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Effects of virtual reality pelvic exercise for 12 weeks on gait and quality of life of chronic stroke patients

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Abstract

Background/Objectives: The purpose of this research was investigate the effects of virtual reality pelvic exercise for 12 weeks on gait and quality of life of chronic stroke patients.

Methods/Statistical analysis: A total of 40 subjects in this study were randomly assigned to groups performing virtual reality pelvic exercise, pelvic exercise using mirrors, and conventional pelvic exercise. Each group conducted a total of 12 weeks of training, 3 times a week, and 30 minutes a day. Measurements included gait speed, time, stride length, cadence, and quality of life. Statistics were analyzed using SPSS version 20.0.

Findings: All groups showed improvements in gait and quality of life, but especially so in the group performing virtual reality pelvic exercises.

Improvements/Applications: Virtual reality Pelvic exercise is believed to positively impact the pelvic movement of stroke patients, thus helping them improve gait and quality of life.

Keywords: Gait, Pelvic, Quality of life, Stroke, Virtual reality

1. Introduction

The effects of a stroke include sensory abnormality, loss of motor skills, muscle weakness, and detriments to cognitive and perceptual abilities depending on areas of blood flow to the brain, resulting in problems with balance and posture control [1]. Stroke patients are often affected not only by balance issues but also by difficulty in controlling posture. Furthermore, they may also experience a failure to recover at a level sufficient to adapt to community life, often leading to the problem of social isolation [2].

A proper gait requires the harmonious movement of the limbs with minimal energy and the movement of the body’s center of gravity forward through effective means [3], but stroke patients experience problems with body recognition while also facing difficulties with overall balance and controlled walking [4]. The characteristic walking patterns of stroke patients include the stance phase of the lower paralyzed extremity, reductions in the cadence and stride length, and a reduction of co-ordination, which limits functional activities [5]. The rotation and tilt of the pelvis, ankle joint movement, knee joint movement, and pelvic movement in stroke patients are important factors that can make for efficient walking [6].

The pelvis is essential to connecting the spine and the lower extremities, supporting weight and increasing the functional range for trunk mobility [7]. A position where the alignment of the pelvis has been dynamically altered not only affects the trunk muscles but also the legs, negatively impacting posture stability along with functional balance and walking [8]. Bobath has identified pelvic exercise as the most effective adjustment point for walking ability [9], whereas Trueblood and others have suggested that pelvic tilting exercise in stroke patients could facilitate normal motor function, reduce excessive muscle tension, and increase weight movement in the paralyzed lower extremities, thereby improving walking patterns [10]. The walking ability is one of the most important outcomes of rehabilitation, determining the range of daily life activities that a stroke patient can perform [11].

Quality of life is the perception of one's place in relation to one's expectations, norms, goals, and interests within the cultural value systems within which an individual lives, as defined by the World Health Organization (WHO). It is a broad concept with variables of physical health, mental state, social and environmental relationships, and self-reliance levels [12].

Among the rehabilitation methods available to stroke patients, rehabilitation using visual feedback helps promote learning about exercise and improves the walking ability of stroke patients [13]. Among the rehabilitation methods currently used by clinicians, mirror balancing exercises are performed by identifying one's appearance in real time, reducing abnormal patterns over the course of modification through continuous visual information, and working to improve balance ability and stability [14]. However, because most of these treatments are performed under the directions of therapists, it can be difficult for patients to motivate themselves, and patients' low expectations of treatment and its effectiveness have led to unsatisfactory outcomes [15]. Recently, with the development of computer technology, virtual reality, which complements the shortcomings of existing interventions and provides a stable and realistic environment, has begun to be applied in the rehabilitation of stroke patients [16,17]. Virtual reality provides real-time feedback because it allows users to interact with a computer in a virtual environment, facilitating real-time performance in a 3-dimensional space on the monitor [18, 19].

Despite this large number of studies on the efficient rehabilitation of stroke patients, research on virtual reality pelvic exercise has thus far been insufficient. Therefore, it is necessary to compare the effects of virtual reality pelvic exercises for stroke patients with pelvic exercises using mirrors and conventional pelvic exercise without mirrors. Taking a closer look at these new developments in clinical treatment will allow us to determine what the most effective interventions are for improving stroke patients' gait and quality of life.

2. Materials and Methods

2.1. Subject

This research was conducted with the participation of 45 patients with stroke hemiplegia who were receiving hospital treatment at R hospital and T hospital in Yongin, South Korea. This research was approved by the Institutional Bioethics Committee of Namseoul University (NSUIRB-201811-001). The selection criteria for subjects were those who had a stroke at least 6 months prior, those with a score of 24 or more points on the MMSE-K (Mini Mental Status Examination-Korean), those who had grades of less than 2 on the modified Ashworth scale (MAS), those who could walk and stand independently without assistance from others, and those who understood the aim of this research and voluntarily consented to participate in it. With random number allocation methods using computers, participants were randomly assigned into group 1 (virtual reality pelvic exercise, VG), group 2 (pelvic exercise using a mirror, MG), or group 3 (conventional pelvic exercise without a mirror, CG). The general and medical characteristics of the subjects were investigated, and evaluation and mediation was conducted by 6 therapists with more than 3 years of experience. The same checks were conducted on the 3 groups before the start of the study, after 6 weeks, and after 12 weeks of intervention, and the collected data were analyzed after statistical processing.

2.2. Intervention

This research was mediated 3 times a week for a total of 12 weeks, with 30 minutes being allocated for each session. All subjects were given treatment commonly performed in hospitals, including physical therapy and occupational therapy. In addition, VG was to complete virtual reality pelvic exercises, MG was to complete pelvic exercise using mirrors, and CG was to complete conventional pelvic exercises without mirrors. The intensity of exercise in each group was applied at ratings of perceived exertion (RPE) ranging from 11–14 [20], which is the most appropriate intensity for stroke patients, and the intensity was increased every 4 weeks. The durations, number of applications, and application times for each group were the same.

Virtual reality pelvic exercise (VG) was performed through a game included in the Valedo system, which requires the anterior-posterior tilt of the pelvis and the left-right tilt of the pelvis. All games were played in a standing position, and the therapist helped the subjects to move and proceed through the game. The intervention time was 30 minutes in total, including 5 minutes of warm-up, 2 minutes for each game, 1 minute of rest before moving on to the next game, and 5 minutes of a cool down after main program were complete. Virtual reality pelvic exercise program is shown in Table 1.

Table 1. Virtual reality Pelvic exercise

Session (time)	Contents	Intensity
Warm up (5min)	Trunk, Upper & Lower limb stretching	
Main program (20min) (2min/program)	Cave : Pelvic anterior & posterior tilt Fruit : Pelvic Right & Left tilt Color : Pelvic anterior & posterior + Right & Left tilt Clock : Pelvic anterior & posterior + Right & Left tilt Balance : Maintain pelvic position V-goal : Go to target then back to home	1~4week: Easy (11~12 RPE) 5~8week: Medium (12~13 RPE) 9~12week: Hard (13~14 RPE) Rest between Program:1min
Cool down (5min)	Trunk, Upper & Lower limb stretching	

The subjects in the pelvic exercise group used mirrors (MG) performed the exercise with the help of therapists while looking at themselves in a full-length mirror. The method of exercise was a modification of the pelvic exercise performed in a preceding study conducted by Carr and Shepherd [21]. It included anterior-posterior and left-right pelvic tilts. The intervention time was 30 minutes in total, consisting of 5 minutes of warm-up, 20 minutes of main program consisting of anterior-posterior and left-right pelvic tilting movement, and 5 minutes cool down. Pelvic exercise program with mirror is shown in Table 2.

Table 2. Pelvic exercise with mirror

Session (time)	Contents	Intensity
Warm up (5min)	Trunk, Upper & Lower limb stretching	
Main program (20min) (3min/program)	Pelvic anterior & posterior tilting exercise with mirror. Pelvic left & right tilting exercise with mirror Pelvic anterior & posterior + left & right tilting	1~4week: 11-12 RPE 5~8week: 12-13 RPE 9~12week: 13-14 RPE Program × 2 set

	exercise with mirror	Rest between Program: 1min between Set: 1min
Cool down (5min)	Trunk, Upper & Lower limb stretching	

A conventional pelvic exercise group (CG) performed the same exercises performed by the group above without mirrors.

2.3. *Measuring instrument*

2.3.1. Gait

The ability to walk was measured using a motion analyzer (iSEN, STT systems, Spain, 2016), and the quantitative gait analysis data for each subject was collected. The tool consists of a 3 axis gyroscope operating at a sample speed of ± 2000 deg/s and 400Hz, a 3 axis low noise accelerometer operating at a sample speed of ± 16g and up to 400 Hz, a 3 axis magnetometer with an operating range of ± 1300 µT, and a barometric sensor in the range of 300–1100 hPa. The gait of each subject was analyzed using a protocol corresponding to the gait analysis. A total of 5 sensors were used in this study, and each sensor was attached to the pelvic area (S1) of the subject, with half of the remaining points on the left and right femur, and the other half on the tibia. Measurement items used in this study included time, speed, cadence, and step length as influenced by the work of Shores [22]. The walking distance standard was set to 10 m. After 3 measurements, the average value was recorded [23].

2.3.2. Quality of life

To measure the quality of life of a stroke patient, the stroke specific quality of life scale (SS-QOL, Cronbach's α = 0.80) developed by Williams et al [24] was used. The SS-QOL consists of 49 items in a total of 12 areas, each of which is measured on a 5 point Likert scale; the higher score means a high quality of life.

2.3.3. Valedo system

To perform virtual reality pelvic exercises, the Valedo motion system (Switzerland) was used. The tool consists of a laptop and 3 sensors (connecting to the sternum, Lumbar 1, and Sacrum 1), which have a radio frequency of 2.4Ghz; a gyroscope operating at 1 mW, 2,000 times per second; an acceleration sensor of up to ±16 g; and a magnetic sensor of 1–2 degrees. Patients in virtual reality groups performed exercises with games specifically developed for improving motor control, body recognition, and stabilization controlled by pelvic movement.

2.4. *Data analysis*

Data analysis in this research was conducted by using SPSS version 20.0 for Windows. All data were tested for normality through the Shapiro–Wilk test. The general characteristics of the study subjects were determined by the mean and standard deviation. The gender, paralyzed side, stroke type, and lesion areas were chi-square tested, and one-way ANOVA was performed for pre-identical homogeneity testing of age, incidence period, MMSE-K score, and group. Two-way ANOVA with repeated measures was performed to analyze the main effects and interactions between each group and time period, and Scheffe’s method was used for the post-test. In the case of main effects or interactions between groups and time periods, one-way ANOVA was performed to determine the differences in each group and time period, and the post-test was completed by using Scheffe’s method. The statistical significance level was set to α = .05.

3. Results and Discussion

A total of 45 participants were in the experiment, with 15 persons each assigned to VG, MG, and CG. However, due to discharge times and health problems, 2 were eliminated from VG, 1 from MG, and 2 from CG. In the results, a total of 5 people were eliminated, and the number of final subjects was 40. Their general body characteristics and MMSE-K scores are shown below in Table 3.

Table 3. The general characteristics of the subjects (N=40)

	VG (n=13)	MG (n=14)	CG (n=13)	*P*
	Mean ± SD	Mean ± SD	Mean ± SD	
Age (years)	64.54 ± 7.11	66.57 ± 8.59	65.62 ± 7.77	.631
Height (cm)	164.23 ± 7.94	164.64 ± 8.09	164.46 ± 7.59	.959
Weight (kg)	63.08 ± 9.27	62.71 ± 9.03	64.62 ± 8.44	.816
Onset (month)	25.54 ± 9.22	27.29 ± 6.18	25.23 ± 7.35	.238
MMSE-K (scores)	27.69 ± 2.36	26.93 ± 1.77	27.38 ± 2.66	.513
Sex (Male/Female)	6/7	8/6	8/5	.718
Stroke type (Infarct/Hemorrhage)	9/4	10/4	8/5	.849
Affected side (Left/Right)	7/6	5/9	5/8	.596

SD: Standard deviation, *: $p < .05$

3.1. *Balance assessment*

The changes in gait time(GT) for VG, MG, and CG over 12 weeks are shown in Table 4. The statistical analysis did not reveal the interaction between groups and time periods, but the main effect was the time period. In the virtual reality pelvic exercise group, there was a significant decrease in gait time after 12 weeks compared to before intervention, and no significant difference was observed between groups with respect to time periods.

The change in gait speed(GS) for VG, MG, and CG over 12 weeks are shown in Table 4. The statistical analysis did not reveal the interaction between groups and time period, but main effects were found in groups and time periods. In the virtual reality pelvic exercise group, significant increases were made after 12 weeks compared to before intervention, and no significant difference was observed between groups with respect to time periods.

The changes in step length(SL) for VG, MG, and CG over 12 weeks are shown in Table 4. The analysis did not produce statistically significant differences for any of the variables.

The changes in cadence(Cad) for VG, MG, and CG over 12 weeks are shown in Table 4. The statistical analysis did not reveal an interaction between groups and time periods, but main effects were found in groups and time periods. In the virtual reality pelvic exercise group, cadence increased significantly after 6 weeks and 12 weeks compared to before intervention. In the pelvic exercise group using mirrors, the cadence increased significantly 12 weeks later compared to before intervention.

Table 4. The statistical analysis and comparison of GT, GS, SL, Cad in each group

		0w	6w	12w		F	*P*	Post-hoc
		Mean ± SD	Mean ± SD	Mean ± SD				
GT (sec)	VG	29.68 ± 4.39	26.60 ± 4.82†	24.21 ± 4.76‡	Group	2.657	.075	
	MG	30.42 ± 4.98	28.46 ± 4.86	27.17 ± 5.03	Time	5.067	.008*	0w>6w,12w
	CG	30.12 ± 5.03	29.24 ± 5.11	28.44 ± 4.93	Group*time	.503	.733	
GS (m/s)	VG	.34 ± .05	.39 ± .07†	0.43 ± .09‡	Group	3.163	.046*	
	MG	.34 ± .07	.36 ± .05	0.38 ± .07	Time	5.784	.004*	0w<6w,12w
	CG	.34 ± .05	0.35 ± .07	0.36 ± .06	Group*time	.808	.522	
SL (m)	VG	.33 ± .05	.36 ± .06	0.38 ± .07	Group	.685	.506	
	MG	.33 ± .05	.34 ± .05	0.35 ± .06	Time	2.382	.097	
	CG	.33 ± .06	.34 ± .06	0.34 ± .06	Group*time	.508	.730	
Cad (step /min)	VG	63.50 ± 1.46	65.42 ± 1.93†	67.98 ± 2.19ac‡‡	Group	13.324	.000*	VG>MG,CG
	MG	60.92 ± 3.22	62.86 ± 3.11†	64.47 ± 3.30a‡	Time	12.974	.000*	0w<6w<12w
	CG	61.67 ± 3.04	62.66 ± 3.42	63.61 ± 3.68	Group*time	.657	.623	

*: *p* < .05; Post hoc test (Time): 0w, 6w=†, 6w, 12w=††, 0w, 12w=‡, 0w, 6w, 12w=‡‡; Post hoc test (Group): VG, MG=a, MG, CG=b, VG, CG=c, VG, MG, CG =d; 0w: Pre-test, 6w: Post-6 weeks, 12w: Post-12 weeks

3.2. *Quality of life assessment*

The changes in SS-QOL for VG, MG, and CG over 12 weeks is shown in Table 5. Statistical analysis showed no interaction between groups and time periods, and no main effects for either groups or time periods. In the virtual reality pelvic exercise group, significant increases were made over 12 weeks compared to before the intervention, and no significant difference observed between groups with respect to time periods.

Table 4. The statistical analysis and comparison of SS-QoL in each group

		0w	6w	12w		F	*P*	Post-hoc
		Mean ± SD	Mean ± SD	Mean ± SD				
SS-QoL (score)	VG	149.23 ± 17.06	160.77 ± 12.66†	164.54 ± 13.00‡	Group	1.971	.144	
	MG	150.93 ± 17.39	155.21 ± 17.21	157.36 ± 15.69	Time	3.006	.054	
	CG	150.46 ±	151.92 ±	152.23 ± 12.88	Group*time	.766	.549	

	12.72	12.76

*: $p < .05$; Post hoc test (Time): 0w, 6w=†, 6w, 12w=††, 0w, 12w=‡, 0w, 6w, 12w=‡‡; Post hoc test (Group): VG, MG=a, MG, CG=b, VG, CG=c, VG, MG, CG =d; 0w: Pre-test, 6w: Post-6 weeks, 12w: Post-12 weeks

The purpose of this research was to compare changes after 6 weeks and 12 weeks among 40 patients diagnosed with stroke, 13 of whom performed virtual reality pelvic exercise, 14 using mirrors, and 13 without virtual reality or mirrors.

To determine the changes in gait, we measured gait time, gait speed, cadence, and the length of each step using iSEN. Looking at the changes in gait time, the main effect was shown in the time period, and gait time significantly decreased 12 weeks after the start of the intervention in the VG. Considering the changes in gait speed, the main effects were seen in groups and time periods. In the VG, there was a significant increase in gait time after 12 weeks compared to before intervention.

With respect to changes in the step length, increases were observed for all groups in the average stride in technical statistics over time. In terms of changes in the cadence, the main effects occurred in groups and time periods, and in the VG, there was a significant increase after 6 weeks and 12 weeks compared to before intervention, and in the MG, there was a significant increase after 12 weeks compared to before intervention. The differences between groups with respect to different periods showed that the group1 exhibited more significant increases than MG and CG after 6 weeks and 12 weeks. These results were consistent with the results of a previous study that reported increased gait ability by applying an augmented reality-based postural control training with stroke patients [25]. Yom et al [26] reported that virtual reality-based ankle exercise is effective for muscle tone, dynamic balance and walking ability in stroke patients. Based on these previous studies, virtual reality pelvic exercise in this study is believed to have a positive effect on the gait time, gait speed, length, and cadence of stroke patients as asymmetrical pelvic position and control were changed symmetrically by improving movement of the pelvis. These findings are consistent with the results of a preceding study demonstrating that feedback mechanism by proprioception and vision could facilitate the reorganization of the neural circuitry of the cerebral surface [27], and that weight shifting to the affected side increased as a result [10].

Using the SS-QOL to measure changes in the quality of life, interactions between groups and time periods did not appear, and main effects in groups and time periods also did not appear. In the virtual reality pelvic exercise group, significant improvements were found 12 weeks later compared to before the intervention, and no significant differences were observed between the groups according to time period. This was consistent with the results of previous studies that showed that virtual reality-based planar motion exercises had a positive effect on improving the quality of life of stroke patients [28]. This was also consistent with the results of another previous study showing that when virtual reality using Nintendo Wii was applied in the rehabilitation of subacute stroke patients, there was an improvement in quality of life, but there was no significant difference from the control groups in this respect [29]. As with the results of this study and the results of the previous studies, it is believed that the quality of life in a group is improved because the interventions applied to the subjects have a positive effect on physical improvements. However, the absence of differences between groups suggests that changes in environmental factors, such as individual economic circumstances, mental health, and social relationships, should be accompanied by changes in the quality of life in order to lead to more efficient quality of life improvements; this is in line with the findings of previous studies, which have reported that the observation of performance techniques to identify tasks, goals, and activities within a wide range of circumstances is required for improving the quality of life of stroke patients [30]. It has also been reported that the measurement of quality of life in clinical practice should be evaluated in the overall environment in which patients live, and not by focusing on the disease [31].

4. Conclusion

The aim of this research was investigate the effects on the gait, quality of life of virtual reality pelvic exercise, pelvic exercise using mirrors, and conventional pelvic exercise without mirrors after 12 weeks for patients diagnosed with stroke. The results showed that all groups that performed 12 weeks of virtual reality exercises, mirror-based pelvic exercises, and conventional pelvic exercises showed increases in pelvic mobility, thereby improving their ability to walk and thus improving quality of life. In particular, virtual reality pelvic exercise was found to have greater effects on these variables than pelvic exercise using mirrors and conventional pelvic exercise. Therefore, virtual reality pelvic exercise is believed to be an effective intervention approach that can help stroke patients walk and generally improve their quality of life.

5. Acknowledgements

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6. References

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