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Original Research

The Effect of Virtual Reality Game Training on Improving Walking Speed and Dynamic Balance Function After Stroke

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Abstract

Background: Stroke is a serious health condition that can cause physical and cognitive impairment, affecting a person's ability to perform daily activities. Important factor that affect the quality of life of stroke patients is the ability to mobilize, especially walking. Virtual Reality is expected to increase walking speed and dynamic balance which are important to improve patient mobility and independence.

Aim(s): Analyze the effect of Virtual Reality (VR) game training using Xbox 360° and Kinect™ devices on post-stroke walking speed and balance

Material and methods: An experimental study involving 18 ischemic post-stroke patients at the Rehabilitation Installation of Prof. Dr. R. D. Kandou Hospital Manado (from June to July 2023). The intervention was a 30 minutes VR game exercises with three sessions per week (a total of 8 sessions for each subject). This subject was assessed using the 10-meter Walk Test (10 MWT) and the Berg Balance Scale (BBS).

Result: There were significant improvements in both walking speed and dynamic balance. Wilcoxon Signed Ranks test results on Walking Speed (10 MWT) obtained a value of Z = -3,754 with a value of ($p = 0.000 < 0.05$). Similar results were obtained in testing the dynamic balance function where the paired t test results were obtained at $t = -14.750$. The results indicate significant differences in the mean value of Subacute Post-Stroke BBS before and after training ($p < 0.05$).

Conclusions: Virtual Reality (VR) game training using Xbox 360° and Kinect™ devices significantly increased walking speed and balance in post-stroke patients.

Keywords: *balance, gait, ischemic stroke, rehabilitation, virtual reality, walk test*

INTRODUCTION

The significant impact of stroke on walking ability and independence impacts on the quality of life of sufferers. Disability due to stroke can affect daily activities, undermine self-confidence and increase the risk of social isolation. In addition, stroke-induced disability can also burden families and damage their quality of life.[1,2]

Restoring walking ability is the most common goal expected by haemiparesis patients in stroke rehabilitation. Walking ability largely determines the expected level of activities of daily living (ADLs). However, mobilisation within the home and community presents its own challenges to the walking ability of stroke patients as such independence requires safe mobilisation.[3] Walking speed is a simple yet highly reliable and responsive and an important predictor of walking ability in the continuum from restricted household ambulation to unrestricted community ambulation. Walking speed is strongly correlated with other parameters, such as dynamic balance, walker use, and fall risk as well as AKS function in the elderly.[3] Medical rehabilitation in post-stroke patients is best done in the sub-acute phase, which is a period of 2 weeks to 6 months from onset, so this phase is the best time to conduct a study to assess the effect of a modality on improving the function of post-stroke patients.[3]

Virtual reality (VR) adapted for patients with functional neurological disorders can increase patients' motivation, confidence, and adherence to these interventions as it provides pleasure in sensorimotor and cognitive exercises and improves motor control.[4,5]

Lee et al [7] stated that post-stroke patients who were given VR balance training for 30 minutes per session on a three times weekly schedule showed that the intervention was more feasible and appropriate for improving post-stroke dynamic balance compared to Task Oriented Training. Impaired mobilisation in this case walking is a disability that greatly affects the quality of life of post-stroke patients. It is expected that the intervention of Virtual Reality game exercises can increase walking speed and dynamic balance which has an impact on improving post-stroke mobilisation function.

MATERIAL AND METHODS

Eighteen ischemic stroke patients participated in this study. This study was approved by the ethical committee, and all participants provided written informed consent. The inclusion criterias were : (1) first ischemic stroke attack, (2) female or male aged 45 years old up to 60 years old when diagnosed with ischemic stroke, (3) montreal cognitive assessment (MoCA-Ina) score ≥ 18, (4) modified rankin scale score between 0 and 3, (5) Berg Balance Scale score ≤ 40, (6) Body mass index (BMI) 18.5 to 24.9, (7) Normal or corrected vision function, (8) Normal hearing function tested by whisper test, (9) Agreeing to take part in the study until completion and signing informed consent. The exclusion criterias are : (1) Neuro-musculoskeletal disorders that affect the intervention such as pain, fracture, sprain, strain, infection, and malignancy, (2) Cardiovascular related contraindications for exercises, (3) History of photosensitive epilepsy, (4) Modified Ashworth Scale (MAS) score > 2 on extremities. The majority of the sample belonged to the age group 55 - 59 years (n=9), mostly male (n=12), and married (n=16). The majority of sample had occupation as housewife (n=6). Data on the characteristics of the research subjects displayed in Table 1, 2, 3 and 4. The eighteen samples exercised for 30 minutes three times per week for 4 weeks until each of them achieved 8 sessions in total. Training is done by providing 4 types of games namely Run the World, Wallbreaker, Kinect Sports: Table Tennis, and Rallyball that have been scheduled by researchers where all these games are run using an Xbox 360 device and Kinect™ sensor with a 43-inch TV display (Figure 1). Each game started with an introduction to the games and a trial run to familiarize and understand the rules of the VR game. Each game exercise will start with the easiest level of difficulty and increase based on the subject's exercise tolerance assessed by the Borg Rate of Perceived Exertion (RPE) scale and clinical symptoms. The subject will undergo a general status examination and an assessment of the Borg RPE scale which will then be repeated after the game training session.

Measurement of the walking speed variable was carried out initially before and after eight sessions of game exercise by assessing the 10 meter walk test (10 MWT) in which the subject was asked to walk along 10 meters (may be with an assistive device), with the time measured starting from the 2 meter mark and ending when the foot passed the 8 meter mark. The test was performed 3 times and the average was calculated as the measurement result.

Figure 1. Subject is playing Kinect Sports, Table Tennis

Measurement of the dynamic balance variable was carried out initially before and after eight sessions of game exercise by assessing the Berg Balance Scale (BBS).

It is a 14-item list with each item consisting of a five-point ordinal scale ranging from 0 to 4, with 0 indicating the lowest level of function and 4 the highest level of function and takes approximately 20 minutes to complete. Studies of various elderly populations (N = 31–101, 60–90 + years of age) have shown high intrarater and interrater reliability (ICC =.98,14,15 ratio of variability among subjects to total = .96–1.0,16 rs =.8817). Test-retest reliability in 22 people with hemiparesis is also high (ICC [2,1]=.98).[8]

Table 1. Distribution of Subject by Age

Age (Years)	Frequency	
	(n)	%
40 – 44	2	11,1
45 – 49	4	22,2
50 – 54	3	16,7
55 – 59	9	50,0
Total	18	100.0

Table 2. Distribution of Subject by Gender

Gender	Frequency	
	(n)	%
Male	12	66,7
Female	6	33,3
Total	18	100

RESULT

Based on data analysis using the help of the SPSS Version 26 program, the statistical data of 10 MWT before and after VR game exercises using Xbox 360° and Kinect^{TM} devices are presented in Table 5. Because the sample size (n) = 18 < 20, data normality testing was carried out with the Shapiro-Wilk Test. The test results are presented in the appendix and state that the 10 MWT data are not normally distributed ($p < 0.05$). Therefore, the difference between the data of 10 MWT before and after VR game exercise was tested with Wilcoxon Signed Ranks Test. The median value of the data of 10 MWT after VR game exercise is higher than that of initial 10 MWT before intervention.

Table 3. Distribution of Subject by Occupation

Occupation	Frequency (n)	%
Teacher	1	5.6
Housewives	6	33.3
Employee	2	11.1
Enterpreneur	1	5.6
Farmer	2	11.1
Private company	3	16.7
Unemployed	2	11.1
Soldier	1	5.6
Total	**18**	**100.0**

Table 4. Distribution of Subject by Marital

Marriage Status	Frequency (n)	%
Widower	1	5.6
Widow	1	5.6
Married	16	88.9
Total	**18**	**100.0**

Table 5. Statistical Results of 10 MWT Data Before and After VR Game Exercise and Wilcoxon Signed Ranks Test Results

Statistics	Before VR exercise (m/sec)	After VR exercise (m/sec)	Test Results
n	18	18	
Minimum	0,16	0,24	
Maximum	0,38	0,52	Z = -3,754
Median	0,2900	0,4000	(p = 0,000 < 0,05)
Mean	0,2800	0,3889	
Standard Deviation	0,06287	0,07676	

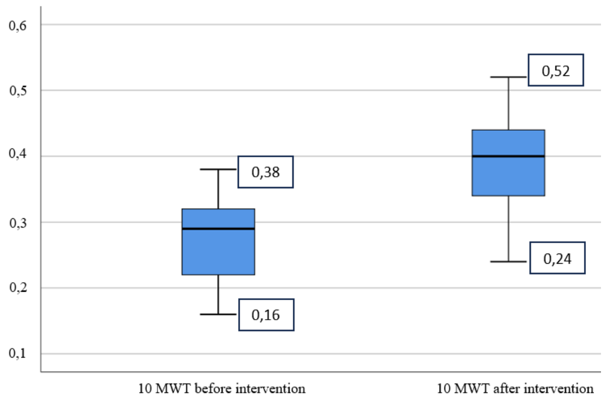

Figure 2. Data Distribution of 10 MWT before and after VR game exercise

Table 6. Statistical Results of BBS Data Before and After VR Game Exercise and Wilcoxon Signed Ranks Test Results

Statistics	Before VR exercise	After VR exercise	Test Results
n	18	18	
Minimum	14,00	24,00	
Maximum	28,00	46,00	t = -14,750
Median	18,0000	34,0000	(p = 0,000 < 0,05)
Mean	18,7778	34,7778	
Standard Deviation	3,88898	6,44940	

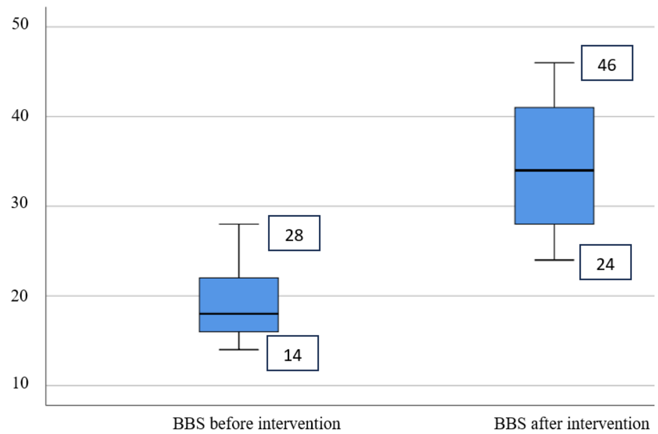

Figure 3. Data distribution of BBS before and after VR game exercise

Table 7. Outcome measurement data (walking speed and Berg Balance Scale) before and

No	Subject	Infarction Lesion Site	Onset (weeks)	Walking speed (meter/second)		Berg Balance Scale	
				Pre	Post	Pre	Post
1	Subject 1	Left internal capsule	9	0,3	0,42	24	42
2	Subject 2	Left internal capsule, right thalamus, and bilateral corona radiata	8	0,32	0,4	22	39
3	Subject 3	Left internal capsule	5	0,34	0,46	28	44
4	Subject 4	Left frontal lobe	5	0,16	0,24	16	28
5	Subject 5	Left internal capsule and parietal lobe	20	0,28	0,52	18	46
6	Subject 6	Bilateral basal ganglia	18	0,34	0,5	18	41
7	Subject 7	Left basal ganglia	14	0,2	0,32	14	28
8	Subject 8	Right basal ganglia and left pons	20	0,22	0,3	14	30
9	Subject 9	Right basal ganglia	16	0,32	0,38	18	34
10	Subject 10	Pons	10	0,32	0,44	18	34
11	Subject 11	Right corona radiata	12	0,38	0,48	20	36
12	Subject 12	Left corona radiata	12	0,22	0,34	16	28
13	Subject 13	Right internal capsule	7	0,18	0,28	14	24
14	Subject 14	Right basal ganglia	11	0,28	0,34	18	28
15	Subject 15	Right ganglia basalis and parietal lobe	7	0,24	0,36	16	32
16	Subject 16	Left basal ganglia	7	0,28	0,4	18	36
17	Subject 17	Right corona radiata	7	0,32	0,42	22	42
18	Subject 18	Right internal capsule	10	0,34	0,4	24	34

The results in Table 6 show that the mean value of the BBS data after VR game exercise intervention is higher than those before intervention. The results of this test indicate that there is a significant difference in the mean value of BBS data before and after the intervention ($p<0.05$). Graphically, the difference in data distribution of BBS Data before and after VR game exercises using Xbox 360° and Kinect™ devices, can be seen in Figure 3. In addition to the distribution of patients based on their demographics, we also included our subjects data based on onset, infarct lesion location, and outcomes respectively in Table 7.

DISCUSSION

The distribution of subjects according to gender where most of the samples were male, namely 12 people or 66.6%. This is in line with the stroke incidence rate by gender in the 2018 Riskesdas, which was 52% in men and 48% in women.[9] Recent studies have reported that women have a higher or similar stroke incidence rate compared to men in younger age strata. Thereafter, in middle age, men show higher stroke incidence rates than women. The difference in stroke incidence rates between men and women decreases with the increasing incidence of stroke in postmenopausal women, and finally, the incidence of stroke in women is close to or even higher than that of men in the eighth decade.[10] The distribution of study subjects according to occupation where most of the study sample occupations were housewives. Apart from the sample characteristics, it turns out that several studies have also found a fairly high prevalence of stroke in the housewife group. Housewives are currently developing a sedentary lifestyle that leads to a lack of physical activity. The duties of housewives are said to discourage them from participating in recommended physical activities due to household assignments. This puts them at greater risk of developing a condition as a result of long-term physical inactivity, such as cerebrovascular disease, cardiovascular disease, and metabolic syndrome.[11] In addition, the female sample in this study was over 45 years old where most women have entered the perimenapause or premenopausal period. The reason for the higher risk profile at premenopause and menopause is not fully understood but is likely influenced by endogenous sex steroid hormones, especially estradiol.[12]

Distribution of the study sample based on marital status where it was dominated by married samples with partners who always accompanied the samples during the study while for samples who were widowed or widowed, their children always drove and accompanied them. This is important because the intervention will not take place well without the cooperation and role of family members in supporting the rehabilitation process. Visser-Meily et al[13] that the rehabilitation process of stroke patients can be improved by paying attention to the role of spouses and family dynamics during the initial rehabilitation process and in long-term care.

Motor and sensitive deficits are common in stroke patients, leading to impaired motor control, balance and gait. In the subacute phase, changes in body alignment occur, which require the incorporation of treatment strategies focused on improving postural control and symmetrical weight bearing. Postural control is one of the important functions to perform daily life activities. The existence of postural control disorders after stroke is mainly caused by static and dynamic balance disorders which can be a consequence of disruption of somatosensory afferent input to the central nervous system, the process of interpreting afferent input in the central nervous system, coordination between balance components namely visual, vestibular, and proprioception, muscle tone and/or strength and voluntary muscle coordination. Therefore, Xbox 360 game exercises with the Kinect™ sensor need to be designed to allow for specific combinations of body movements, weight transfer and changes in direction. The games selected aim to stimulate the various motor and sensory components used to improve balance. To maintain patient safety, the medical rehabilitator is allowed to modify the scheduled sessions to suit the capacity of the participants.[6]

Room setup is also very important to ensure that the Xbox 360 device and Kinect™ sensor can work optimally in providing a good and safe game practice experience : (1) Free the area between the sensor and the player, (2) One-player setup: stand about 1.4 meters away from the sensor, (3) Two-player setup: stand about 1.8 meters away from the sensor, (4) Ensure that the room is adequately and evenly lit, (5) Keep the Kinect™ sensor out of direct sunlight or within 0.3 meters from loudspeakers, (6) Place the Kinect™ sensor as close as possible to the edge of a flat and stable surface, (7) Position the KinectTM sensor between 0.6 meters and 1.8 meters from the floor, and (8) Do not place the sensor directly above the Xbox console.[7]

Virtual reality systems facilitate the emergence of movement as well as interaction and simulation of human movement, through the performance of varied and progressive functional activities, with high levels of repetition and intensity, providing real time multisensory feedback during task-oriented training and facilitating motor learning. The main basis for the use of video games is their ability to produce plastic reorganization of the central nervous system, through the activation of adaptive neuroplasticity mechanisms.[14]

Stein et al[15] stated that balance therapy can be categorized into five main areas, namely exercise programs, biofeedback training, sensory training, cognitive training, and external devices. In this study, researchers used Xbox 360 and Kinect™ devices which are included in the areas of exercise programs, cognitive training, and slightly incorporate sensory training. This can be explained where in the aspect of the exercise program, a series of structured and scheduled games have been arranged which will require patients to perform activities such as walking in place, stepping in various directions, reaching, kicking, and bending. These activities require somatosensory input, afferent processing and interpretation in the central nervous system, coordination of balance components, and coordination of voluntary muscles so that they are suitable for training static and dynamic balance in subacute poststroke to improve good postural control. Game training with Xbox 360 and Kinect™ also trains cognitive function as it requires the ability to understand game rules, analyze game situations, and respond to situations with an action according to game rules. A slight sensory training effect is also provided through the use of a textured mat, which provides tactile stimulation on the surface of the soles of the feet to increase somatosensory input and reduce the incidence of falls during training.

The mean walking speed after stroke varies from 0.4 to 0.8 m/s. Walking speeds of less than 0.4 m/s define household ambulation; speeds between 0.4 and 0.8 m/s define limited community ambulation; and speeds greater than 0.8 m/s define full community ambulation.[16] This study shows that the median walking speed after VR training is 0.4 m/s, so it can be concluded that most subjects will be able to perform community ambulation.

Slower gait speed is associated with a higher risk of balance loss, and dynamic balance measures can better predict falls than gait speed or static balance measures.[17,18] This suggests that maintaining dynamic balance is important for maintaining gait speed.

Among stroke survivors, both cadence and walking speed were found to be associated with dynamic balance, and dynamic balance has been associated with gait.[19] This suggests that dynamic balance is a key factor in maintaining gait speed in stroke survivors. Therefore, the improvement of walking speed here is related to the improvement of dynamic balance in the subject so that this will also improve the functional ability to perform daily activities. Dynamic balance during walking deteriorates due to aging in multiple physiological systems, such as muscular and sensory, and this deterioration is correlated with gait parameters such as step width and margin of stability.[20] This suggests that maintaining dynamic balance is important for maintaining gait speed as we age.

This study, which uses semi-immersive Virtual Reality devices in the form of Xbox 360 and Kinect™ to provide balance training for subacute ischemic stroke patients, is the first study conducted at Prof. Dr. R. D Kandou Manado Hospital. Similar studies are often conducted in foreign institutions and some in the country, but not many have done so by considering the cost efficiency and benefits that can be obtained by patients. The use of Virtual Reality game exercises also proved to be quite popular with patients and can increase adherence to exercise where this kind of structured, repetitive, and feedback exercise modality is effective for achieving post-stroke rehabilitation targets. During this study, none of the subjects experienced any side effects or complications of therapy.

The limitation of this study include the lack of safety means in order to prevent injury if the patient falls where the researcher only provides a mat on the exercise area to improve proprioception perception on the soles of the feet and so that the surface of the exercise area is not slippery. Another shortcoming is that it is not specific to determine the clinical characteristics of ischemic stroke to be studied, for example with the Bamford classification where the lacunar subtype will certainly have a better prognosis than other subtypes. This study did not apply a comparison with a control group that received conventional therapy, so the effectiveness of the intervention in this study cannot be compared with other rehabilitation modalities. Also since this is a pre & post test study design, a larger study with controls is needed to avoid bias as to whether the improvement effect is due to spontaneous recovery or intervention or both.

Our suggestions include virtual reality game exercise therapy can be included in one of the supplementary therapies to improve the balance of subacute ischemic post-stroke at the Medical Rehabilitation Installation of Prof. Dr. R. D Kandou Hospital Manado. Future research with similar topics can use a control group that undergoes conventional therapy so that its effect can be compared with Virtual Reality game exercise therapy. At last, further research using exercise modalities with semi-immersive Virtual Reality devices can increase patient safety by providing handle bars or mats that line the walls and floor surfaces of the research area.

CONCLUSION

Virtual Reality game exercises using Xbox 360 devices and Kinect™ sensors as supplementary therapy along with conventional therapy proved effective for improving walking speed and dynamic balance of subacute ischemic stroke survivors with the provision of therapy for 8 sessions. Virtual Reality game exercises also increased individual compliance with medical rehabilitation programs due to the effect of fun and being able to increase self-confidence.

DISCLOSURES

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Conflict of interest

None to declare

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Author Contribution

The authors confirm contribution to the research as follows: study conception and design: Christopher Lampah; data collection: Christopher Lampah, Brain Anggana, Jonathan Prayogi Suyono, and Alfred Setiono; analysis and interpretation of results: Siemona L. E Berhimpon; draft manuscript preparation: Meilany Feronika Durry. All authors reviewed the results and approved the final version of the manuscript.

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