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ORIGINAL ARTICLE

Integrated self-management program effects on hemodialysis patients: A quasi-experimental study

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Abstract

Aim: To evaluate the effects of an integrated self-management program using a mobile application, a short message service using a smartphone, and face-to-face counseling and education among hemodialysis patients.

Methods: A quasi-experimental study design was used. The participants of this study were 84 hemodialysis patients (42 in the experimental group and 42 in the control group). The experimental group received the integrated self-management program for 8 weeks. The data were analyzed by using the independent *t*-test and Mann–Whitney U test to identify differences in self-efficacy, treatment compliance, the ratio of interdialytic weight gain to dry weight, and serum potassium and phosphorus levels between the experimental group and the control group at the end of the program.

Results: The scores for self-efficacy and treatment compliance were significantly higher in the experimental group than in the control group. The ratio of interdialytic weight gain to dry weight significantly decreased in the experimental group, compared to the control group. The serum potassium and phosphorus levels in the experimental group were not significantly lower than those of the control group.

Conclusion: The findings suggest that the integrated self-management program that was implemented in this study could be a potentially effective intervention to improve the self-management of hemodialysis patients. Further research on various nursing intervention programs is warranted, including a mobile application program to improve hemodialysis patients' self-management.

Key words: mobile applications, renal dialysis, self-care.

INTRODUCTION

Although self-management is a very important factor in hemodialysis patients' treatment, many patients do not comply with self-management guidelines because they require lifestyle changes and behavioral limitations (Clark, Farrington, & Chilcot, 2014; Kaba *et al.*, 2007; Matteson & Russel, 2010; Oquendo, Asencio, & de Las Nieves, 2017). According to the guidelines of the National Kidney Foundation's "Kidney Disease Outcomes Quality Initiative", non-adherence includes missed and shortened treatments and the non-management of interdialytic weight gain and serum phosphorus levels (National Kidney Foundation, 2006). A meta-analysis in one study showed 33.0%–80.9% compliance with medication, treatment, diet, and water restriction guidelines by hemodialysis patients (Matteson & Russel). Compliance with dietary and water management guidelines was particularly low, with 25%–86% of participants experiencing difficulties in managing dietary and water restrictions (Oquendo *et al.*). As patients who do not adhere to treatment have a higher mortality rate (Clark *et al.*; Oquendo *et al.*), self-management intervention strategies are needed to induce desirable behavioral changes in patients and to improve their treatment outcomes.

Various self-management intervention programs for hemodialysis patients have been developed and used, including an educational program (Brogdon, 2013; Griva

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et al., 2018; Lin, Liu, Hsu, & Tsai, 2017; Lingerfelt & Thornton, 2011; Zolfaghari, Asgari, Bahramnezhad, AhmadiRad, & Haghani, 2015) and an empowerment program (Moattari, Ebrahimi, Sharifi, & Rouzbeh, 2012). Although these interventions were effective in increasing self-efficacy and hemodialysis treatment compliance (Lingerfelt & Thornton; Moattari *et al.*), the effects on the physiological parameters, such as interdialytic weight gain and serum potassium and phosphorus levels, were reported to be inconsistent (Griva *et al.*; Lin *et al.*; Matteson & Russel, 2010). Additionally, self-management by hemodialysis patients requires long-term intervention, as opposed to one-time educational or short-term intervention programs, in order to ensure that it is maintained over an extended period (Griva *et al.*).

In recent years, health care using mobile devices has been actively promoted for the management of patients with chronic illnesses (Patrick, Griswold, Raab, & Intille, 2008). As health-related mobile applications are known to be beneficial for patients' self-management (Miller, Cafazzo, & Seto, 2014), they can be very useful for hemodialysis patients who require consistent management. However, few studies have been conducted to verify the effectiveness of such applications (Hayashi *et al.*, 2017; Welch *et al.*, 2013) and most of the existing mobile applications for hemodialysis patients have been developed without analyzing users' needs (Hayashi *et al.*; Welch *et al.*). Additionally, these programs do not reflect the multifaceted nature of hemodialysis self-management, as they include only dietary management and water restriction among the contents (Connelly *et al.*, 2012; Welch *et al.*). This study thus aimed to develop an integrated self-management program by using a mobile application that incorporated various self-management domains (dietary and water restriction, blood pressure, arteriovenous fistulas, medication, and exercise), a short message service (SMS) program using a smartphone, and face-to-face counseling and education for hemodialysis patients. It also evaluated the program's effect on self-efficacy, treatment compliance, and physiological parameters, including the ratio of interdialytic weight gain to dry weight and the serum potassium and phosphorus levels of hemodialysis patients.

METHODS

Study design

A quasi-experimental study design (a non-synchronized, non-equivalent pretest–post-test control group design) was used.

Participants

A convenience sample was recruited from the outpatient hemodialysis center of a tertiary hospital in South Korea. The inclusion criteria were: (i) patients who were 19–60 years of age; (ii) patients who received hemodialysis two-to-three times per week and had received hemodialysis for >3 months; and (iii) patients who were using an Android-based smartphone. The exclusion criteria were: (i) patients who participated in an education program within the past month; (ii) patients who were hospitalized for >3 days during the intervention period; and (iii) patients with changes to their potassium and phosphorus excretion medication during the intervention period.

The sample size was calculated by using the G*Power 3.1.9 program, based on a previous study on hemodialysis patients' self-management (Park & Lee, 2010). The effect size of the independent *t*-test was 0.62 with a power of 0.80 and a significance level of 0.05. The minimum sample size was calculated as 38 per group. A total of 92 participants was selected, with 46 participants in each group in order to account for a predicted drop-out rate of 20%.

The nurses in the dialysis clinics selected the patients who met the inclusion criteria for this study and fully informed them of its aims and procedures. A total of 102 patients was approached, 10 of whom declined to participate. The study was initiated with a total of 92 patients as participants. Four of those in the experimental group stopped participating in the program for personal reasons and four in the control group declined to participate in the post-test. No patient was hospitalized for >3 days or had changes to their potassium and phosphorus excretion medication during the intervention period. Therefore, 84 patients completed the study.

Measurements

Self-efficacy

Self-efficacy was measured by using the scale that had been developed to assess self-efficacy in Korean hemodialysis patients (Song, Kim, Lee, Lee, & Shu, 1999). The reliability and validity of this tool have been established (Song *et al.*). A total of 11 items was ranked on a 4-point Likert scale, with higher scores indicating higher self-efficacy. The Cronbach's alpha for the scale was 0.80 when developed (Song *et al.*) and 0.78 in this study.

Treatment compliance

Treatment compliance was measured by using the Compliance of Patient Role Behavior tool that had been developed for Korean hemodialysis patients. The reliability and validity of this tool have been established (Cho, Choi, & Sung, 2011; Lee *et al.*, 2009). It measures hemodialysis patients' compliance with dietary and water restrictions, medication, exercise, the dialysis schedule, and arteriovenous fistula management. A total of 16 items was ranked on a 5-point Likert scale, with higher scores indicating higher patient compliance. The Cronbach's alpha for the scale was 0.86 when developed by Lee *et al.* and 0.82 in this study.

Ratio of interdialytic weight gain to dry weight

The interdialytic weight gain was measured by calculating the difference between the body weight before dialysis and the dry body weight. The body weight before dialysis was measured by using an electronic digital scale (CI-2001B Weighing Scale; CAS Korea, Seongnam, South Korea). "Dry body weight" refers to the lowest weight after dialysis that a patient can tolerate without any reduction in hypotension or blood volume (Kouw *et al.*, 1992). This was estimated by using a body composition monitor (FMC Corporation, Stade, Germany), which measures the body weight using the patient's current Body Mass Index and body water content. The ratio of interdialytic weight gain to dry weight was calculated based on the averages of two or three measurements >1 week before the pretest and the post-test value was calculated by using the averages that were taken within 1 week and 8 weeks following the program.

Serum potassium and phosphorus levels

The levels of serum potassium and phosphorus were collected from the patients' medical records. The pretest value was checked with the data before dialysis within 1 week prior to the intervention and the post-test value was checked before dialysis within 1 week and 8 weeks following the program.

Participants' demographic, clinical, and smartphone-related characteristics

The patients' demographic factors included their sex, age, job, educational level, and family income. The clinical factors included the duration of hemodialysis, frequency of hemodialysis, and potassium and phosphorus medication. The smartphone-related factors included the frequency of smartphone use, duration of smartphone use, and mobile application experience.

Integrated self-management program for hemodialysis patients

The integrated self-management program that was implemented in this study was developed based on the literature regarding hemodialysis patients using the model of empowered caring and the self-care theory of Orem. In the model of empowered caring, empowerment is an active, internal process of growth that occurs within the context of a nurse–client relationship (Falk-Rafael, 2001). Active participation and increased awareness are critical to the empowering process; increases in self-awareness and active participation enhance knowledge and skills. This enables individuals to make right choices and achieve desirable outcomes and health goals. According to this model, the attributes of self-awareness, active participation, knowledge, and skills lead to changes in oneself, relationships, and behavior. Changes in oneself include increased self-confidence and self-esteem. Changes in relationships include changes in relations with the family, friends, and healthcare providers. Changes in behavior include healthier goal-directed choices and self-advocacy (Falk-Rafael). In the previous literature, the model of empowered caring has been used to improve the adaptation of elderly residents of nursing homes (Chang & Park, 2012). Moreover, it has been reported that the nursing interventions based on Orem's self-care theory, which promote support, the use of educational strategies for knowledge and skills, and the improvement of participation in treatment, can promote self-care by hemodialysis patients (Simmons, 2009).

Previous research has stated that self-management programs, including knowledge and skill acquisition, self-efficacy development, and the provision of support, affect the knowledge level, treatment compliance, and physiological indices, including dialysis weight gain and the serum potassium and phosphorus levels in hemodialysis patients (Griva *et al.*, 2018; Lin *et al.*, 2017; Matteson & Russel, 2010; Milazi, Bonner, & Douglas, 2017).

The self-management program that is presented in this study comprised the use of a mobile application, SMS messages twice per week, and face-to-face counseling and education twice per month. The mobile application included self-awareness, knowledge and skills acquisition, self-efficacy promotion, and active participation. The SMS messages encouraged dietary and exercise management, confirmed hospital visit appointments, and supported self-care diary records. The SMS messages were sent on days when the participant did not receive dialysis (e.g. patients receiving dialysis on Monday, Wednesday, and Friday received a SMS on Tuesday and Thursday). The SMS content included the following: "Cook vegetables high in potassium, eat only a little fruit, and add 600 mL of water to your urine!," "Did you access the Kidney Love application today? Get useful information on dialysis, record today's data, and use it for self-management," "Protein intake is important when hemoglobin levels are low. How about beef and bluefish today?," and "Did you take the prescribed medicine at the correct time? It is good to take phosphorus excretion medication right after meals!"

Face-to-face counseling and education were conducted during dialysis on the day of the patient's visit to the dialysis clinic. Face-to-face counseling and education were conducted every 2 weeks from the first counseling and education session (e.g. the first and third Mondays of the month). Face-to-face counseling and education concerned the use of the mobile application and related questions about hemodialysis self-management (e.g. seasonal fruit selection, travel precautions, relationships between drugs and food, and how to take medication). Education and counseling via a bulletin board that was linked with the mobile application and SMS, combined with face-to-face counseling, aimed to positively change patients' relationship with healthcare providers by encouraging interaction between them. The researcher posted information about self-management on the bulletin board and the participants freely described their opinions. Although it was difficult to receive the participants' feedback via SMS, the bulletin board that was published posted the participants' opinions and the researcher's messages, allowing them to interact (Table 1).

Mobile application development for hemodialysis patients

The development of the mobile application for the hemodialysis patients occurred via a process of analysis, design, development, operation, and evaluation. The first step was an analysis of user needs and content. A survey was conducted among 30 hemodialysis patients who were aged 19–60 years to investigate the users' needs, educational experience, satisfaction with previous self-management programs, information collection methods, self-management needs and preferred methods, and smartphone application experience. A content analysis was conducted through a selection of the areas to be included in the program; it incorporated prior literature, various hemodialysis teaching materials, and hemodialysis website analysis.

In the second step (design phase), the information design was structured into six high-level menus and 17 submenus comprising the application introduction, hemodialysis library, health keeper, health diary or chart, alarm, and questions and answers. The information that was collected in each menu was arranged appropriately and the necessary content and forms were summarized. A strategy for interaction between the researcher and participants was established in the interaction design, which enabled counseling and education through a bulletin board. In the motivation design, a strategy was developed to enable the participants to continuously and actively use the mobile application and to practice and independently monitor self-management. First, a "Program User Guide" was designed to allow the participants to easily use the mobile application. Messages, such as "self-management day 1" and "self-management day 2," were displayed when the participants used the health diary in order to allow them to monitor their self-management. The health diary or chart was designed to allow the participants to compare their body weight, blood pressure, and momentum at weekly and monthly intervals by using a graph. The evaluation design assessed the overall usage frequency of the mobile application.

The third step, development, involved the process of developing the mobile application, consisting of storyboarding, media production, and integrated production. Integrated production occurred by integrating the produced media according to the storyboard. The developed mobile application was named "Kidney Love."

The fourth step, operation, was to pilot the developed mobile application. Two trained nurses explained the method, purpose, and usage of the application to 11 participants and conducted a pilot test of the application for 2 weeks.

In the fifth and final step, evaluation, eight experts and the 11 participants who had used the program for 2 weeks assessed the program's validity and usage issues, errors, and appropriateness. Following this review, the mobile application was finalized through revision and supplementation according to the opinions of the users and experts. The SMS messages and face-to-face counseling and education were provided by the researcher.

Data collection

The data collection for the control group was conducted from January 1 to February 28, 2016; the pretests and

Table 1 Integrated self-management program

Mobile application		
Application menu	Contents	Component
Menu (main page)	Introduction to the application and menu	
Application introduction	Greeting	
	User guide for the application	
Hemodialysis library	Introduction to chronic renal failure (definition, diagnosis, and treatment)	Knowledge and skills
	Hemodialysis (purpose and method)	
	Diet for hemodialysis patients	
	Medication for hemodialysis patients	
	Exercise for hemodialysis patients	
	Clinical examination (including blood tests)	
	Fistula management	
	Check of knowledge level (quiz)	
	Medical assistance and hemodialysis	
	Checklist for self-management	
	Introduction to related website	
Health keeper	Record demographic information	Self-awareness
	Record blood test results	Self-efficacy
	Record daily body weight and blood pressure	Active participation
	Check and record fistula status	
	Select and listen to favorite music, perform exercise, and record exercise duration	
	Check and record diet	
	Record medication	
	Record general condition	
Health diary or chart	Weekly chart (body weight, blood pressure, and exercise duration)	Self-awareness
		Self-efficacy
	Monthly chart (blood test results, body weight, blood pressure, and exercise duration)	
Alarm	Hemodialysis schedule	Self-efficacy
	Time for medication	Active participation
	Time for exercise	
Q&A	User guide for the Q&A	Knowledge and skills
	Frequently asked questions and answers	Active participation
	Questions	Support
	Announcement promoting participation via bulletin board	
Short message service using smartphone(twice per week)		Support
Dietary management encouragement		
Exercise		
Medication adherence encouragement		
Confirmation of hospital appointment		
Self-care diary record		
Face-to-face counseling and education(twice per month)		Support
Use of mobile applications		Knowledge and skills
Questions about hemodialysis self-management		

Q&A, Questions and answers.

post tests were conducted at intervals of 8 weeks. The general characteristics, self-efficacy, and treatment compliance were investigated through questionnaires; the ratio of interdialytic weight gain to dry weight and serum potassium and phosphorus levels were measured via the medical records. The collection of the questionnaire data on self-efficacy and treatment compliance was conducted by a nurse in the dialysis clinic during dialysis. The questionnaire was filled out and completed by the participants, with help from the nurse only when necessary. The same nurse then examined the ratio of interdialytic weight gain to dry weight and the serum potassium and phosphorus levels by using the medical records.

The data collection for the experimental group occurred from March 15 to May 15, 2016. The pretests and post tests were conducted in the same manner as for the control group and the integrated self-management program was applied for 8 weeks. At the end of the program, a post test was conducted. For both the control and the experimental groups, pretests and post tests were conducted by one nurse. Two training nurses with experience in hemodialysis participated in the mobile application program training as research assistants. The researcher spent 1 h explaining the purpose and use of the mobile application to the two nurses and they were given 1 week to use and familiarize themselves with the application. They were subsequently able to ask the researcher any questions they had during this period. After the research assistants mastered the use of the application, they explained how to use the application to the experimental group. The research assistants installed the application directly on the experimental smartphone and took 15–20 min to explain its use. Two additional explanations were given during the patients' regularly scheduled hemodialysis visits to ensure that the participants were fully familiar with its method of use. Additionally, the research assistants instructed the participants to access the application at least once per day to record their data and to use the records for self-management.

The use of and satisfaction with the application was investigated after the end of the program. The application use was investigated based on the frequency of uses per day, the average duration of a single-use session, the most frequently used menus, the time spent using the health keeper, and the time spent using the hemodialysis library. Satisfaction was measured by using a 5-point scale to investigate the application's efficiency, the convenience of the system, the design, the usefulness of the information, and overall satisfaction.

Ethical considerations

This study was conducted in accordance with the ethical standards of the Committee on Human Experimentation of the institution in which the experiments were done and the Helsinki Declaration of 1975. The Institutional Review Board (IRB) approved this study. All the participants were required to provide informed consent in compliance with the IRB's ethical regulations. They were given the option to voluntarily withdraw their informed consent at any point during the research and their personal data were kept strictly confidential throughout the study. After the study was completed, the mobile applications were provided to those who wanted to continue to use them in the control group.

Data analysis

The statistical analyses were conducted by using the IBM SPSS program (v. 24.0; IBM Corporation, Armonk, NY, USA). All the data were expressed as numbers (percentages) or means ± standard deviation. The Shapiro–Wilk's test was used to analyze the normality of the variables. An independent *t*-test, Mann–Whitney U test, or chi-squared test was carried out in order to identify the homogeneity of the variables between the experimental group and the control group at the pretest. The data were analyzed by using an independent *t*-test and Mann–Whitney U test to identify the differences between the experimental group and the control group at the end of the program. A two-tailed *P*-value of <0.05 was considered to be statistically significant.

RESULTS

Participants' demographic, clinical, and smartphone-related characteristics

The descriptive demographic, clinical, and smartphone-related characteristics of the participants are summarized in Table 2. There was no significant difference in the demographic, clinical, and smartphone-related characteristics between the control and experimental groups.

Pretest variable homogeneity between the two groups

The homogeneity of the variables between the experimental and the control groups in the initial pretest is presented in Table 3. There were no significant differences between the two groups' self-efficacy, treatment compliance, ratio of interdialytic weight gain to dry weight, or serum potassium and phosphorus levels.

Table 2 Homogeneity of demographic, clinical, and smartphone-related characteristics (n = 84)

Variable	Category	Exp. (n = 42) Mean ± SD or N (%)	Con. (n = 42) Mean ± SD or N (%)	t or χ^2	P
Age (years)		51.48 ± 10.15	48.93 ± 9.37	−1.20	0.235
Sex	Female	20 (47.6)	17 (40.5)	0.44	0.510
	Male	22 (52.4)	25 (59.5)		
Marital status	Married	30 (71.4)	25 (59.5)	2.28	0.552
	Single	6 (14.3)	9 (21.4)		
	Divorced	3 (7.1)	6 (14.3)		
	Widowed	3 (7.1)	2 (4.8)		
Family income (Won/month)	≤100	23 (54.8)	25 (59.5)	0.86	0.865
	101–200	10 (23.8)	7 (16.7)		
	201–300	6 (14.3)	6 (14.3)		
	>300	3 (7.1)	4 (9.5)		
Education	≤Elementary	6 (14.3)	6 (14.3)	1.07	0.783
	Middle	11 (26.2)	8 (19.0)		
	High	19 (45.2)	19 (45.2)		
	≥College	6 (14.3)	9 (21.4)		
HD frequency (times/week)	2	6 (14.3)	12 (28.6)	2.55	0.111
	3	36 (85.7)	30 (71.4)		
HD duration (months)		54.26 ± 7.72	63.97 ± 10.00	0.77	0.444
Potassium excretion medication	Yes	20 (47.6)	27 (64.3)	2.37	0.187
	No	22 (52.4)	15 (35.7)		
Phosphorous excretion medication	Yes	26 (61.9)	29 (69.0)	0.49	0.647
	No	16 (38.1)	13 (31.0)		
Smartphone use	Poor	9 (21.4)	13 (31.0)	3.52	0.172
	Normal	20 (47.6)	23 (54.8)		
	Good	13 (30.0)	6 (14.2)		
Smartphone use duration (years)	<1	9 (21.4)	10 (23.8)	1.22	0.897
	1< duration ≤2	5 (11.9)	7 (16.7)		
	2< duration ≤3	4 (9.5)	5 (11.9)		
	3< duration ≤5	9 (21.4)	6 (14.3)		
	>5	15 (35.7)	14 (33.3)		
Health-related application experience	Yes	18 (42.9)	13 (31.0)	1.28	0.258
	No	24 (57.1)	29 (69.0)		

Con., Control group; Exp., experimental group; HD, hemodialysis; SD, standard deviation.

Effects of the integrated self-management program

The results in Table 4 show that there were differences in self-efficacy, treatment compliance, the ratio of interdialytic weight gain to dry weight, and serum potassium and phosphorus levels between the experimental group and the control group. The self-efficacy scores increased significantly in the experimental group (4.79 ± 3.51), compared to the control group (−1.05 ± 2.05; t = −9.30, P < 0.001). Treatment compliance significantly increased

Table 3 Homogeneity of the variables between the two groups (n = 84)

Variable	Exp. (n = 42) Mean ± SD	Con. (n = 42) Mean ± SD	t or Z	P
Self-efficacy	2.87 ± 0.42	2.66 ± 0.53	−1.94	0.057
Treatment compliance	3.63 ± 0.58	3.47 ± 0.54	−1.35	0.180
Ratio of IDWG to dry weight (%)	4.43 ± 1.41	4.86 ± 1.47	−1.29	0.198
Serum potassium level (mEq/L)	5.32 ± 0.82	5.67 ± 0.82	−1.85	0.064
Serum phosphorus level (mg/dL)	4.97 ± 1.45	5.69 ± 1.91	−1.81	0.070

Con., control group; Exp., experimental group; IDWG, interdialytic weight gain; SD, standard deviation.

Table 4 Comparison of self-efficacy, treatment compliance, ratio of interdialytic weight gain to dry weight, and serum potassium and phosphorus levels before and after the integrated self-management program

Variable	Category	Exp. (n = 42) Mean ± SD	Con. (n = 42) Mean ± SD	t, Z, or F	P
Self-efficacy	Pretest	31.52 ± 4.60	29.29 ± 5.89	−9.30	<0.001
	Post test	36.31 ± 3.50	28.24 ± 4.76		
	Difference	4.79 ± 3.51	−1.05 ± 2.05		
Treatment compliance	Pretest	58.12 ± 9.29	55.48 ± 8.61	−10.66	0.001
	Post test	69.69 ± 5.57	53.74 ± 7.84		
	Difference	11.57 ± 7.63	−1.74 ± 2.71		
Ratio of IDWG to dry weight (%)	Pretest	4.43 ± 1.41	4.86 ± 1.47	−2.83	0.005
	Post test	3.87 ± 1.35	4.91 ± 1.42		
	Difference	−0.56 ± 0.88	0.05 ± 1.08		
Serum potassium level (mEq/L)	Pretest	5.32 ± 0.82	5.67 ± 0.82	−0.10	0.918
	Post test	5.31 ± 0.78	5.63 ± 0.70		
	Difference	−0.01 ± 0.86	−0.04 ± 0.84		
Serum phosphorus level (mg/dL)	Pretest	4.97 ± 1.45	5.69 ± 1.91	−1.81	0.070
	Post test	4.42 ± 1.51	5.75 ± 2.01		
	Difference	−0.55 ± 1.34	0.07 ± 1.95		

Con., control group; Exp., experimental group; IDWG, interdialytic weight gain; SD, standard deviation.

in the experimental group (11.57 ± 7.63), compared to the control group (−1.74 ± 2.71; $t = -10.66$, $P = 0.001$). The ratio of interdialytic weight gain to dry weight decreased significantly in the experimental group (−0.56 ± 0.88%), compared to the control group (0.05 ± 1.08%; $Z = -2.83$, $P = 0.005$).

In contrast, the serum potassium levels decreased in the experimental group (−0.01 ± 0.86 mEq/L), compared to the control group (−0.04 ± 0.84 mEq/L), but the difference between the groups was not statistically significant ($Z = -0.10$, $P = 0.918$). The serum phosphorus levels also decreased in the experimental group (−0.55 ± 1.34 mg/dL), compared to the control group (0.07 ± 1.95 mg/dL), but the difference between the groups was not statistically significant ($Z = -1.81$, $P = 0.070$).

Application use and satisfaction

The application use data were as follows: the frequency of uses per day was 1.21 ± 0.41; the average duration of a single-use session was 10.24 ± 4.59 min; the most frequently used menus were the health keeper, health diary or chart, and hemodialysis library; the time spent using the health keeper was 5.00 ± 3.52 min (in a single session); and the time spent using the hemodialysis library was 4.43 ± 1.59 min (in a single session). The satisfaction scores were as follows: the application efficiency was 3.81 ± 0.39, convenience of the system was 3.68 ± 0.47, application design was 3.81 ± 0.39, usefulness of the information was 3.74 ± 0.44, and overall satisfaction was 3.61 ± 0.48.

DISCUSSION

This study was conducted in order to identify the effect of an integrated self-management program using a mobile application, smartphone SMS, and face-to-face counseling and education, based on previous research about self-efficacy, treatment compliance, the ratio of interdialytic weight gain to dry weight, and serum potassium and phosphorus levels, of hemodialysis patients. Most of the previous mobile application programs for hemodialysis patients were developed without analyzing the users' needs and covered only a limited set of self-management domains, such as diet and weight management, which does not reflect the multifaceted characteristics of self-management. In an effort to overcome these limitations, this study aimed to incorporate the multifaceted characteristics of hemodialysis patients' self-management, including dietary management, exercise, medication, arteriovenous fistula management, and dialysis schedule management. The study's findings showed that the model of empowered caring and self-care theory can be applied to improve hemodialysis patients' self-management. Further research is needed regarding nursing interventions for hemodialysis patients to improve their self-management based on various theoretical frameworks. Additionally, this study recruited 30 hemodialysis patients and analyzed their characteristics and self-management needs in order to reflect the factors that are related to hemodialysis patients. Self-management mobile applications that are similar to the one developed in this study should be developed by analyzing and further reflecting hemodialysis patients' needs.

The self-efficacy scores significantly increased in the experimental group in this study after 8 weeks. This finding is consistent with previous research (Moattari *et al.*, 2012; Park & Lee, 2010) and a meta-analysis study showed that self-management programs were effective for the self-efficacy of patients with chronic renal failure (Lin *et al.*, 2017). Improving self-efficacy could be an effective strategy for managing treatment compliance and interdialytic weight gain, as self-efficacy is known to be associated with treatment compliance (Cho *et al.*, 2011; Zrinyi *et al.*, 2003) and interdialytic weight gain (Aliasgharpour, Shomali, Moghaddam, & Faghihzadeh, 2012). This study showed that the treatment compliance scores increased significantly in the experimental group after implementation of the integrated self-management program. As hemodialysis patients who do not adhere to treatment have a higher mortality rate than those who do comply with treatment (Oquendo *et al.*, 2017), hemodialysis patients should strictly and thoroughly manage their standard lifestyle habits and behaviors; a variety of nursing interventions should be developed to improve compliance with patient role behaviors, including mobile application interventions, as implemented in this study. Additionally, because treatment compliance also has been reported to be associated with interdialytic weight gain and serum potassium levels (Naalweh *et al.*, 2017), enhancing treatment compliance could be a useful method for managing the physiological indicators.

The ratio of interdialytic weight gain to dry weight decreased significantly in the experimental group after the program; this result is consistent with previous self-management research (Aliasgharpour *et al.*, 2012; Griva *et al.*, 2018; Lin *et al.*, 2017). A previous self-management mobile application for hemodialysis patients showed no effect on the interdialytic weight gain, but that program included a small number of participants and did not calculate the interdialytic weight gain as a ratio reflecting body weight (Welch *et al.*, 2013). This study's program consisted of mobile application use, SMS messages twice per week, and face-to-face counseling and education twice per month. The factors that were included in this study's program might have collectively contributed to the observed management of interdialytic weight gain. Therefore, it is necessary to develop and provide programs that reflect the various attributes that are related to self-management in order to control the inter-dialytic weight gain.

This study did not find statistically significant differences in the serum potassium and phosphorus levels between the two groups after the program. Thus, the number of patients with normal serum potassium and phosphorus levels in the two groups was further analyzed after the program. For the serum potassium, 27 patients in the experimental group and 20 patients in the control group were within the normal range in the pretest; 25 patients in the experimental group and 21 patients in the control group were within the normal range in the post test. For the serum phosphorus, 20 patients in the experimental group and 12 patients in the control group were within the normal range in the pretest; 26 patients in the experimental group and 13 patients in the control group were within the normal range in the post test. The number of patients with normal serum phosphorus levels increased in the experimental group, but the change was not statistically significant. This is consistent with a randomized control study that provided 6 week empowerment interventions (Moattari *et al.*, 2012). However, it is contrary to studies on the effectiveness of educational or behavioral interventions on compliance with phosphorus level control (Milazi *et al.*, 2017) and the effects of a self-management intervention randomized trial (Griva *et al.*, 2018). The following reasons might explain why the program was not effective in changing the levels of serum potassium and phosphorus. First, the type and dosage of the potassium and phosphorus excretion medications were not controlled, although the use of the potassium and phosphorus excretion medications was tested for homogeneity between the groups in the pretest. Second, the serum potassium and phosphorus were measured immediately after the end of the program and thus the long-term effects could not be measured. Finally, it is possible that the experimental group contained fewer participants for effective change because the number of patients with normal levels of serum potassium and phosphorus was high in the experimental group, compared with the control group. Further research is needed to control for the aforementioned limitations and to confirm the long-term effects of the program on the levels of serum potassium and phosphorus.

Hyperphosphatemia is a biochemical abnormality that is commonly found in patients with chronic renal failure; it is known to be highly correlated with a poor prognosis and mortality of dialysis patients. Additionally, hypophosphatemia can increase the risk of malnutrition (Collinson, McMullan, Tse, & Sadler, 2014). Therefore, because it is important for hemodialysis patients to maintain adequate levels, nurses should be conscious of the serum phosphorus levels and seek methods to stabilize them.

This study has some limitations. First, it could not identify the program's long-term effectiveness. Second, although the use of potassium and phosphorus excretion medication was tested for homogeneity between the experimental and control groups in the pretest, the types and dosages of potassium and phosphorus excretion medications were not investigated. Further studies will be needed to confirm the long-term effects of self-management programs on the serum potassium and phosphorus levels, while controlling for various variables that could affect these levels. Nevertheless, this study's strength is that the implemented program incorporated the various domains that are required for hemodialysis patients' self-management. The integrated self-management program used a mobile application, smartphone SMS, and face-to-face counseling and education and was developed according to the users' needs, which were analyzed in the development stage.

CONCLUSION

The integrated self-management program had significant effects on self-efficacy, treatment compliance, and the ratio of interdialytic weight gain to dry weight. However, the program had no effect on the serum potassium and phosphorus levels of the hemodialysis patients. Further research is needed to develop and assess a nursing intervention program that can improve the physiological indicators of serum potassium and phosphorus levels. Furthermore, it is necessary to develop a nursing intervention program that involves a mobile application in order to improve the self-management of hemodialysis patients.

DISCLOSURE

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

O. L. P. and S. R. K. designed the study,; O. L. P. collected the data; and O. L. P. and S. R. K. analyzed the data and prepared the manuscript.

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