

The Effect of a Virtual Reality Exercise Program on Physical Fitness, Body Composition, and Fatigue in Hemodialysis Patients

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Abstract. [Purpose] The aim of the present study was to investigate the effects of a virtual reality exercise program (VREP) on physical fitness, body composition, and fatigue in hemodialysis (HD) patients with end-stage renal failure. [Subjects and Methods] A nonequivalent control group pretest-posttest design was used. Forty-six HD patients were divided into exercise (n=23) and control groups (n=23); while waiting for their dialyses, the exercise group followed a VREP, and the control group received only their usual care. The VREP was accomplished using Nintendo's Wii Fit Plus for 40 minutes, 3 times a week for 8 weeks during the period of May 27 to July 19, 2013. Physical fitness (muscle strength, balance, flexibility), body composition (skeletal muscle mass, body fat rate, arm and leg muscle mass), and fatigue were measured at baseline and after the intervention. [Results] After the VREP, physical fitness and body composition significantly increased, and the level of fatigue significantly decreased in the exercise group. [Conclusion] These results suggest that a VREP improves physical fitness, body composition, and fatigue in HD patients. Based on the findings, VREPs should be used as a health promotion programs for HD patients.

Key words: Hemodialysis, Virtual reality exercise, Physical fitness

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INTRODUCTION

In late 2011, there was a total 63,341 patients receiving renal replacement therapy in South Korea; 42,596 of these were hemodialysis (HD) patients, accounting for 67.2% of the total, and the number of maintenance hemodialysis patients is on the rise¹⁾. Because the physical fitness level of HD patients tends to improve their functional levels²⁾, exercise therapy is an important nursing intervention for HD patients in improving their physical performances³⁾. Various exercise interventions including strength training, aerobic exercise, and resistance exercise using sandbags and elastic bands for HD patients have been studied and reported to be effective in obtaining physical and physiological improvements^{4–7)}. Despite the effective results from previous studies, exercise intervention programs have not been established as an active practice⁸⁾, with the participation rate being low⁸⁾, the rate of high dropout from programs being 20–30%, and the rarely exercising rate being, 48% in HD patients. The reasons for the lack of exercise, according to the hemodialysis patients, include tiredness following dialysis treatments, unexplainable fear of exercise, time and

locational constraints, and lack of motivation⁹⁾. From the medical professionals' point of view, the possibility of damage and other barriers have been discouraging them against strongly recommending an exercise intervention for dialysis patients⁹⁾. It should also be noted that even the most effective exercise programs would not be able to keep the interest of patients if they are composed only of repetitive routines. Therefore, careful planning of the content of the exercise programs with the motivation and continued participation of the patients in mind is essential¹⁰⁾. In recent years, utilizing virtual reality to increase the amount of physical activity of patients while overcoming some of the aforementioned limitations of exercise programs has been gaining ground in clinical practices¹¹⁾. Virtual reality has been applied as a clinical intervention for improving mobility or cognitive functions and has also been demonstrated to be a positive nursing intervention for chronic patients, as illustrated by the results of a 10-week virtual reality exercise program applied to elderly diabetes patients, who showed improved balance, muscle strength, walking, and falls efficacy^{12–14)}. The aim of this study was to propose a new nursing intervention method for hemodialysis patients through a virtual reality exercise program and investigate its effects on fitness, body composition, and fatigue.

SUBJECTS AND METHODS

Subjects

The subjects were adult (≥18 years) men and women re-

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Table 1. Characteristics of the patients

Characteristics	Exer	Cont
Age (year)	60.8 ± 6.9	57.7 ± 9.5
Height (cm)	166.1 ± 6.9	167.8 ± 9.9
Gender		
Male	15 (65)	13 (57)
DM		
Yes	14 (61)	18 (78)
Dry weight (kg)	62.3 ± 13.7	60.6 ± 8.8
Duration of HD (months)	54.4 ± 49.2	38.2 ± 25.2
Kt/V urea	1.2±0.1	1.2±0.1
Hemoglobin (g/dl)	10.5±0.7	10.2±0.7
Physical fitness		
Back strength (kg)	61.1 ± 13.7	56.9 ± 12.9
Grip strength (kg)	29.7 ± 8.6	26.3 ± 7.9
Leg strength (kg)	35.4 ± 14.0	32.6 ± 12.6
Flexibility (cm)	6.5 ± 5.6	5.7 ± 3.5
Balance (sec)	6.9 ± 3.5	7.3 ± 3.1
Body composition		
SMM (kg)	25.1 ± 5.1	25.9 ± 5.7
AMM (kg)	5.0 ± 1.1	5.5 ± 1.3
LMM (kg)	14.1 ± 3.3	14.7 ± 3.7
BFR (%)	24.8 ± 8.8	24.8 ± 8.2
Fatigue (score)	6.7 ± 0.8	6.8 ± 1.0

Values are means ± SD or numbers (%). Exer, exercise group (n=23); Cont, control group (n=23); DM, diabetes mellitus; HD, hemodialysis; K, dialyzer clearance of urea; t, dialysis time; V, volume of distribution of urea; SMM, skeletal muscle mass; AMM, arm muscle mass; LMM, leg muscle mass; BFR, body fat rate

ceiving HD treatment for the management of end stage renal disease. Sample size was calculated based on previous study⁷). For sufficient statistical power (0.95), setting at effect size at 1.19⁷, alpha at 0.05, a total 40 subjects were estimated to be required for the independent t-test, according to G power 3.0 software. In the present study, the sample size was adjusted to 48 to account for an anticipated dropout rate of 20%. The exercise (n=24) and control (n=24) groups were recruited between May 2013 and August 2013 from a C dialysis clinic in Kyeonggi Province, South Korea. This study meets the ethical standards of the Declaration of Helsinki (1975, revised 1983,) and the Institutional Review Board of C University approved all procedures. Written informed consent was obtained from all subjects.

The patients who received HD on Monday, Wednesday, and Friday were assigned to the exercise group; those who received HD on Tuesday, Thursday, and Saturday were assigned to the control group. Without giving any information about the rest of the study, the same intervention was applied to the control group 8 weeks later. Demographic, laboratory, and baseline characteristics of the two groups were not different (Table 1). The control group did not participate in any of the exercises during the study. For the HD treatment, the same dialysis machine, needle puncture diameter, blood flow rate, dialysate, and heparin dosage were used for

Table 2. Protocol of VREP

Wk	Repetition	RPE	Exercise type	Exercise content	Duration (min)
1–2	2–3	10–11	Game	Hula-hoop	30
				Dance step	
				Rhythm parade	
			Strength	Twist upper body	
				One arm pull back	
				Chair position	
3–5	2–3	12–13	Game	Half moon position	30
				Flying game	
				Twist	
			Strength	Rhythm Kung Fu	
				Knee flexion and pull	
				Balance walk	
6–8	2–3	14	Game	Chair position	30
				Half moon position	
				Mii Triathlon	
			Strength	Balance bead	
				Juggling	
				Leg wide open, side flexion	
Yoga	Lifting the side limbs	30			
	Half moon position				
	Knee hugging position				

VREP, virtual reality exercise program; Wk, week; RPE, rating of perceived exertion

each dialysis. During the data collection period of 8 weeks, one patient from the exercise group dropped out due to an emergency cardiovascular surgery, and one patient from the control group was excluded due to refusal to participate in post-test measurements, resulting in a dropout rate for the study of 4.3%. The average participation rate for the exercise group was 94% (88% – 100%) and 12 patients had an attendance rate of 100%. The patients were notified at the beginning of the study that an attendance rate below 80% would automatically exclude them from the study.

Methods

The Wii Fit Plus software, launched by Nintendo in 2010, was administered as the virtual reality exercise program (VREP) to the exercise group (Table 2). The VREP was applied 3 times a week, 40 minutes each time, for 8 weeks, as recommended by the Life Options Rehabilitation Advisory Council (LORAC)⁷). The exercise intensity was individualized based on the rating of perceived exertion (RPE), which was measured for each patient before the start of the program, and was gradually intensified over the course of the exercise program. The exercise group participated in the VREP 3 times a week while waiting for their dialyses at the on-site gym. Each attendance and exercise score was automatically logged into a centralized computer system and recorded per patient after each session; data were managed in batches by the researcher. A previous study con-

ducted on elderly diabetes patients¹⁴) was used as the basis for the VREP; 18 positions from the 69 Wii Fit Plus games, as well as muscle strengthening movements and yoga movements, were selected. The researcher facilitated the VREP, which was designed as a group exercise program consisting of warm-up, main exercise, and cool-down segments. The warm-up and cool-down segments were intended to prepare the patients for optimal physical results from the main exercise and to prevent accidents. Starting from upper to the lower extremities, the VREP consisted of 8 stretching positions as suggested by the LORAC and lasted for 5 minutes. Each target position, designed to be an RPE level of 8–9 points (very easy), was held for 5–10 seconds and repeated twice. The main exercise segment was allocated 30 minutes, with the purpose being improvement of muscle strength, flexibility, and balance. It consisted of 3 games, 2 muscle strengthening movements, and 2 yoga movements, and was conducted in that order. With individual differences in fitness in mind, a minimum of 2 repetitions with no limit on the maximum was set for each movement. Tailoring to individual fitness levels and gradually focusing on the number of repetitions and accuracy of each movement, the routine allowed patients to exercise autonomously; a bell was rung in order to direct the patient to the next movement after 10 minutes. Every movement was demonstrated on a screen for the patient to watch and follow. The sequence of the exercise program and the types of movements are as shown in Table 2. The effect of the exercise program was measured by a physical therapist using physical fitness measuring equipment (Helmas III, O2run, Seoul, South Korea). The measurements were taken the day after HD, as stable blood pressure and cardiovascular function should be regained by that time.

Back, handgrip, and leg strength were measured for each patient. Back strength was measured twice in kilograms using a digital dynamometer, with the patient in a standing position while holding the measuring bar with both arms spread wide and the waist slightly bent; the higher of two measurements was selected. Handgrip strength was measured in kilograms with the patient holding onto the measuring device in hand with full grip. Two measurements were made and the higher of the two was recorded. Leg strength was measured twice in kilograms based on the force exerted when the patient pushed forward on a pedal with both legs and ankles in a sitting position with the back up against a backrest; the higher of the two measurements was chosen. Flexibility was measured by using sit-and-reach box. Sitting on the box with his/her feet firmly planted on one end, the patient was asked to extend his/her hands towards his/her feet as far as possible without bending his/her knees; the better of two tries was recorded in centimeters. To measure balance, the patient was asked to stand on one leg with both eyes closed. The duration of until the patient lost his/her balance and touched the ground with his/her other foot was recorded in seconds, and the longer of two tries for each of the legs was recorded. Body composition, based on skeletal muscle mass (SMM), arm muscle mass (AMM), leg muscle mass (LMM), and body fat rate (BFR), was measured using an Inbody s10 body composition analyzer (Biospace,

Seoul, South Korea). Fatigue was assessed with the Visual Analogue Scale, with 1 denoting the lowest level of fatigue and 10 denoting. The data collected were analyzed using the SPSS statistics (version 18.0) and a homogeneity test between the two groups was conducted with the χ^2 -test and t-test. The post-test comparison regarding the effects of the VREP between the two groups was analyzed with an unpaired t-test.

RESULTS

The back strength of the patients noticeably increased in the exercise group, after VREP, from 61.1 kg to 63.1 kg ($p=0.001$), however, there was almost no change in the control group. Similar improvements in leg strength were observed in the exercise group, improving from a pre-test value of 35.4 kg to a post-test value of 37.2 kg ($p < 0.001$), but no difference was observed in the control group ($p=0.032$). The difference in flexibility (sit and reach test) between the two groups after the VREP was not dramatic, as the flexibility in the exercise group increased by 1.0 cm, although the flexibility of the control group also increased by 0.2 cm. The difference in balance between the two groups after the VREP improved significantly ($p < 0.001$), as the duration until the patients lost their balance in the exercise group increased by 1.0 second, while that in the control group showed an increase of only by 0.3 seconds. The differences between the pre- and post-test physical strength figures for both the control and exercise groups are shown in Table 3.

Of the body composition measures, skeletal and leg muscle mass changed significantly between the two groups after the VREP (Table 4). Skeletal muscle mass showed a significant increase in the exercise group, from 25.1 kg to 26.2 kg ($p < 0.001$), while no change was observed in the control group. Leg muscle mass also increased noticeably in the exercise group, from 14.1 kg to 14.2 kg ($p=0.016$), but no change was observed control group.

The level of fatigue in the exercise group showed a dramatic decrease, from 6.7 points to 4.9 points ($p > 0.001$), while almost no changes were noted in the control group (Table 5).

DISCUSSION

The increase of elderly HD patients and the duration of HD treatments point to the increasing importance of systematic exercise programs for dialysis patients^{15, 16}. Despite the positive effects reported on maintaining and improving patients' physical functions^{17, 18}, exercise programs for HD patients are not yet a part of the typical care plan⁶. This study investigated the effects of a VREP on HD patients, and it had no limitations regarding the types of participants, and the benefit of providing visual feedback, or the interest to the participants. Virtual reality is a simulated reality in which the participant can experience an environment as if it is reality by means of a television or computer screen¹⁹; the image of the user appears on the screen as an avatar, and the objects and tasks the user interacts with in reality create a life-like virtual feedback on the screen¹². Virtual reality has been used in the medical field for rehabilitating patients'

Table 3. Comparison of the effect of the VREP on physical fitness between the exercise and control groups

Variables	Group	Pre-test	Post-test
Back strength (kg)	Exer	61.1 ± 13.7	63.1 ± 15.0**
	Cont	56.9 ± 12.9	57.0 ± 13.0
Grip strength (kg)	Exer	29.7 ± 8.6	29.5 ± 8.4
	Cont	26.3 ± 7.9	26.2 ± 8.0
Leg strength (kg)	Exer	35.4 ± 14.0	37.2 ± 13.9*
	Cont	32.6 ± 12.6	31.5 ± 12.7
Flexibility (cm)	Exer	6.5 ± 5.6	7.5 ± 5.1
	Cont	5.7 ± 3.5	5.9 ± 3.1
Balance (sec)	Exer	6.9 ± 3.5	8.2 ± 3.5**
	Cont	7.3 ± 3.1	7.5 ± 3.2

Values are means ± SD. VREP, virtual reality exercise program; Exer, exercise group (n=23); Cont, control group (n=23). * p<0.05; **p<0.01.

Table 4. Comparison of the effect of the VREP on body composition between the exercise and control groups

Variables	Group	Pre-test	Post-test
SMM (kg)	Exer	25.1 ± 5.1	26.2 ± 4.9***
	Cont	25.9 ± 5.7	26.0 ± 5.7
AMM (kg)	Exer	5.0 ± 1.1	5.1 ± 1.1
	Cont	5.5 ± 1.3	5.4 ± 1.3
LMM (kg)	Exer	14.1 ± 3.3	14.2 ± 3.3*
	Cont	14.7 ± 3.7	14.6 ± 3.7
BFR (%)	Exer	24.8 ± 8.8	24.6 ± 8.4
	Cont	24.8 ± 8.2	24.8 ± 8.2

Values are means ± SD. VREP, virtual reality exercise program; Exer, exercise group (n=23); Cont, control group (n=23); SMM, skeletal muscle mass; AMM, arm muscle mass; LMM, leg muscle mass; BFR, body fat rate. *p<0.05; ***p<0.001.

Table 5. Comparison of the effect of the VREP on fatigue between the exercise and control groups

Group	Pre-test	Post-test
Exer	6.7 ± 0.8	4.9 ± 1.1***
Cont	6.8 ± 1.0	6.7 ± 1.2

Values are means ± SD. Exer, exercise group (n=23); Cont, control group (n=23). ***p<0.001.

cognitive and motor functions and has proven effective in improving physical functions, such as posture, balance, and motor functions²⁰). It has been reported to have contributed positively to self-efficacy and life satisfaction of patients with low back pain, and to have improved upper extremity function, quality of life, walking, balance, and daily life skills in stroke patients¹³). It has been reported that, through virtual reality based programs, walking speed, time, and abilities were improved significantly in amputation patients¹⁹), while physical health was reportedly improved in patients with cognitive impairments²¹). Nintendo's Wii Fit Plus, launched in 2011, was used as the virtual reality

exercise software in this study. It reflects the movements of the user in real time using a balance board system. The accuracy of movements and balancing by the participant is reflected as a scoring system generated by the software. The virtual exercise trainer provides audio and video feedback to enable the participant to follow the exercise movements more accurately. The rate of accuracy is scored and made available to the participant upon completing the whole routine; the scoring system provides motivation for the participant to keep improving²²).

According to this study, the 8-week VREP improved leg strength, back strength, flexibility, and balance significantly, but did not have much impact on handgrip strength. This result is consistent with a previous study on elderly diabetes patients, in which a 10-week VREP performed twice a week noticeably improved leg strength and balance in the exercise group¹⁴), as well as an 8-week VREP in elderly patients that showed improvements in leg strength and balance²³). Previous exercise studies for HD patients that combined resistance training and aerobic exercise using elastic bands demonstrated significant improvements in handgrip strength^{4,5}), but this was not the case in this study. The fact that this particular study had fewer movements that required gripping and pulling with the upper body compared with the previous studies is thought to be the reason. The 3.2% improvement shown in back strength, which is closely related to handgrip strength, suggests that longer administration of the VREP and addition of movements involving more of the upper body could improve grip strength. Consistent with a previous study on stroke patients using a Nintendo Wii system for balance improvement²⁴), flexibility and balance in the exercise group improved as a result of the VREP in this study, which consisted of games, muscle strengthening movements, and yoga movements that prompted the participants to repeatedly bend and straighten the waist, neck, and knees while supporting themselves against the floor. As in previous studies involving stretching and other flexibility exercises²⁵), the VREP showed a positive effect on balance and standing on one leg with the eyes closed.

In terms of body composition, the exercise group in this study showed a significant increase in skeletal muscle mass and leg post-test measurements but while displayed no difference in body fat ratio and arm muscle mass. The body composition results differ from those of a previous study that showed an increase in muscle mass and a significant decrease in body fat ratio after a 12-week resistance exercise program⁴). The relatively short duration and low intensity of the VREP administered in this study could have been a factor, as body fat rate is affected by the rate of muscle mass increase as well as the duration and intensity of physical activity. That said, the exercise group did display a decrease in body fat of 0.8%, a promising result to consider in case the VREP continues over a longer term.

This study showed significant improvements in leg muscle mass only, which can be explained by the lack of movements focusing on the arm muscle mass, as most movements involved having both feet on the ground. A more balanced program involving both upper and lower body movements is recommended for the future. The improvements in leg

muscle mass, on the other hand, show the potential of the VREP as an effective nursing intervention in terms of physical independence for many HD patients.

Fatigue in the exercise group after taking part in the VREP decreased noticeably, and this was thought to be due to the general improvement in physical fitness in the patients, which reduced the amount of fatigue perceived.

No injuries or side effects were incurred as a result of the VREP, as the intensity of each exercise routine, consisting of games, muscle strength movements, and yoga, was tailored to the individual patients. The fact that the VREP was conducted while the patients waited for HD, as well as the assistance provided by the virtual trainer, increased accessibility to exercise. The individual scoring system, the scores from which were subsequently managed in batched, made it easy to track the progress and attendance of each patient. The reduced demand on the researchers' time to facilitate and manage the exercise program⁴⁾ was a distinctive benefit provided by the virtual reality system compared with previous studies based on real-life exercise sessions²⁶⁾. The participation rate for this study averaged 95%, significantly higher than that of previous studies (70–88%)^{4, 5)}. The sense of achievement provided as part of the VREP through the game format with a scoring system while improving physical fitness could be the reason.

As the VREP is relatively new and does not have many precedent clinical studies, more studies with a variety of parameters are needed to verify the results yielded in this study. The VREP performed in this particular study appeared to be less effective in reducing the body fat ratio, although 8 weeks is a short period to fully understand the impact of the exercise program. On that note, a longer VREP lasting 6 months to 1 year is desirable to look into its long-term impacts. Additional research and development to diversify the instruments and software used in the exercise programs for clinical environments would also be beneficial. The main aim of this study was to bring physical benefits to dialysis patients through an effective exercise program while improving the previously documented limitations of accessibility and motivation. It is a positive stride towards providing a nursing intervention that improves the physical health of HD and other chronic patients.

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