The Effectiveness of Virtual Reality Training for Post-stroke Balance: A Literature Review

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Abstract. Virtual reality Training (VRT) is a technology that allows a user to interact in a virtual world that appears real to the user. According to some studies, VRT improves the balance of chronic and acute stroke patients. According to other studies, VRT is only effective in patients with chronic post-stroke after six months. As a result, the goal of this study was to determine the efficacy of virtual reality training in post-stroke patients. From 2012 and 2022, relevant English-language study strategies such as " virtual reality training," "balance," and "stroke" were available through databases such as ScienceDirect, PEDro, and PubMed. The inclusion criteria for this review were an article with an RCT method used to study stroke patients in both acute and chronic phases in this review. The study was analyzed using a PICO (population or problem, intervention, comparison, outcome) framework, which was developed as a key component in the review process. A total of 7 articles met the criteria, with a PEDro score of 6 on average. VRT for intervention revealed a significant improvement in balance as measured by the Berg Balance Scale (BBS), Timed Up and Go Test (TUGT), and Balance with Tinetti's POMA (Performance Oriented Mobility) with $P < 0.001$ when comparing before and after treatment. This review provides evidence of the effectiveness of post-stroke patient interventions for balance during the chronic phase.

Keywords: Virtual Reality Training · Balance · Stroke

1 Introduction

According to the World Health Organization (WHO), in 2017 cerebrovascular disease including stroke is the cause of many deaths every year compared to other causes in the world [1]. In 2010, the global prevalence was estimated to be 33 million [2]. The brain is a highly adaptable organ. Recent findings have shown that brain development and nerve cell changes are not limited to childhood, as previously thought. Although dead neurons do not regenerate, the human brain's adaptive capacity or plasticity is remarkable, especially in young people [3]. The clinical stages of stroke are classified according to when they occur. The majority of the changes in the chronic phase occur between 12 and 24 weeks, which is the initial chronic phase. The main issues that post-stroke patients face in the chronic phase are impaired balance and posture control, which leads to increased falls and instability when walking [4].

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Stroke patients typically have motor control deficits, which contribute to decreased balance, postural control, mobility, and proprioception [5]. Because balance is influenced by postural control [6].

The COVID-19 pandemic is a new challenge that has never happened before in the health sector, especially in the field of physiotherapy. At present, a new habit pattern has been implemented where controlling the transmission of the virus requires social distancing restrictions. So there is a need for innovation in long-distance communication technology to overcome this problem [6].

Virtual reality training (VRT) can help with postural and balance issues. VRT is a technology that allows users to interact in a virtual world that appears real to the user. Unlike traditional interfaces, virtual reality places the user in a 3D world by stimulating as many senses as possible, including sight, hearing, touch, and even the sense of smell. A balance exercise using VRT can improve balance and develop fine gross motor functions and coordination is a breakthrough that can be developed [8].

Within six months, the authors indicated that VRT is effective in post-chronic stroke patients. This is demonstrated by the availability of EEG and EMG-based VRT, $p = 0.04$), for the resting state ($r = 0.83$, $p = 0.17$), and alpha hemispheric asymmetry ($r = 0.82$, $p = 0.18$). The EEG correlation results were insignificant. In the meantime, EMG activation revealed a significant difference in signal amplitude 2 (3) = 2044.43, $P < 0.001$, and resting state amplitude 2 (3) = 1711.63, $P < 0.001$ These findings imply that patients with balance disorders can be measured to be effective with EMG activation. As a result, this EMG-based VRT platform is suitable for people with chronic phase strokes [9].

A meta-analysis of randomized controlled trials provides clinical evidence of the effectiveness of video game-based VRT aimed at improving functional balance in post-stroke individuals within two weeks. This intervention gives the result that there is no increase in balance in subacute patients because patients still need physiotherapeutic supervision [10]. Therefore, the purpose of this study was to determine the effectiveness VRT for balance in post-stroke patients.

2 Methods

This type of research is a literature review, which begins by analyzing relevant articles on the topic/discussion being reviewed.

2.1 Identification and Selection of Trials

Search scientific articles published between 2012 and 2022. The searchable databases were PubMed, ScienceDirect, and PEDro. The retrieved article references were manually checked for further study as needed. The terms “virtual reality training,” balance,” and “stroke” were used to search the database. The authors screened titles and abstracts and then assessed the titles and abstracts according to the inclusion criteria.

2.2 Inclusion and Exclusion Criteria

The study that will be included is reviewed first, by determining the inclusion criteria and exclusion criteria. The following inclusion criteria were used: (1). Journals are published in English, (2). A Randomized Controlled Trial (RCT)'s a study that compares pre and post-intervention, (3). Adult stroke patients in both the acute and chronic phases, (4). Analyzing all types of virtual reality training therapy for balance improvement. The study is not used if there are exclusion criteria such as: (1). Type of study conference abstract, case report, dissertation or, article review, (2). Stroke sufferers with balance problems.

The database scale (PEDro) is used to assess the quality of the results of study methods that meet the inclusion criteria.

Quality rating scale with 11 items. The following categories are used to rate studies from very good to poor: A score of 9–10 is considered very good, a score of 6–8 is considered good, a score of 4–5 is considered fair, and a score of less than 4 is considered bad. The author assessed the quality of PEDro scale independently.

3 Results

3.1 Article Search Results

Based on the results of a literature search through 3 databases, namely PubMed, ScienceDirect, and PEDro using customized keywords. Researchers get a total of 434 articles that match these keywords. Then after checking using the Mendeley application, there were 49 duplicate articles, so the articles were excluded and the remaining 385 articles. Then the researcher conducted a screening based on the title and abstract ($n = 28$) and full text ($n = 7$) whose topics match the criteria and objectives of the literature study. Figure 1 Survey Strategy Flow.

3.2 Characteristics of Included Trials

3.2.1 Participants

All studies included both male and female participants. Study participants ranged in age from 50 to 69 years. The median time to intervention was around 3 years after the stroke. Seven trials included participants in the chronic post- stroke phase, and two trials included participants in the acute post-stroke phase [13].

3.2.2 Interventions

Two research trials with virtual reality games based on interactive rehabilitation exercises (IREX). Three trials used virtual reality treadmills, while three others used commercial game systems such as Nintendo WiiSport and WiiFit. VR programs range in length from 20 min per session [11–14].

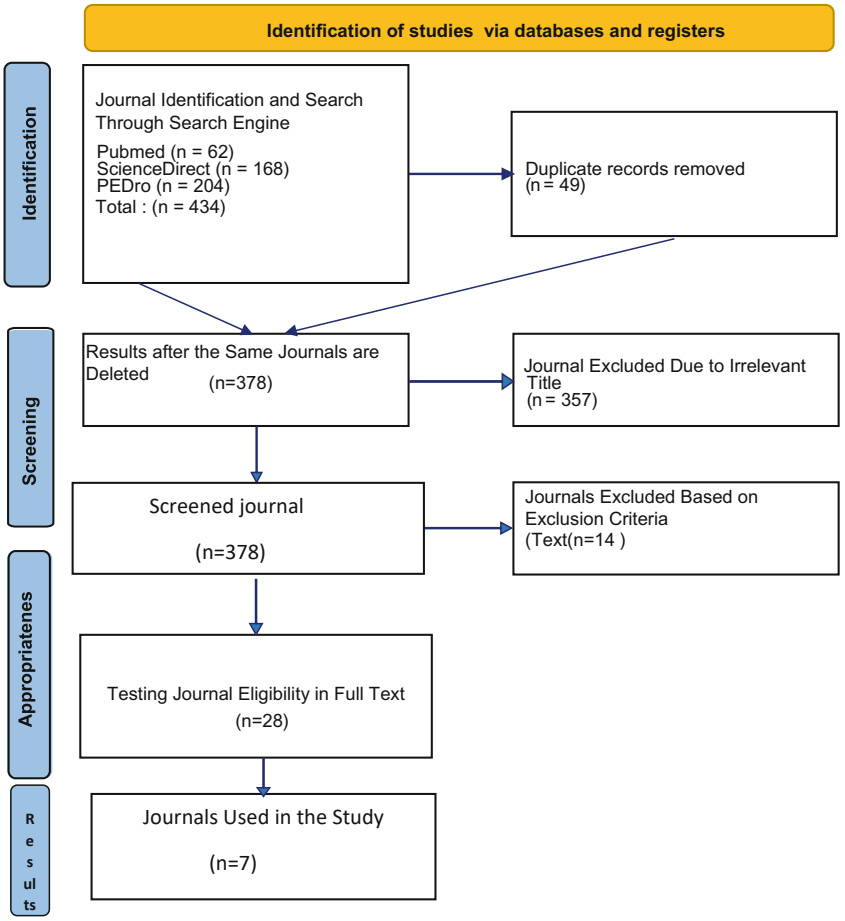

Fig. 1. Survey Strategy Flow

3.2.3 Control Group

Five studies used the same intervention dose in the experimental and control groups. Another study stated that the control group received no intervention. Three research studies compared treadmill-based VRT balance training [15].

3.2.4 Outcome Measurements

All research studies recorded initial and post-intervention results. Seven research studies used TUGT and BBS. Five research studies used power platforms such as the Chedoke-McMaster Stroke Rating scale, foot domain, and gait temporospatial parameters to evaluate the balance of chronic and subacute post-stroke patients. All studies showed significant improvement in balanced outcomes [16].

3.2.5 Articles Included in the Review

Following the screening process, articles are reviewed using the PICO method as a framework in the review process to determine whether the article is suitable for use as a research basis. The PICO standard has four points, which are as follows: (population, intervention, comparison, and outcome). Subjects who will participate in the study; intervention, specifically the treatment given to patients; In the article, a comparison or comparison affects the intervention group. The achievement or study result in a study related to the treatment given to research subjects is referred to as the outcome.

The article's subject population is stroke patients, and the intervention is some exercises to improve function, particularly in the area of balance, in stroke patients. The outcome is the result of measuring the progress of functional improvement or reduction, particularly the patient's balance.

3.3 Study Results

AUTHOR (YEAR)	**STUDY DESIGN**	**POPULATION**	**INTERVENTION**	RESULTS	**OUTCOMES**
Taesung In and Kyeonglin Lee (2012)	RCT (Randomized Controlled Trial)	n = 22 **Experimental Group**: n = 11 Gender = 5 males, 6 females age(years) = 65,26 Time since stroke > 6 months **Control Group**: n = 11 Gender = 5 males, 6 females age(years) = 63,13 Time since strokes > 6 months	**Eksperimental Group**: Intervention = Nintedo Wii Fit Frequency = 6 weeks Time = 30 min/session **Control Group**: Intervention = Occupational Therapy Frequency = 6 weeks Time = 30 min/session	The independent t-test or chi-square test is used to compare group characteristics. Meanwhile, data from before and after rehabilitation were analyzed using paired t-tests and independent t-tests between groups. TUGT and BBS measurement tools in the intervention group showed significant results compared to the control group ($P < 0.05$). Postural movement speed was not statistically different between the two groups ($P < 0.05$).	Berg Balance Scale (BBS) dan Times Up and Go Test (TUG)

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AUTHOR (YEAR)	STUDY DESIGN	POPULATION	INTERVENTION	RESULTS	OUTCOMES
Yoo Soon Bang and Kyung Hyun Son (2013)	RCT (Randomized Controlled Trial)	n = 14 **Experimental Group:** n = 7 Gender = 3 males,4 females age(years) = 65,5 Time since stroke > 6 months **Control Group**: n = 7 Gender = 3 males,4 females age(years) = 63,12 Time since stroke = > 6 months	**Eksperimental Group**: Intervention = VRT-based treadmill. Frequency = 6 weeks Time = 30 min/session **Control Group**: Intervention = non-VR treadmill Frequency = 6 weeks Time = 30 min/session	Gait and balance parameters of post-stroke patients were compared using BBS in the eksperimental group and the TUGT in the control group.. BBS Measuring Instrument, the TUGT stated that it recorded significant results in the speed and balance of the experimental intervention group compared to the control group ($P < 0.05$).	BBS and TUGT
Hyung Young Lee and You Lim Kim (2013)	RCT (Randomized Controlled Trial)	n = 30 **Eksperimental Group:** n = 15 Gender = 5 males, 10 females age(years) = 62 Time since stroke = 3 years **Control Group:** n = 15 Gender = 5 males, 10 females age(years) = 61,5 Time since stroke = > 6 months	**Eksperimental Group:** Intervention = Nintedo Wii sports and Wii Fit Frequency = 5 weeks Time = 50–60 min/session **Control Group:** Intervention = Ps games Eye Toy: Play 2 and Kinetic Frequency = 5 weeks Time = 50–60 min/session	There was no statistically significant difference between the experimental and control groups ($P > 0.05$).	BBS and Gait performance 6-min walk test 3-m walk

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AUTHOR (YEAR)	STUDY DESIGN	POPULATION	INTERVENTION	RESULTS	OUTCOMES
Young Kim et al. (2014)	RCT (Randomized Controlled Trial)	n = 30 **Eksperimental Group:** n = 15 Gender = 5 males, 10 females age(years) = 65 Time since stroke > 6 months **Control Group:** n = 15 Gender = 5 males,10 females age(years) = 63,5 Time since stroke = > 6 months	**Eksperimental Group:** Intervention = VRT-based treadmill Frequency = 6 weeks Time = 30 min/session **Control Group:** Intervention = Occupational therapy and functional electrical stimulation. Frequency = 6 weeks Time = 30 min/session	Time for dynamic balance and gait of post-stroke patients in TRWVR (treadmill training based real-world video recording) control and experimental groups was compared. BBS measuring instrument showed significant results in postural movement while walking, and gait parameters in the experimental and control groups ($P < 0.05$). There was a significant increase in the experimental intervention group to control the group's postural movements during static and dynamic standing ($P > 0.05$).	BBS and TUGT, and gait temporospatial parameters
Yoo Kang et al. (2014)	RCT (Randomized Controlled Trial)	n = 59 **Eksperimental Group:** n = 30 Gender = 15 males, 15 females age(years) = 60 Time since stroke < 6 months **Control Group:** n = 29 Gender = 13 males, 16 females age(years) = 64 Time since stroke = < 6 months	**Eksperimental Group:** Intervention = IREX VR games in standing. Frequency = 3 weeks Time = 30 min/session **Control Group:** Intervention = IREX VR games in sitting Frequency = 3 weeks Time = 30 min/session	The intervention was compared between groups. The control group received a Chedoke-Mc Master intervention, whereas the experimental group received TUG. The experimental and control groups experienced a significant increase. The Chedoke-McMaster foot score was significantly higher in the experimental group than in the control group ($P < 0.05$).	TUGT and Chedoke-Mc Master Stroke Assessment scale leg domain

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AUTHOR (YEAR)	STUDY DESIGN	POPULATION	INTERVENTION	RESULTS	OUTCOMES
Roxana Steliana and Naddine (2014)	RCT (Randomized Controlled Trial)	n = 50 **Eksperimental Group:** n = 25 Gender = 10 males, 15 females age(years) = 60 Time since stroke < 6 moths **Control Group:** n = 25 Gender = 10 males, 15 females age(years) = 65 Time since stroke = < 6 months	**Ekspermental Group:** Intervention = Wii Fit Frequency = 4 weeks Time = 20 min/session **Control Group:** Intervention = balance therapy Frequency = 4 weeks Time = 20 min/session	Comparison of the balance therapy control group and the Wii Fit experimental group. Measuring instruments Bathel Index, and 10 m walk test showed significant results in the experimental group compared to the control group (P < 0.05).	BBS 10 m walking test
Nara Kim and Yuhyung Park (2015)	RCT (Randomized Controlled Trial)	n = 20 **Eksperimental Group:** n = 10 Gender = 5 males, 5 females age(years) = 57 years Time since stroke < 6 months **Control Group:** n = 10 Gender = 5 males, 5 females age(years) = 56,6 Time since stroke = < 6 months	**Eksperimental Group =:** Intervention = VR step training. Frequency = 5 weeks Time = 1 h/session **Control Group:** Intervention = Occupational Therapy. Frequency = 5 weeks Time = 1 h/session	Comparison of the control group using traditional therapy versus the experimental group using virtual-based exercises. The experimental and control groups experienced a significant increase in BBS measuring instrument and the 10 m walk test (P < 0.04). Significant increase in the experimental group against the control group.	Berg Balance Scale (BBS) Tinetti Performance Oriented Mobility Assessment BBAC 10 m walking test

4 Discussion

Research studies are very supportive the effectiveness of the VRT on static and dynamic balance in stroke patients. Five of the seven studies stated that the patient was in the chronic phase of stroke. The best score on the PEDro scale [18, 17]. Provides the strongest evidence that virtual reality balance is effective for improving dynamic and static balance in chronic stroke patients. According to Taesung In and Kyeonglin Lee [19], to improve dynamic balance, use a treadmill-based VRT program. However, in that study, virtual reality training did not appear to have any benefit in acute-phase post-stroke patients [20]. They found no statistically significant differences between the groups in terms of balance-related outcomes [21].

Fig. 2. VRT with Nintendo Wii Fit (Cho, Lee and Song, 2012), **Figure 3** VRT with Treadmill (Cho and Lee,2013), **Figure 4** VRT with IREX VRT Games in Sitting (Mcewen *et al.*, 2014), Figure **5** VRT with IREX VR Games in Standing (Mcewen *et al.*, 2014), and Figure **6** VRT with Video Based Games (Cho and Lee,2013).

Fig. 3. VRT with Treadmill (Cho and Lee,2013),

Fig. 4. VRT with IREX VRT Games in Sitting (Mcewen *et al.*, 2014),

Two research studies demonstrated balance during the acute stage [15]. In other studies stated that the dynamic balance between groups increased significantly. In other studies used different measurement tools to assess balance ability. Therefore, the effectiveness of VRT was not significant in the acute and subacute stages [23].

All study results have the same methodological flaws. None of the studies constituted the primary outcome. As a result, study results may contain a single type of error. Due to the small sample size and lack of external validity. The intensity and duration of the intervention varied greatly between studies. The number of sessions varies, ranging from 20 min to one hour[11–21] in duration.

All of these studies demonstrated the use of a variety of VRT systems, ranging from highly accessible devices to standard commercial gaming devices. Although all of them fall into the "VRT" category, there may be differences between VRT devices, thus different levels of effectiveness in balancing abilities [27] (Figs. 2, 3, 4, 5 and 6).

4.1 Quality Assessment

The PEDro scale, which contains 11 assessment items, is used to evaluate the study's quality. If the item is listed in the article, it is given the statement "Yes" and is worth 1 point; if it is not listed, it is given the statement "No" and is worth 0 points. The first item

Fig. 5. VRT with IREX VR Games in Standing (Mcewen *et al.*, 2014),

Fig. 6. VRT with Video Based Games (Cho and Lee,2013).

(eligibility criteria) was not calculated, so the maximum total score is 10. The included studies' mean PEDro score was 7.

All articles assigned participants to groups at random, reported the same group at baseline reporting point size estimates of variability, reported results of statistical comparisons between groups and reported patient prognostic indicators. Four articles reported using hidden allocation, and six articles reported using an "intention to treat" analysis. Six articles blinded raters, but no articles blinded therapists (Table 1).

Table 1. PEDro Scale

	Taesung In and Kyeonglin Lee,2012 [3]	Yoo Soon Bang and Kyung Hyun Son, 2013 [4]	Hyung Young Lee and You Lim Kim, 2013 [17]	Young Kim et al., 2014 [32]	Song et al., 2014 [31]	Roxana Steliana and Naddine, 2014 [33]	Nara Kim and Yuhyung Park, 2015 [28]
Random allocation	Y	Y	Y	Y	Y	Y	Y
Concealed allocation	N	Y	Y	Y	N	N	Y
Baseline comparability	Y	Y	N	Y	Y	N	Y
Blinded Participants	N	N	N	N	Y	N	N
Blinded Therapist	N	N	Y	N	N	N	N
Blinded Assesors	N	Y	N	Y	Y	Y	Y
Adequate Follow-Up	Y	N	Y	N	N	N	Y
No missing data or, if missing, itention to treat analysis	Y	Y	Y	Y	N	Y	Y
Between group analysis	Y	Y	Y	Y	Y	Y	Y
Point estimates and variability	Y	Y	N	Y	Y	Y	Y
Total Score	6/10	7/10	6/10	7/10	6/10	5/10	8/10

Notes*: Y = *yes;* N = *no*

5 Conclusion

All Research Studies state some significant evidence showing that VRT is effective for standard rehabilitation programs for chronic stroke patients. This is proven by the effectiveness of Board Based VRBT on the balance of chronic stroke patients within 6 months. The study was conducted randomly in the experimental and control groups.

The experimental group was given standard rehabilitation exercises (physical and occupational therapy) and VRBT, while the control group received a standard rehabilitation exercise program. BBS and TUGT are used to assess dynamic and static balance. After completing the 6-week intervention program, the group showed significant improvement in dynamic and static balance using BBS and TUGT. VRBT was more effective than the control group. The effect of VR training in acute or subacute stroke patients is less pronounced on balance. This has been proven in the effectiveness of video game-based virtual reality in acute stroke patients within 3 months. The study was conducted randomly in the experimental and control groups. Patients in the experimental group were given interventions with Wii Fit-based VR, three times a week for four weeks. Patients in the control group received a balanced exercise intervention three times per week for four weeks. 10MWT and measuring instrument BBS is used to assess dynamic and static balance. After completing the intervention program for 4 weeks, During the intervention, the patient must be under the supervision of a physiotherapist. This group has not shown an increase in the static and dynamic balance of post-stroke patients. This is because the patient has not been able to intervene independently, the patient still needs tools and full supervision from a physiotherapist.

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Authors' Contribution. All authors contributed with their respective assignments: U.B.R and R.A.N provided research ideas, and directions and verified any results, R.S carried out material development. The final results were discussed jointly by all authors.

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