after intervention

Health literacy	iCKD group (N=52)		Non-iCKD group (N=49)		*P-value*
	Reaching BP goal (N=22)	Without reaching BP goal (N=30)	Reaching BP goal (N=11)	Without reaching BP goal (N=38)	
Accessing					
Baseline	26.67±7.77	32.99±10.87	26.01±10.78	25.63±7.91	0.119
Post 3M	31.04±9.67	36.11±10.56	28.59±8.75	29.38±8.28	0.116
Post 6M	31.88±9.3)	29.51±6.52	29.45±9.11	28.96±10.16	0.587
Post 6M-baseline	5.21±7.53	-3.47±7.29	3.45±6.21	3.33±9.52	0.010
p-value for post 6M *v.s.* baseline	<0.001	0.127	0.006	0.134	
Understanding					
Baseline	34.37±6.59	36.11±7.81	34.48±6.76	35.42±6.41	0.840
Post 3M	35.52±6.19	37.15±7.84	34.91±6.81	36.46±7.63	0.756
Post 6M	35.94±6.31	35.07±6.27	35.34±5.53	37.71±6.96	0.554
Post 6M-baseline	1.56±7.59	-1.04±5.06	0.86±6.24	2.29±7.46	0.590
p-value for post 6M *v.s.* baseline	0.201	0.491	0.463	0.186	
Appraising					
Baseline	25.94±8.14	29.86±9.54	24.86±8.73	25.63±9.77	0.423
Post 3M	29.69±10.08	29.51±8.96	28.45±7.88	27.50±7.93	0.819
Post 6M	29.58±8.74	28.47±7.50	26.72±10.12	27.92±9.28	0.640
Post 6M-baseline	3.65±8.13	-1.39±6.96	1.87±7.60	2.29±9.12	0.301
p-value for post 6M *v.s.* baseline	0.007	0.504	0.196	0.275	
Applying					
Baseline	28.96±7.49	35.07±10.28	28.30±7.33	28.75±6.47	0.064
Post 3M	31.98±8.56	32.29±9.42	30.32±7.29	31.04±7.70	0.827
Post 6M	32.71±7.70	31.25±7.22	30.46±10.03	30.00±7.72	0.597
Post 6M-baseline	3.75±8.38	-3.82±8.61	2.16±8.00	1.25±8.67	0.058
p-value for post 6M *v.s.* baseline	0.007	0.152	0.158	0.527	
Communication/Interaction					
Baseline	30.52±5.29	36.11±9.79	31.03±8.30	33.96±8.36	0.076
Post 3M	33.23±5.29	38.54±8.91	33.48±3.77	31.88±6.93	0.018
Post 6M	34.17±6.48	33.33±7.11	33.19±7.00	34.38±9.55	0.927
Post 6M-baseline	3.65±7.32	-2.78±8.40	2.16±6.16	0.42±9.45	0.067
p-value for post 6M *v.s.* baseline	0.003	0.276	0.070	0.846	
Total score					

Baseline	29.29±5.46	34.03±7.84	28.94±7.09	29.88±6.10	0.117
Post 3M	32.29±6.86	34.72±7.80	31.15±5.77	31.25±6.47	0.420
Post 6M	32.85±6.92	31.53±5.78	31.03±7.38	31.79±6.90	0.744
Post 6M-baseline	3.56±5.68	-2.50±5.66	2.10±3.78	1.92±7.05	0.014
p-value for post 6M *v.s.* baseline	<0.001	0.154	0.006	0.239	

Abbreviations: CKD: chronic kidney disease

Figure 1. The flow chart of this study



Supplementary Files

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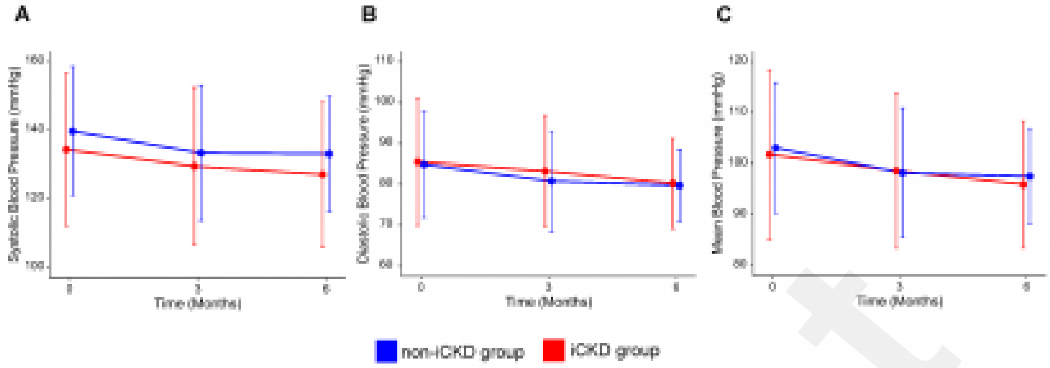
A
B
C
Systolic Blood Pressure (mmHg)
Diastolic Blood Pressure (mmHg)
Mean Blood Pressure (mmHg)
Time (Months)
Time (Months)
Time (Months)
non-iCKD group
iCKD group