LITERATURE REVIEW

Utilization of Virtual Reality for Upper Limb Motoric Rehabilitation of Post-Stroke Patients: A Sytematic Review

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ABSTRACT

Background: Stroke is a neurological disorder which is classified as ischemic or hemorrhagic. The increasing incidence of stroke worldwide has increased the need for rehabilitation. Virtual Reality (VR) is a new technology that is still being developed for the rehabilitation of post-stroke patients. Several studies have shown that VR has good benefits to help the rehabilitation of post-stroke patients, especially in terms of patient motor skills.

Methods: A systematic review was conducted by searching the PubMed and Science Direct databases with all articles using English, randomized controlled trials and articles published in 2020-2024. The keywords used were "Virtual Reality", "VR", "Neurorehabilitation", "Rehabilitation", "Motor Function", "Stroke", "Recovery".

Results: A total of 870 studies were initially identified, 10 of those studies fulfilled the inclusion criteria for this systematic review. Total of 348 participants (178 VR groups and 170 control groups) were included in this systematic review and the results showed from most of the studies show a significant increase in the VR group in patient motor skills based on FMA-UE, ARAT, AROM, Grip Strength Test, DASH, JTT, WMFT and 9HPT assessments.

Conclusion: This systematic review shows that the use of VR for motor rehabilitation of post-stroke patients has better outcomes compared to patients who only receive conventional therapy.

Keywords: Stroke, Virtual Reality, Motoric Function, Upper Limb, Rehabilitation

ABSTRAK

Latar belakang: Stroke merupakan suatu penyakit kerusakan vaskuler yang bersifat iskemik ataupun hemoragik. Kejadian stroke yang meningkat di seluruh dunia menyebabkan kebutuhan akan rehabilitasi juga meningkat. Virtual Reality (VR) merupakan suatu teknologi baru yang masih dikembangkan untuk rehabilitasi pasien pasca stroke. Beberapa studi menunjukkan bahwa VR memiliki manfaat yang baik untuk membantu rehabilitasi pasien pasca stroke terutama dalam hal motorik pasien.

Metode: Sebuah tinjauan sistematis dilakukan dengan pencarian pada basis data PubMed dan Science Direct dengan keseluruhan artikel menggunakan bahasa Inggris dan artikel yang dipublikasikan pada tahun 2020-2024. Kata kunci yang digunakan adalah "*Virtual Reality*", "VR", "*Neurorehabilitation*", "*Rehabilitation*", "*Motor Function*", "*Stroke*", "*Recovery*".

Hasil: Sebanyak 10 studi dengan total 348 peserta (178 kelompok VR dan 170 kelompok kontrol) dimasukkan dalam tinjauan sistematis ini dan didapatkan hasil berupa terdapat peningkatan signifikan dalam 8 studi pada kelompok VR dalam motorik pasien berdasarkan penilaian FMA-UE, ARAT, AROM, Grip Strength Test, DASH, JTT, WMFT dan 9HPT.

Kesimpulan: Tinjauan sistematis ini menunjukkan penggunaan VR untuk rehabilitasi motorik pasien pasca stroke memiliki hasil yang lebih baik dibandingkan dengan pasien yang hanya mendapatkan terapi konvensional.

Kata Kunci: Stroke, Virtual Reality, Fungsi Motorik, Ekstremitas Atas, Rehabilitasi

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INTRODUCTION

Stroke is defined as an acute syndrome, focal neurological deficit due to vascular damage to the central nervous system.[1] The vascular damage that occurs can be ischemic or hemorrhagic.[1] The most common type of stroke is ischemic stroke which is mostly caused by atherosclerosis of small blood vessels, cardiac embolism or atherothromboembolism.[1] Hemorrhagic stroke is usually caused by intracerebral hemorrhage which can be located in the basal ganglia, brainstem, cerebral or in the lobe area.[1]

The incidence of stroke worldwide is estimated to continue to increase every year. The Global Burden of Disease in 2019 stated that the incidence of stroke from 1990 to 2019 based on risk factors increased quite high, from 91.5 million to 125 million people.[2] The most common risk factors found are high systolic blood pressure, high BMI, high fasting plasma glucose levels, pollution factors and also smoking.[2] It is estimated that stroke occurs more often in women than in men, and mostly occurs in patients aged 50 years and over.[2] Stroke is estimated to be the second leading cause of death worldwide and is a disease that can cause disability in patients.[2,3]

The need for rehabilitation is expected to continue to increase along with the increasing disability in post-stroke patients.[3] Rehabilitation carried out on post-stroke patients aims to help restore decreased body functions, maximize independence in daily activities and assist in participation in the community or in the family.[3] Rehabilitation practices for stroke have many options such as physiotherapy, pharmacological therapy, neuromodulation or additional therapy using technology such as Virtual Reality (VR) or robotics.[4] The use of technology in rehabilitation, especially in post-stroke patients, is still something that continues to be studied regarding its benefits and safety, but from previous studies it has been stated that the use of technology for post-stroke patient rehabilitation has satisfactory results.[4,5]

Virtual Reality (VR) is a new rehabilitation modality that is mainly used for motor function rehabilitation in post-stroke patients.[5] VR technology allows patients to experience an environment created by a computer with the illusion of a virtual environment that can produce realistic or unrealistic events.[5] Through VR technology, patients can interact with the impressions felt in the real environment and are not even aware of the virtual environment that occurs.[5]

Previous research has shown that VR has advantages in rehabilitation.[4,5] This is associated with increased neuroplasticity due to the orientation of tasks performed using VR and also repetitive and intensive exercises that cause recovery in the motor area.[4,5] Repetition of exercises performed using VR is given through the game features that are flexible in it settings so that it can be adjusted to the disabilities experienced by the patient.[4,5] Exercise using games in VR is also believed to increase patient motivation in undergoing rehabilitation.[5] In addition, the use of VR can also be considered as a tele-rehabilitation tool.[5]

The use of VR as a support for rehabilitation in post-stroke patients is still classified as a new rehabilitation. There is still much research that needs to be done to further assess the benefits and side effects of using VR for post-stroke rehabilitation. This study will compare various previous studies related to the use of VR for post-stroke rehabilitation.

METHODS

This literature uses the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines for systematic reviews.

Literature Search Strategy

In this literature, the articles used come from searching sources in PubMed and Science Direct with publication years between 2020-2024. The keywords used in the search are "Virtual Reality", "VR", "Neurorehabilitation", "Rehabilitation", "Motor Function", "Stroke", "Recovery" using booleans in the form of OR and AND. The articles used in this study are full articles published in English and have a group with an intervention in the form of Virtual Reality. From all the articles found, screening was carried out on the title and abstract to find relevant articles, then if there was duplication, it would be excluded. After screening, the appropriate articles will be downloaded and assessed for their eligibility.

Article Selection

The inclusion criteria used in this study were (1) Research design using Randomized Controlled Trials (RCTs) where there was a comparison between the group receiving VR intervention and the control group. (2) Articles evaluating interventions using VR without additional interventions, (3) Articles conducted on ischemic or hemorrhagic stroke patients. (4) Patient age > 18 years. (5) Articles published in trusted journals. (6) Articles in the year of publication 2020-2024. The exclusion criteria used in this study were (1) Articles published not in English. (2) Articles whose entire text could not be found. (3) Technical articles. (4) Incomplete clinical trials. (5) Pilot Study.

Data Collection

Data from selected studies were extracted using a table containing author names, year of publication, sample size, stroke onset, motor area involvement, description of intervention, outcomes, and results.

Risk-of-bias assessment

The risk-of-bias assessment of RCT studies in this literature used the Cochrane risk-of-bias (ROB-2) tool for RCT studies, which contains 5 sections/domains such as randomization process, deviations from the intended intervention, missing outcome data, outcome measures, and selection of reported outcomes. In each section, there are several questions with the answer options 'yes', 'probably yes', 'probably no', 'no' or 'no information'. Each domain is concluded with "low risk of bias", "some concerns", or "high risk of bias".[6]

RESULTS

Search results and study selection

The search conducted from data sources obtained a total of 870 articles. After removing duplicate articles, a total of 849 articles were screened in title and abstract. A total of 69 articles were reviewed further and then 10 articles were systematically reviewed (**Figure 1**).

Study characteristics

Articles included in this systematic review mostly discussed motor rehabilitation in patients with ischemic stroke. In the articles found, one study discussed acute stroke (<30 days)[7], six studies discussed subacute stroke (<6 months)[8-12,15], two studies discussed chronic stroke (>6 months)[13,14] and one study did not include the onset of stroke.[16] All studies discussed motor rehabilitation in the upper extremities[7-16], three studies added functional assessment[7,9,12], one study added inflammatory markers in stroke patients10, six studies added functional use and dexterity assessment[9,11,13-16], one study added cognitive assessment to its study16 and three studies added quality of life assessment in post-stroke patients.[9,14,16]

Risk-of-bias assessment

Of the total 10 studies, 5 studies were judged to raise some concerns, 4 studies were assessed as having a low risk of bias and 1 study were assessed as having a high risk of bias. (**Figure 2**). In the randomisation process domain, there was 1 study with high risk because the study did not explain in detail the randomisation method used.[8] All studies did not blind the sample or the intervention provider because in VR interventions it is not possible to do blinding, but as many as 5 studies did not explain the possibility of deviation from the intervention given, thus causing some concerns in the domain deviations from the intended interventions.[7-16] In missing outcome data domain, all studies were at low risk of bias.[7-16] In domain 4 (measurement of outcome), there were 2 studies with some concerns because they did not explain the blinding of the outcome assessors.[9,11] In the domain selection of the eported result domain, all studies were at low risk of bias.[7-16]

Results of the studies

A total of 348 participants (178 in the VR group and 170 in the control group) participated in the studies conducted by each researcher. This systematic review focused on upper limb motor rehabilitation, but other assessments were also found in the studies found. The results of each study are presented in **Table 1**.

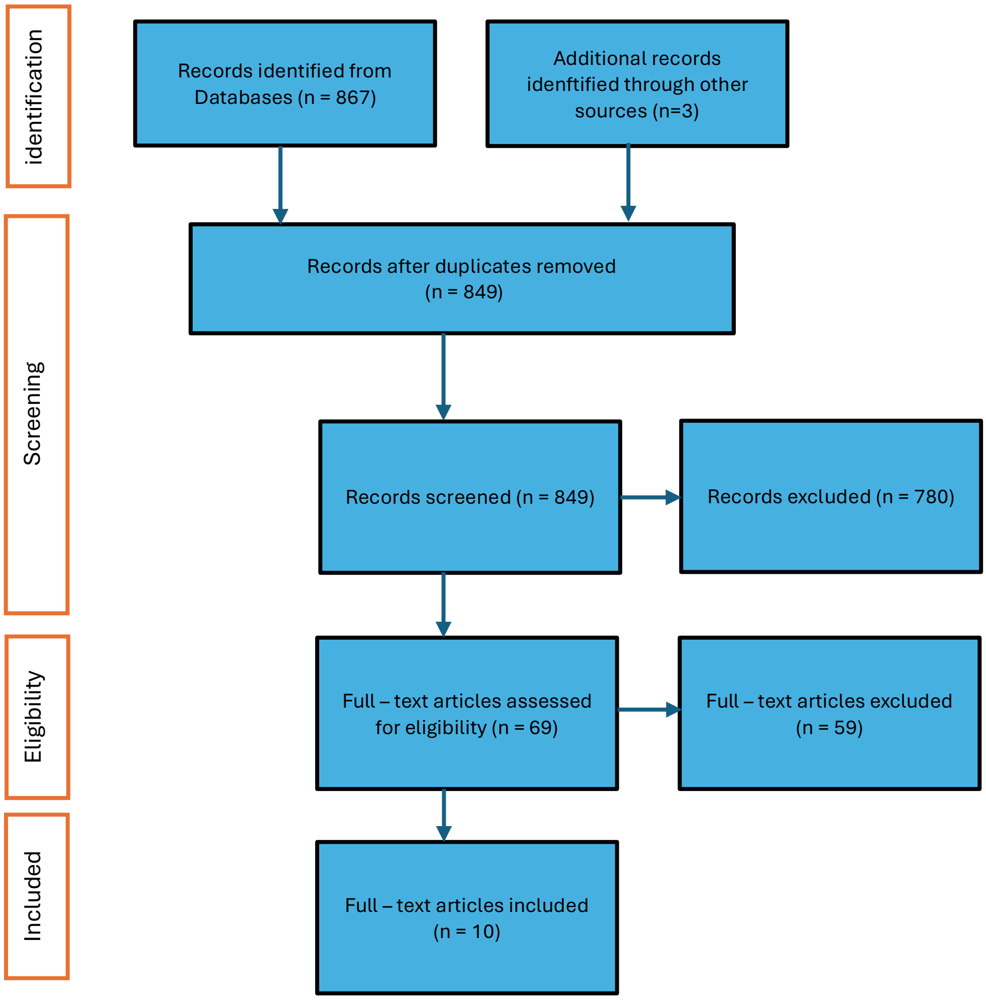

Figure 1.

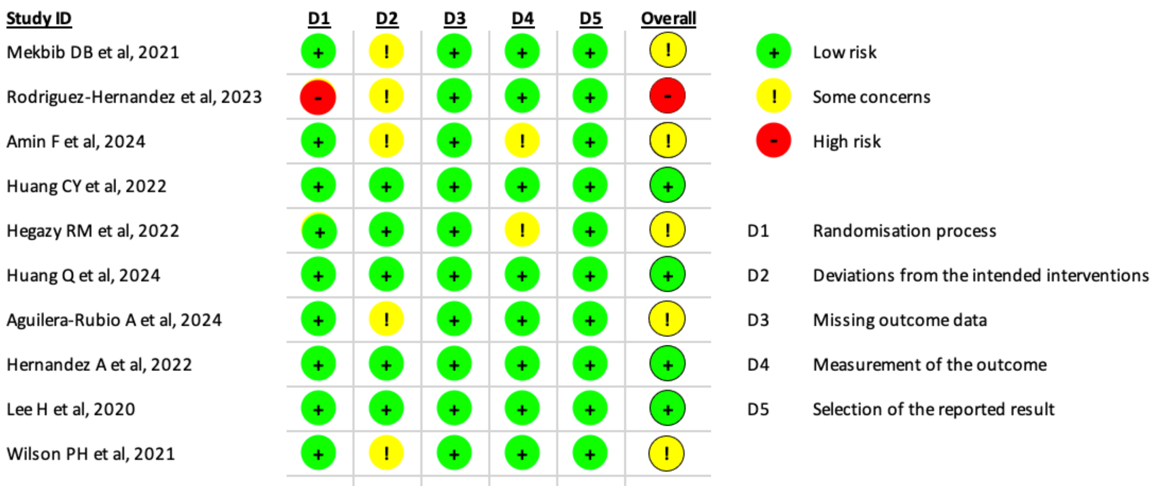

Figure 2. Results of Risk – Bias Assessment

Table 1. Summary of the RCT included in systematic review

Authors	Number of Samples		Stroke onset	Control group	Type of Intervention	Intervention Protocol	Outcome measure	Main finding
	VR group	Control group						
Mekbib et al, 2021[7]	12	11	< 3 months	Occupation therapy	• Immerse HMD VR • HTC Vive tracking stations • Leap Motion tracking technology • ALIENWARE high graphics laptop • Occupational Therapy	• Session duration: 1 hour of VR + 1 hour of occupation therapy • Frequency: 4 days/ weeks • Program duration: 2 weeks	• FM-UE • BI • Resting-state fMRI	Both groups showed significant improvement in BI (P<0.05). VR group showed significant improvement in FM-UE compared to control. Neural activity increased after intervention.
Rodriguez-Hernandez et al, 2023[8]	23	20	≤ 6 months	Conventional rehabilitation + occupational therapy	• HandTutor glove © • 3DTutor © • Rechametrics © • Mediotouch © software • Conventional Therapy	• Session duration: 50 minutes VR + 100 minutes conventional therapy • Frequency: 5 days/ week • Program duration: 3 weeks	• FM-UE • ARAT • Ashworth Scale	Both groups showed improvement in FMA-UE but higher in the VR group. The improvement in ARAT was higher in the intervention group. The decrease was lower in the intervention group based on the Ashworth scale.
Amin F et al, 2024[9]	26	26	Subacute(< 6 months)	Conventional rehabilitation	• Immerse Oculus Quest 2 Virtual Reality Device • Unity3D game engine • Occupational Therapy	• Session duration: 24 minutes VR + 24 minutes conventional in the first 2 weeks, • 40 minutes VR + 40 minutes conventional in the last 4 weeks • Frequency: 4 days/ week • Program duration: 6 weeks	• FM-UE • ARAT • BBT • MBI • SSQOL	Both groups showed significant improvements both between groups (p<0.05) and within groups (p<0.05)

Table 1. Summary of the RCT included in systematic review (Continue)

Authors	Number of Samples: VR group	Number of Samples: Control group	Stroke onset	Control group	Type of Intervention	Intervention Protocol	Outcome measure	Main finding
					• Occupational Therapy	• 40 minutes VR + 40 minutes conventional in the last 4 weeks • Frequency: 4 days/ week • Program duration: 6 weeks		
Huang CY et al, 2022[10]	15	15	> 3 months	Conventional rehabilitation	• HMD Virtual Reality • Infrared laser emitter units • HTC Vive (HTC Corporation, New Taipei City, Taiwan)	• Session duration: 60 minutes/ day • Frequency: 2-3 times/ week • Program duration: 16 sessions	• FM-UE • AROM • IL-6 • HO-1 • 8-OHdG	Significant improvement in total FMA-UE score and shoulder flexion AROM in the VR group. There were no significant results for biomarkers IL-6, HO-1 and 8-OHdG in both groups.
Hegazy et al, 2022[11]	10	10	< 6 months	Task oriented training program	• VR Immersive Goggles • Controllers • PlayStation Console • Task Oriented Training Program	• Session duration: 60 minutes (10 - 15 minutes VR + Task Oriented Training Program) • Frequency: 3 times/ week • Program duration: 6 weeks	• UEFI • Grip Strength Test	Significant improvements in UEFI and Grip Strength Test assessments in the VR group compared to the control group
Huang Q et al, 2023[12]	20	20	Subacute	Conventional rehabilitation	• Immersive Virtual Reality	• Session duration: 30 minutes	• FM-UE • BI	Significant improvement in VR

Table 1. Summary of the RCT included in systematic review (Continue)

Authors	Number of Samples VR group	Number of Samples Control group	Stroke onset	Control group	Type of Intervention	Intervention Protocol	Outcome measure	Main finding
				and occupational therapy	• Conventional Therapy	Conventional therapy + 30 minutes VR • Frequency: 5 days/ week • Program duration: 3 weeks		
Aguilera-Rubio A et al, 2024[13]	18	8	> 6 months	Conventional rehabilitation	• LMC®	• Session duration: 60 minutes/ day • Frequncy: 2 times/ week • Program duration: 8 weeks	• Grip strength • BBT • ARAT • DASH • Technology Satisfaction Questionnaire	Intergroup analysis showed no significant improvement Intragroup analysis showed significant improvement in both groups
Hernandez A et al, 2022[14]	26	25	> 6 months	Home-based exercise program manual (Graded Repetitive Arm Supplementary Program [GRASP])	• Jintronix software Microsoft Kinect depth-detecting infrared sensor camera	• Session duration: ≥ 20 minutes/ day • Frequency: 5 times/ week • Program duration: 4 weeks	• FM-UE • SIS • Motor activity Log	There was no statistically significant difference between the two groups, but there was minimal clinical difference in the intervention group that actively practiced

Table 1. Summary of the RCT included in systematic review (Continue)

Authors	Number of Samples		Stroke onset	Control group	Type of Intervention	Intervention Protocol	Outcome measure	Main finding
	VR group	Control group						
Lee HS et al, 2020[15]	18	18	<6 months	Recreational video games	• RAPAEL Smart Glove	• Session duration: 30 minutes/ day • Frequency: 3 days/ week • Porgram duration: 8 weeks	• BBT • JTHFT • Grip strength test • WMFT • TMT	Significant improvement in VR group in BBT, grip strength test and WMFT assessment. There was improvement in VR group from JTT and TMT time score but not significant compared to control group.
Wilson PH et al, 2021[16]	10	7	NA	GRASP	• Elements EDNA-22™ System	• Session duration: 30 minutes/ day • Frequency: 3-4 sessions/ week • Program duration: 8 weeks	• BBT • 9HPT • MoCA • SIS • NFI	Significant improvement in BBT, MoCA scores for intervention group. Mild-moderate improvement in 9HPT exercise for both groups and moderate improvement in intervention group in SIS and NFI.

9HPT, 9-Hole Pegboard Test; ARAT, Action Research Arm Test; AROM, Active Range of Motion; BBT, Box and Block Test; BI, Barthel Index; DASH, Disabilities of the Arm, Shoulder and Hand; FM-UE, Fugl-Meyer Upper Extremity; GRASP, Graded Repetitive Arm Supplementary Program; HMD, Head Mounted Display; JTHFT, Jebsen-Taylor hand function test; LMC®, Leap Motion Controller®; MBI, Modified Barthel Index; MoCA, Montreal Cognitive Assessment; NA, Not Available; NFI, Neurobehavioral Functioning Inventory; SIS, Stroke Impact Scale; SSQOL, Stroke-Specific Quality of Life; TMT, Trail making test; VR, Virtual Reality; WFMT, Wolf Motor Function Test;

Motor Rehabilitation Assessment

All studies assessed upper limb motor rehabilitation in patients who received VR intervention (178 patients) and also in the control group (170 patients). Motor assessment was done by looking at FMA-UE, ARAT, AROM, Grip Strength Test, DASH, JTT, WMFT and 9HPT. One study discussed acute stroke (<30 days)7, six studies discussed subacute stroke (<6 months)[8-12,15] and two studies discussed chronic stroke (>6 months).[13,14] Of all these studies, 8 studies showed significant improvements in the group that received VR compared to the control group.[7-16]

DISCUSSION

The purpose of this systematic review is to assess the use of VR in motor rehabilitation of post-stroke patients. In the studies found, there were various types of VR use, both with Head-Mounted Display (HMD), Arm glove, Jintronix software, EDNA-22 system and also the addition of leap motion devices to see the movement of the patient. In general, VR used in published articles showed improvements in the process of upper extremity motor rehabilitation of patients. This is indicated by improvements in indicators such as FMA-UE, ARAT, BBT, AROM, WMFT, Grip Strength, DASH, and JTT although in some studies there were no significant differences when comparing the intervention group with the control group. A systematic review study conducted previously by Khan et al in 2021 showed that the use of VR for post-stroke patient rehabilitation has advantages that can be used as an additional therapy for the future in the rehabilitation process, especially for motoric outcomes.[4]

These advantages involve improvements in mobilization, which can help reduce disability, family or caregiver burden, reduced costs related to institutionalization and also improvements in quality of life.4 Another study conducted by Rutkowski et al in 2020 also stated that the use of VR has benefits in post-stroke patient rehabilitation with improvements in the assessment of upper and lower extremity function (balance).[17] The improvement in the results of the assessment in patients who received VR as therapy can occur due to the additional stimulation and motivation provided by the artificial environment, thereby increasing the pleasure of the motor learning process from the gamification process provided through VR.[5,17] The existence of repetition, flexible rehabilitation and depending on each individual to achieve the best motor performance from the relearning process allows patients to achieve a better level of rehabilitation so that they can restore their body functions to near normal.[5,17]

VR that used in published studies has various characteristics. There are studies that use immersive VR types such as Head Mounted Display, Immerse Oculus Quest 2 Virtual Reality Device, or non-immersive VR such as HandTutor glove ©, Jintronix software, RAPAEL Smart Glove, and also Elements EDNA-22™ System. A previous study by Patsaki et al in 2022 by conducting a systematic review of 12 studies stated that the use of immersive VR has a potential effect in carrying out motor rehabilitation of post-stroke patients.[18] It was stated that the immersive VR maximizes recovery by increasing patient motivation and also patient compliance in undergoing rehabilitation process.[18] Another study conducted by Maier et al in 2019 which compared the use of Specific Virtual Reality (SVR) and Non-specific Virtual Reality (NSVR) showed that the use of SVR had better motor recovery results in post-stroke patients compared to the group that received NSVR.[19] SVR is a Virtual Reality that is specifically designed for stroke rehabilitation management, while NSVR is a Virtual Reality system that has a recreational function and/or also includes the use of video games such as Nintendo

Wii, Microsoft Xbox Kinect, and Sony PlayStation EyeToy.[19] Better results were shown in patients who received SVR therapy due to a combination of specific exercises in patient rehabilitation, direct feedback, increasing levels of difficulty, implicit feedback, exercise variables and also mechanisms. from SVR which allows patients to use weaker leg areas.[19] Although showing good results, Maier et al stated that the number of participants included in the NSVR group was still relatively small, allowing for insignificant results due to the lack of participants.[19] Another study conducted by Hao et al who conducted a systematic review and meta-analysis on the comparison of the use of Immersive VR with Non-immersive VR for functional recovery of the upper extremities in post-stroke patients stated that the use of Immersive VR had a better recovery rate when compared to the use of Non-immersive VR and conventional rehabilitation.[20]

Study Limitations

This literature has several limitations. The form, type of intervention, duration of use and frequency of use of VR in several studies still vary, so it cannot recommend the use of a particular VR specifically to be applied to the population. Several studies also still use quite small samples. This systematic review is also not included with a meta-analysis.

CONCLUSIONS

Based on this systematic review, VR, which is a new modality in motor rehabilitation of post-stroke patients, has quite good effectiveness in the motor rehabilitation process of post-stroke patients compared to patients who only receive conventional or occupational therapy. Further research is still needed to examine the benefits of VR for post-stroke patient rehabilitation, both in the type of stroke that can be used for rehabilitation with VR, stroke onset, type of VR or also training time with VR, as well as the use of VR combined with other therapies so that post-stroke patient rehabilitation becomes better and can restore the function of the affected limbs to normal or close to normal.

CONFLICT OF INTEREST

The authors declared there is no conflict of interest

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