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E-Learning Model in Chronic Kidney Disease Management
A Controlled Clinical Trial

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Introduction. Chronic kidney disease (CKD) is a challenging health problem. The present study examined impact of self-care education through e-learning on improving kidney function among individuals with CKD.
Materials and Methods. The studied population consisted of CKD patients receiving care at 10 centers for treating noncommunicable diseases in Tehran. Three centers were randomly selected and 39 patients with a glomerular filtration rate (GFR) less than 60 mL/min/1.73 m^2, minimum education of grade 9, minimum of 2 years of referrals, and computer literacy of the individual or a first-degree relative were included in the study, while 92 patients were assigned into the control group. Changes in GFR were compared after 6 months following an e-learning program for the patients in the intervention group.
Results. The mean change in GFR was 7.5 ± 8.9 mL/min/1.73 m^2 for the intervention group after the e-learning intervention, while this was -2.3 ± 8.5 mL/min/1.73 m^2. The two groups were also significantly different in terms of age, marital status, education level, mean arterial pressure, and serum high-density lipoprotein level, and therefore, multivariable comparison of GFR was made incorporating these factor into the analysis and showed a significant improvement of GFR in the intervention group.
Conclusions. According to the results of this study, effects of the e-learning educational intervention on improvement in kidney function and CKD treatment were established.

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INTRODUCTION

Chronic kidney disease (CKD) is a noncommunicable disease with a growing prevalence.[1] The prevalence of CKD in Iran is 12.7%,[2] and the prevalence of a glomerular filtration rate (GFR) less than 60 mL/min/1.73 m^2 is approximately 10% in patients with diabetes mellitus and hypertension.[3]

Chronic care model of CKD is known to decrease progression of decreasing GFR. However, education is the Achilles heel of chronic kidney management programs.[4,5] One part of education division is self-management. Self-managed and self-management are defined as "making your own decisions about how to organize your work, rather than being led or controlled by a manager" and "candidates should have good self-management and communication skills," respectively.[6] Education of general public, especially those with high cardiovascular risk, facilitates prevention of CKD.[7] Reliable and valid tools should be used for assessing the literacy levels of patients with CKD. This could be helpful in detecting risk factors involved in the development and progression of CKD in people with low levels of literacy.[8]

The present study was carried out to determine the effectiveness of virtual training in terms of its impact on physiological measures affecting the development of kidney dysfunction. If this study confirms the efficiency and effectiveness of this approach, we can develop a virtual training system for prevention, screening, management, treatment, and monitoring of chronic kidney disease.

MATERIALS AND METHODS

The population examined by this clinical trial consisted of CKD patients receiving care from Tehran University of Medical Sciences at centers for treating noncommunicable diseases. The centers offer services to patients (29 836 individuals) at risk of cardiovascular disease. The last examination indicated that 7.8% of these patients had a GFR less than 60 mL/min/1.73m^2. The inclusion criteria were that the participants should have diabetes mellitus, a minimum education level of grade 9, access to the internet directly or through a first-degree relative, computer literacy, a GFR less than 60 mL/min/1.73 m^2 , and having visited or been referred to a center at least 2 times.

Individuals were not selected randomly; rather, noncommunicable centers were used as measuring units and 3 centers were selected for intervention using the appropriate formula to calculate the sample size, while 7 centers were used as controls. Sixty-five patients should have been studied for each group. However, since only 39 individuals volunteered in the intervention group, the size of the control group was increased to 92 in order to maintain the strength of the test.

The e-learning model utilized in this study was the ADDIE (analysis, design, development, implementation, and evaluation) model. Learners, education method, and software and hardware infrastructures were analyzed. In the analysis of CKD-related education, requirements for educational content were identified using the Kidney Disease: Improving Global Outcomes to cover these topics: What is CKD? How is CKD diagnosed? How is CKD classified? What are the stages of development for CKD? What are CKD risk factors? What complications are caused by CKD and how are they identified? How to provide care for CKD patients? How to follow up? To develop the instructional model, focus group sessions were held with experts, including software engineers, advisors, and supervisors, and staff working at centers for treating noncommunicable diseases to review available documents on educational interactions and evaluation methods. Based on the audience's access to and familiarity with computer, a computer-based system was used to offer the educational content. A comprehensive review of available software for content development led us to the open-source system Joomla. The system was designed in a way that attracts maximum possible number of audience and motivates them to study the content. Following these evaluations, a system was developed and launched at http://barahimi.com.

Once the educational content was developed, patients in the intervention group were contacted but all of them refused to cooperate. Therefore, we decided to use a verbal educational class for the patients. Once the invitations were sent, 39 individuals attended an orientation session for participation in the study. During these training sessions, group discussions were held to describe how to use the educational system developed for this purpose. During the interventions, required information, including serum creatinine, age, sex, height, and weight were collected and recorded in electronic files by a team at treatment centers according to the instructions developed by these centers. The information was extracted and recorded on questionnaires developed for this purpose. Other data, including internet literacy (of the individual or a first degree relative) were recorded by interviewers. In addition, the educational content at http://barahimi.com was accessible during the interventions. The individuals in the control group received typical treatment without using this model. Then, improvement in kidney function for all participants was evaluated during the training sessions and 6 months following the intervention based on GFR. Six months later, relevant data were again extracted from electronic files for both groups, collected through questionnaires, and analyzed for further evaluation.

Once coded, the data were entered into the SPSS software (Statistical Package for the Social Sciences, version 21.0, IBM Corp, New York, NY, USA). Descriptive statistical techniques and statistical tests were applied to both groups and descriptive statistics (frequency, mean, standard deviation, and percentage) and inferential statistical techniques (the analysis of variance, the chi-square test, and the *t* test for paired samples) were used for data analysis.

RESULTS

In total, 39 CKD patients participated in the intervention. In addition, 92 CKD patients were assigned to the control group. All individuals who met the inclusion criteria were included in the study. Sex distribution in the control and the intervention groups were comparable (Table 1). The mean age was 58 ± 9 years in the intervention group and 67 ± 9 years in the control group ($P < .001$). Thus, age was controlled for in investigation of the impact of the educational intervention on changes in GFR (Table 2). The mean intervals between the two GFR measurements was 325 ± 224 days in the control group and 328 ± 328 days in the

Table 1. Demographic Data of Patients With Chronic Kidney Disease Participating in an E-Learning Intervention Versus the Control Group at the Centers for Treating Noncommunicable Diseases

Characteristic	Intervention Group	Control Group	All	*P*
Number of patients	39	92	131	
Age, y	58.1 ± 9.6	67.5 ± 9.7	...	< .001
Sex				
Female	16 (48.0)	35 (36.1)	51 (39.0)	
Male	23 (59.0)	57 (61.9)	80 (61.0)	.75
Education level				
Up to grade 12 and higher	21 (53.0)	30 (32.6)	51 (38.9)	
Grade 9	18 (47.0)	62 (67.4)	80 (61.1)	.02

Table 2. Clinical Data of Patients With Chronic Kidney Disease Participating in an E-Learning Intervention Versus the Control Group at the Centers for Treating Noncommunicable Diseases

Parameter	Intervention Group	Control Group	Mean Difference 95% Confidence Interval	*P*
Glomerular filtration rate, mL/min/1.73 m^2				
Baseline	51.1 ± 8.0	49.9 ± 7.6	-4.2 to 1.8	.44
After 6 months	57.8 ± 11.5	47.6 ± 8.7	-14.8 to -5.7	< .001
Change	7.5 ± 8.9	-2.3 ± 8.5	-13.3 to -6.1	< .001
Hemoglobin A1c, %				
Baseline	6.7 ± 1.3	6.6 ± 1.2	-0.8 to 0.6	.77
After 6 months	6.1 ± 1.3	6.8 ± 1.5	-.03 to 1.3	.06
High-density lipoprotein, mg/dL				
Baseline	48.6 ± 11.5	43.7 ± 11.0	-9.2 to -0.6	.03
After 6 months	46.2 ± 11.7	45.5 ± 10.4	-5.1 to 3.8	.77
Triglyceride, mg/dL				
Baseline	175.5 ± 145.7	165.1 ± 83.1	-60.5 to 39.6	.68
After 6 months	154.0 ± 89.3	159.6 ± 92.1	-29.1 to 40.8	.75
Low-density lipoprotein, mg/dL				
Baseline	113.4 ± 43.9	99.7 ± 29.2	-29.1 to 1.7	.08
After 6 months	105.4 ± 39.7	95.7 ± 26.5	-23.8 to 4.5	.18
Weight, kg				
Baseline	75.3 ± 10.6	73.9 ± 12.7	-5.7 to 3.0	.53
After 6 months	74.8 ± 11.1	72.7 ± 12.2	-6.5 to 2.3	.35
Height, cm	163.8 ± 7.5	162.4 ± 9.5	-4.6 to 2.3	.35
Waist, cm				
Baseline	95.2 ± 11.1	97.8 ± 10.6	-1.2 to 7.0	.26
After 6 months	95.0 ± 11.7	96.8 ± 11.0	-2.7 to 6.4	.43
Mean arterial pressure, mm Hg				
Baseline	93.1 ± 7.2	97.5 ± 11.4	1.1 to 7.7	.009
After 6 months	93.6 ± 5.9	94.3 ± 7.8	-1.7 to 3.2	.56
Body mass index, kg/m^2				
Baseline	28.1 ± 3.4	28.1 ± 4.5	-1.5 to 1.4	.96
After 6 months	27.6 ± 4.2	27.7 ± 4.5	-1.8 to 1.2	.69
Duration between measurements, d	323.9 ± 232.8	297.4 ± 218.4	-120.8 to 67.9	.58

intervention group. The duration of intervention as a confounding factor was not significant (P = .66).

Education levels of the individuals in the control group were different from those in the intervention group (Table 1), and therefore, were incorporated into the analysis as a confounding variable in order to identify the effects of the intervention after controlling for education level. Marital status distribution was also different among the individuals in the control group from those for the intervention group. Age and marital status were incorporated into the analysis as a confounding variable in order to identify the intervention effects after controlling for marriage groups.

No significant difference was found between the control and the intervention group in terms of mean Hemoglobin A1c (P = .77). The difference was still not significant after the intervention (P = .06), although a substantial difference was observed in terms of clinical and marginal considerations. Prior to the intervention, the average high-density lipoprotein cholesterol level and the mean arterial pressure in the control group were significantly different from the values found in the intervention group (P = .03 and P = .009, respectively). However, the difference was not significant after the intervention (P = .78 and P = .56), although it was marginally and clinically considerable. Other variables presented in Table 2 did not exhibit significant differences prior to and after the intervention (Table 2).

Analysis of covariance was used to examine impacts of the intervention on changes in GFR. Since average age, marriage and education of the individuals in the control group were different from those in the intervention group, age, marriage, education, mean arterial pressure, and high-density lipoprotein cholesterol were incorporated into the analysis as a confounder variable in order to identify the intervention effects after controlling for age, marital status, and education level. It should be noted that the average GFR changes in the intervention group was 7.5 ± 8.9 mL/min/1.73 m^2, while it was -2.3 ± 8.5 mL/min/1.73 m^2 for the control group (Tables 2 and 3), indicating an improvement in kidney function in the intervention group compared to the control group (P < .001), while a progress was observed in CKD among individuals in the control group. The difference in GFR changes between the two groups remained significant after adjustment for confounding factors (Table 3).

Table 3. Effect of E-Learning Intervention on Glomerular Filtration Rate in Patients With Chronic Kidney Disease Adjusted for Other Factors

Factor	Sum of Squares	*F*	*P*
E-learning	1357.8	18.034	< .001
Age	111.3	1.480	.23
Marital status	257.9	3.355	.07
Education level	1.4	0.018	.89
Mean arterial pressure changes	3.4	0.046	.83
High-density lipoprotein changes	3.8	0.500	.82

DISCUSSION

To the best of our knowledge this study is one of the first e-learning intervention studies in CKD prevention. The results of this study confirmed effects of the e-learning educational intervention on improvement in kidney function and CKD treatment. Since CKD has such concomitant illnesses as diabetes mellitus, cardiovascular disease, and depression, providing care for CKD patients requires a team responsible for primary health care. It seems that one way for better treatment of CKD and for facilitating diagnosis of signs and symptoms of this condition is to teach patients about self-care (self-management). Motivating the patient for self-care and cooperation with the health care team as well as motivating care providers to focus on risk factors and CKD complications play an essential role in improving the patient's quality of life and a quick response to the condition for early treatment.[9] Education also plays a critical role in providing CKD patients with required care.[10] Face-to-face training, group education, and distant learning are among programs that can be used for educating CKD patients. Distant education includes correspondence education, information technology-based education, or using smart phones for training. Applications used for this purpose can be installed on computers and smart phones or accessed online. These tools have been shown to be effective in controlling blood pressure and blood glucose in CKD patients.[11]

Chronic kidney disease care providers may use information technology-based tools as a key feature in supporting self-care programs. Developers and organizers of electronic programs need to collaborate to design tools to meet different needs of patients at various stages of self-care process. Assessment of CKD patients' literacy is a reliable tool to identify risk factors involved in contracting and progress of CKD in patients with low education levels.[8] One study has shown effectiveness of training hemodialysis patients in coping and communication skills on improving quality of life for these patients.[12] At stage 4 of CKD, educating the patient is useful in persuading the patients and their family about the conditions and also in starting CKD care programs.[13] A study of 54 patients randomly assigned to either a self-management group or the control group indicated a higher level of GFR in the self-management group 1 year after intervention (20.2 ± 29.1 mL/min/1.73 m^2 versus 10.7 ± 15.7 mL/min/1.73 m^2). The individuals in the self-care group experienced less frequent hospitalizations.[14]

A study conducted in 2013 by Ong and colleagues to develop an electronic tool for self-management is used as a basis to assess the needs of CKD patients.[15] In 2011, Young and coworkers showed positive effects of electronically assisted education for CKD patient on providing better information to the patients and their families for starting life with stage 4 CKD.[13] An interventional study based on clinical trials by Wright Nunes and colleagues demonstrated the effectiveness of a web-based educational intervention in all CKD stages for a group of 150 patients compared to a control group consisting of 401 CKD patients.[16] Lin and colleagues showed that a self-management program for CKD patients resulted in a significant improvement in self-efficacy of the patients over a period of 1 year as well as an insignificant improvement in self-management behavior, a considerable decrease in serum creatinine, and a stable level of GFR.[17] These experimental data showed that the self-management program developed in this study has stopped CKD progress. An individual with acceptable self-management abilities will obtain more information to achieve the desirable result. Therefore, health care providers for CKD patients should motivate these patients to engage in self-management programs by teaching them self-regulating strategies to stop CKD progress. A stable change in behavior is the key to successful health care.

In an interventional study conducted by Barahimi and colleagues in Iran within a nation-wide CKD management program, the program content was developed by taking into account definition, progress, classification, clinical symptoms, diagnosis methods, short- and long-term complications, treatment objectives, proper nutrition, exercise, self-management, CKD control, prevention and therapy, pregnancy in women with CKD, and intensifying factors. Educational methods included individual and group consultations. Physicians, nurses, and nutritionists received required training. In addition, the public received training on initial prevention, adjusting nutritional behaviors, reducing salt intake, proper physical activity, avoiding smoking, and modifying lifestyle. The training and medical intervention resulted in 1% reduction in hemoglobin A1c in patients with diabetes mellitus and an improvement by 21% in CKD patients.[18] In a cross-sectional interventional study of 51 hemodialysis patients at Imam Khomeini Hospital conducted by Rajaee and colleagues, an intelligent website was used to assess quality of life. Stage 4 and stage 5 CKD patients received training on communication skills and problem solving in focus group discussions prior to onset of an alternative treatment. The results indicated 20% improvement in individuals' knowledge after implementation of this educational program.

Numerous studies have been carried out in other countries with respect to e-learning for CKD patients. However, the authors were not able to find a study on effectiveness of e-learning for CKD patients in Iran. Several medical e-learning systems have been developed in other languages for internet-based education. Two credible sources in this area are the Kidney International Foundation and Health Education England.

The findings of our study established the effectiveness of the intervention in kidney function improvement. In the present study, face-to-face education and therapeutic interventions were the same for both groups, and these interventions were supplemented by e-learning programs. As users could freely access the website developed for the purpose of this study, these individuals were able to use the website without registration requirements. Therefore, a limitation of the present study was that it was not possible to count the number of the website users in the intervention group. A factor involved in progression of CKD is kidney failure, which was not evaluated in the groups. Other factors included proteinuria level, smoking, cardiovascular disease, and ongoing exposure to nephrotoxins. Another limitation of the study was small sample size due to low levels of literacy among many patients in this study. Patient literacy programs seem to be effective in improving patients' health-related knowledge, thereby positively affecting the treatment process. Reliable infrastructures and internet connections are necessary for development of e-learning and this requires proper planning by decision makers. Further studies are needed in this area as studies on e-learning, particularly for CKD patients, are relatively small in number. Future studies can use larger sample sizes, particularly for stage 1 and 2 CKD. The findings of the present study suggest that e-learning leads to a significant difference between the control group and the intervention group in terms of kidney function.

CONCLUSIONS

The findings of our study established the effectiveness of the intervention in kidney function improvement. Therefore, it is recommenced that our primary healthcare system should particularly focus on this mode of education for patients.

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CONFLICT OF INTEREST

None declared.

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