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Exergame for post-stroke rehabilitation among elderly patients: A systematic review and meta-analysis

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Abstract

Advancement in gaming technology, including exergame, is thought to offer a promising innovation in rehabilitative treatment owing to its interactive and joyful natures. Elderly, in addition to being prevalent in stroke, they have different perspectives and adaptability toward the utilization of exergame in post-stroke rehabilitation. The aim of this study was to evaluate the effectiveness of exergame-based rehabilitation in ameliorating stroke-associated cognitive impairment among elderly patients. This systematic review followed the Preferred Reporting Item for Systematic Review and Meta-Analysis (PRISMA) guideline. The literatures were retrieved from the searches on PubMed, Scopus, and Embase databases using a combination of 'exergame', 'stroke', and 'elderly' along with their respective synonyms. Included studies were controlled observational studies and randomized clinical trials with subjects' mean age >60 years old, measuring global cognitive and/or five cognitive domains (attention, language, executive function, memory, and visuospatial ability). Quality appraisals were performed based on the Cochrane 'risk-of-bias tool' and Physiotherapy Evidence Database Scale. Studies with high and good qualities were included in the meta-analyses. Six randomized controlled trials involving 179 patients were included in meta-analysis. Studies had variations in terms of type (combination of exergame-based and conventional rehabilitation or exergame-based only) and duration of interventions (30–110 min), length of observation (2–6 weeks), and tools used to examine cognitive outcomes. As compared with conventional rehabilitation, exergame-based rehabilitation was significantly more effective to improve global cognitive based on Montreal Cognitive Assessment Score in acute stroke patients (n=4; mean difference (MD) 3.66; 95% confidence interval (95%CI): 2.08, 5.24; p<0.00001), but significantly less effective in chronic stroke patients (n=2; MD -1.54; 95%CI: -2.28, -0.81; p<0.0001). In conclusion, global cognitive of elderly patients with acute strokes could be improved through exergame-based rehabilitation which is more effective as compared with conventional therapy.

Keywords: Acute stroke, elderly, global cognitive, MoCA, virtual reality

Introduction

The prevalence of stroke is high, especially among the elder population [1], and the burden of this disease is predicted to persist in the increasing trend owing to the aging population [2]. Around 67% of patients who recovered from stroke experienced a cognitive impairment [3]. The impairment may occur in one or more cognitive domains namely attention, memory, language, visuospatial abilities, and executive function [4]. This condition increases the risk of lower quality of life, being dependent, and even morbidity and mortality [5]. Currently, cognitive rehabilitation (CR) has been recognized as the standard practice for post-stroke treatment by the Cognitive Rehabilitation Task Force (CRTF) [6]. Growing evidence shows that computerized cognitive training, including exergame, is useful in facilitating cognitive recovery in post-stroke patients [7]. Exergame is a combination of exercise and video game that requires its users to do physical activity during playing it and using a set of devices [8]. Exergame training enables patients to

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enhance their motor and cognitive functions in the course of performing game tasks [9]. Several exergame devices that have been utilized for rehabilitative purposes are Nintendo Wii and XBOX Kinect [9,10]. Previously, the effectiveness of exergame-based rehabilitation has been reported to be associated with its playfulness and perceived usefulness [10].

Several systematic reviews and meta-analysis studies have been performed on the benefits of computer-based training as compared with conventional training for post-stroke rehabilitation [11–13]. Computer-based training is convenient and individualized, which contributes to its increased popularity in the rehabilitative treatment [11]. However, none of the aforementioned systematic review and meta-analysis studies specifically covered elderly populations undergoing post-stroke rehabilitation. In the elderly population, response to such technology might be different as compared with the general population, hence affecting the efficacy and adherence to the treatment. For example, the acceptance of exergame-based rehabilitation among elderly people is solely based on efficacy rather than joyfulness [10]. However, concrete evidence needs to be established through a systematic review to evaluate the effectiveness of exergame for elderly patients undergoing post-stroke rehabilitation. Herein, the clinical benefits were assessed based on global cognitive and its five domains namely attention, memory, language, visuospatial abilities, and executive function.

Methods

Search strategy

The literature search was performed on three major scientific literature databases, *viz* PubMed, Scopus, and Embase on 29 December 2022. Truncated title of 'exergame-based rehabilitation for elderly post-stroke patients' along with the synonyms were used as the keyword combination. The keyword was searched within the title, keyword, and abstract of the literature. Boolean operators 'OR' and 'AND' were used when applicable. The search was refined by publication date yielding a result of published literature from 2010 onward, in which this decision was based on the fact that exergame technology started to advance rapidly after the stated year [14,15], hence more robust protocols. The keyword combinations used in PubMed, Scopus, and Embase, respectively, have been presented in **Table S1** (**Appendix A**).

Inclusion and exclusion criteria

Inclusion criteria of the included studies were based on the PICOS framework [16] are followed. Population (P) was stroke patient groups over the average age of 60 years). Intervention (I) was exergame-based interventions that met the following definition: "the combination of exercise and games"). Control (C) was the comparison group received either a traditional intervention or no intervention. Traditional interventions included any activities designed to be therapeutic for the impairment, activity, or participation level that did not include the use of exergame, ranging from motor and/or cognitive training to health education. Outcome (O) was cognitive function, including global cognition, attention, executive function, memory, language, and visuospatial ability. Study included observational and randomized clinical trials (RCTs) testing the effect of exergame on one or more cognitive outcomes in post-stroke patients with average age of 60 years old.

In this present study, exergame is defined as computerized training that involves physical activities to accomplish gaming task(s) using a set of devices and software. Review articles, case reports, conference abstracts, and editorials were excluded. Non-English written papers were manually excluded.

Screening and selection of the records

The literature screening and selection were guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [17]. Duplicate removal was performed automatically on Mendeley Desktop v1.19.8 after importing all searched records into the software. Thereafter, the screening was carried out through the 'title and abstract' and followed by the full content screening based on the eligibility criteria stated previously. The whole screening and selection process was performed independently by two reviewers (T.F.D. and

M.A.N.), as suggested by a previous study [18]. The included studies in the final stage should be approved by the consensus agreement from the two reviewers. Any discrepancies that emerged were resolved by re-checking the articles, discussion, and consultation with the third reviewer (G.T.).

Data extraction and synthesis

Data extracted from the literatures include the patients' characteristics, details on the exergame used as the intervention, and outcome. The patients' characteristics were age, gender, the severity level of cognitive impairment, types of stroke, and time since stroke (day). The severity level of cognitive impairment was based on Montreal cognitive assessment (MoCA) at baseline. In the used in the treatment and treatment frequency (min/day) and duration (day). The outcomes included were divided into global cognitive and five domains of cognition *viz* attention, memory, visuospatial ability, language, and executive function.

All values were presented in mean ± standard deviation (SD), where values presented in the median would be converted by a method proposed in a previous publication [19]. Global cognitive was measured by MoCA and Mini-Mental State Examination (MMSE), Functional Independence Measure (FIM); attention was measured by Corsi Block Tapping Test Forward (Corsi F), Trail Making Test (TMT) A, and Wechsler Adult Intelligence Scale IV Forward (WAIS F); memory was measured by Corsi Block Tapping Test Backward (Corsi B), Ray Auditory Verbal Learning Test Immediate (RAVLT I), Ray Auditory Verbal Learning Test Delay (RAVLT D), and Wechsler Adult Intelligence Scale IV Backward (WAIS B); executive function was measured by TMT B, Wechsler Adult Intelligence Scale IV Coding (WAIS C), and Frontal Assessment Battery (FAB); Visuospatial was measured by Star Cancellation (SCT).

Quality appraisal

The risk of bias in the included studies was assessed with the Cochrane 'risk-of-bias tool' [20] by the two researchers (T.F.D. and M.A.N.). The criteria included allocation concealment, random sequence generation, blinding of outcome assessment, blinding of participants and personnel, incomplete outcome data, selective reporting, and any other bias. Each criterion was classified as having 'low', 'high', or 'unclear' risk of bias.

In addition, the risk of bias was assessed by a scoring method specified for physical therapy – Physiotherapy Evidence Database (PEDro) Scale [21]. PEDro is comprised of 11 assessment items, where all studies should pass the first item for being specified in their eligibility criteria. Thereafter, for each assessment item, the study would be given a score '1' if it passed and '0' if it did not. Hence, the range for the total score of the PEDro scale is 0—10 points. Studies with a score of 6—10 would be categorized as 'high quality', 4—5 – fair quality, and ≤ 3 – poor quality. Studies with poor quality based on the PEDro scale were excluded from the meta-analysis.

Statistical analysis

The mean difference (MD) and its 95% confidence interval (95% CI) were calculated for data generated from MoCA, Corsi B, Corsi F, TMT A, TMT B, WAIS B, WAIS C, WAIS F, RAVLT D, RAVLT I, FAB, and SCT. The mean difference, 95% CI, *p*-value, and *z*-value were calculated to evaluate the significance of exergame effectiveness as compared to the control group. To overcome heterogeneity between studies, associated with different study designs (i.e., frequency, duration, and exergame settings) and patients' characteristics (i.e., types of stroke, cognitive impairment severity, and time since stroke), random-effect or fixed-effect models were applied in the calculation based on the level of heterogeneity. The heterogeneity was judged based on I-squared (I^2), where $I^2 \geq 50\%$ suggested that the studies analyzed were highly heterogenous [22]. Further, publication bias would be performed if each outcome was reported by more than 10 studies. All statistical analysis was carried out based on the software developed by Cochrane Collaborations – RevMan version 5.4.1. [23].

Results

Characteristics of the included studies

The PRISMA flow diagram for the included studies based on the eligibility criteria in this review has been presented in **Figure 1**. As many as 6 studies met the inclusion criteria and were included in this review participated by a total number of 179 patients (59% male) ranging from 5 to 25 participants per group. All of the included studies were randomized clinical trials. Among these studies, the average age of participants ranged from 62 to 77 years old. Studies were conducted in Spain, Australia, Turkey, Czech Republic, and United Kingdom. Summary of the characteristics of the included studies along with their outcomes have been presented in **Table 1**.

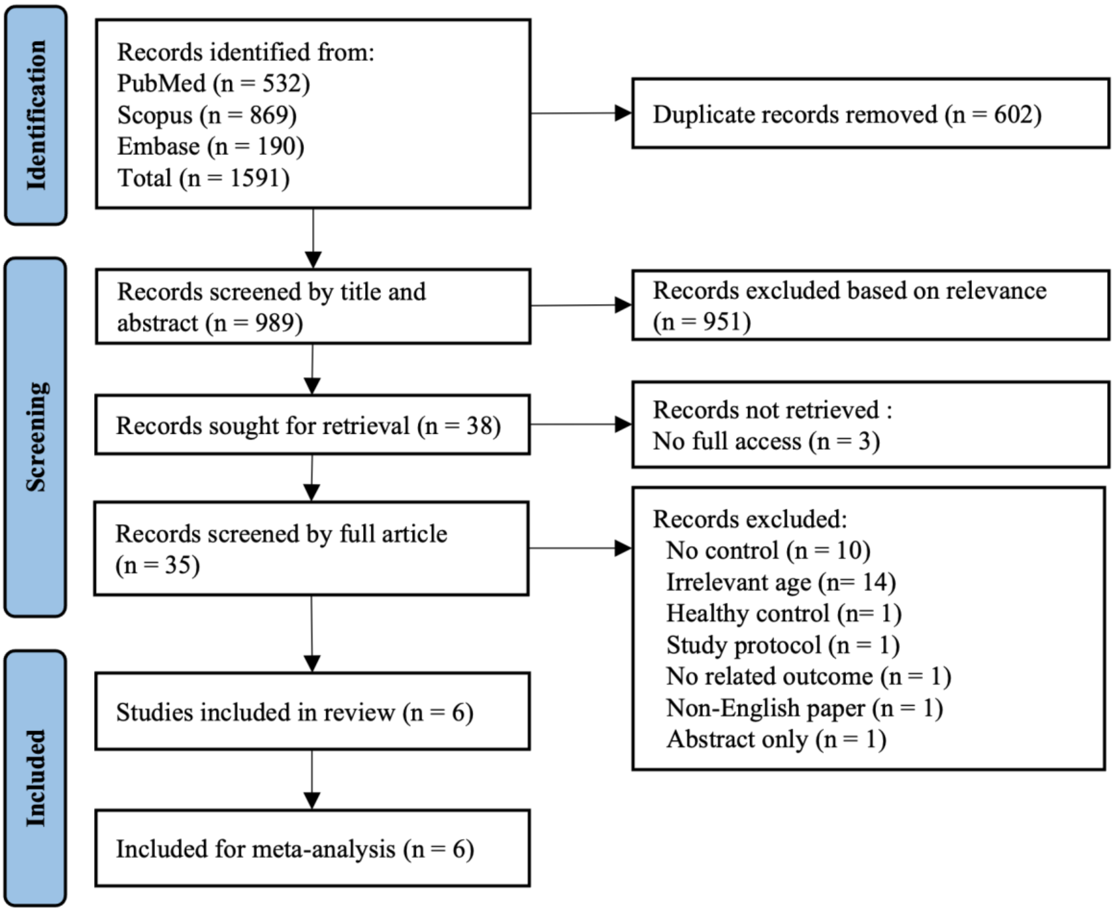


Figure 1. PRISMA diagram for the screening and selection process of the published studies.

Results from the quality appraisal

The results of the risk of bias analysis for each included study based on Cochrane 5.2.0. risk of bias tool is presented in **Figure 2S** (**Appendix B**). The summary of this analysis is presented in **Figure 2**. Overall, all included studies performed randomized sequence generation and concealed the allocation process [24–27,29], except for one study having an unclear allocation mechanism [28]. Three studies did not blind the participants [25–27], two studies had unclear mechanisms [24,28], and only one study implemented the double-blinding of participants [29]. Furthermore, there were two studies blinded the assessor when measuring the outcome [25,29], three studies did not blind the subjects [26–28], while one study was unclear [24]. All studies reported the completed outcome [24,26–29], except for [25] having measured outcomes <85% compared to the initial data.

Duta et al. Narra X 2023; 1 (1): e73 - http://doi.org/10.52225/narrax.v1i1.73

Table 1. Characteristics and PEDro scores of included studies

Author, Year, Ref	Country	Characteristics		Treatment		Outcome			PEDro
		Experimental	Control	Experimental	Control	Variable	Experimental	Control	
Maier et al, 2017(24)	Spain	n=6 Age: 66.3±6.8 y.o. M/F: 4/2 CI: Mild Type: 3 HS, 3 IS TSS: 1,211.17± 1,116.57 d	n=5 Age: 64±7 y.o. M/F: 3/3 CI: Mild Type: 1 HS, 4 IS TSS: 1,742.60± 2,309.99 d	3 Cognitive training scenarios using RGS set-up (10 min), 5 d/w for 6 w.	Conventional cognitive task (30 min), 5 d/w for 6 w.	Global cognitive			7
						MMSE	27.00±1.10	27.80± 2.39	
						MoCA*	21.5±0.37	23.1±0.80	
						Attention			
						Corsi F	6.00± 2.28	6.00± 1.41	
						TMT A	74.67±34.59	55.40±26.31	
						WAIS Forward	5.00± 1.41	5.40± 0.89	
						Memory			
						Corsi B	4.00±1.09	4.00± 1.87	
						RAVLT Immediate	28.00± 13.21	35.40± 7.50	
						RAVLT Delay	3.33± 2.73	7.60± 1.67	
						WAIS Backward	3.50± 1.05	3.40± 0.89	
						Executive Function			
						TMT B	217.67±131.22	262.60±190.89	
						WAIS Coding	32.50±14.15	35.60± 21.33	
						FAB	15.83± 2.79	16.00± 1.58	
						Visuospatial			
						SCT	53.50±0.55	53.60± 0.55	
Maier et al., 2020(25)	Spain	n=19 Age: 63.63± 6.73 y.o. M/F: 11/8 CI: Mild Type: 8 HS, 11 IS, 1 Undefined TSS: 851.16± 805.26 d	n=19 Age: 67.21± 6.45 y.o. M/F: 12/7 CI: Mild Type: 5 HS, 14 IS TSS: 12,625.9± 1376.1 d	3 Cognitive training scenarios using RGS set-up (10 min), 5 d/w for 6 w.	Conventional cognitive task (30 min), 5 d/w for 6 w.	Global cognitive			6
						MoCA	21.38±4.11	22.21±3.68	
						MMSE	27.50±1.46	27.62± 2.36	
						Attention			
						Corsi F	6.06± 2.08)	5.86± 1.46	
						TMT A	73.69±40.13	58.36±27.91	
						WAIS Forward	5.19± 1.28	5.36± 1.15	
						Memory			
						Corsi B	5.00±2.03	4.93± 2.20	
						RAVLT Immediate	32.69±10.71	32.64± 9.34	
						RAVLT Delay	5.25± 3.15	6.21±2.49	
						WAIS Backward	3.81± 1.38	3.43±1.02	
						Executive Function			
						TMT B	228.44±136.98	209.21±138.36	
						WAIS Coding	30.06±13.43	27.29±16.51	
						FAB	16.44± 2	16.43±1.65	
						Visuospatial			
						SCT	52.69±4.47	53.21±1.63	
Rogers, et al., 2019(26)	Australia	n=10 Age: 64.3±17.4 y.o. M/F:4/6 CI: Mild	n=11 Age: 64.6±12.0 y.o. M/F:5/6 CI: Mild	Conventional care (3 h) + VRT (30—40 min), 3 d/w for 4 w.	Conventional care (3 h), 3 d/w for 4 w.	Global cognitive			7
						MoCA	24.8±2.6	21.4±3.6	
						Memory			
						GMLT	87.5±9.5	108.0±13.2	

Author, Year, Ref	Country	Characteristics		Treatment		Outcome			PEDro
		Experimental	Control	Experimental	Control	Variable	Experimental	Control	
		Type: 1 HS, 9 IS TSS: 22.8±14.8 d	Type: 2 HS, 9IS TSS: 30.0 ±15.9 d			Executive Function SST	 46.9±6.2	 61.0±11.5	
Ozen, et al., 2021(27)	Turkey	n= 15 Age: 62.00±13.12 y.o. M/F: 10/5 CI: Mild Type: 3 HS, 12 IS TSS: 151.8 ± 98.4 d	n= 15 Age: 69.80 ± 8.41 y.o. M/F:7/5 CI: Mild Type: 2 HS, 13 IS TSS: 145.8 ± 86.1 d	Conventional care (1 h, 20 sessions) + CGATSE (30 min) using Rejoyce, 5 d/w for 4 w.	Conventional care (1 h, 20 sessions) + OT (30 min), 5 d/w for 4 w.	Global cognitive MoCA MMSE	 21.86±5.79 27.80±1.93	 19.33 ±6.12 26.33±2.49	8
Gueye, et al., 2021(28)	Czech Republic	n= 25 Age: 66.56 ± 12.26 M/F:14/11 CI: Mild Type: 5 HS, 20 IS TSS: 14.88± 6.45 d	n= 25 Age: 68.12 ± 11.97 M/F:15/10 CI: Mild Type: 1 HS, 24 IS TSS: 16.4± 7.25 d	VRT using Armeo IG (45 min), 4 d/w for 3 w.	Conventional care (45 min), 4 d/w for 3 w.	Global cognitive MoCA FIM	 25.6±3.54 110.8±8.17	 22.9±5.53	6
Chatterjee, et al., 2022(29)	United Kingdom	n= 22 Age: 77.5±13.5 y.o. M/F:17/13 CI: 11 severe, 11 mild Type: 3 HS, 27 IS TSS :9.5±4.75 d	n=7 Age: 60.25± 16.53 y.o. M/F:4/6 CI: severe (all) Type: 3 HS, 7 IS TSS: 9±8.25 d	Conventional care + VRT-based using VIRTUE, 5 d/w for 2 w.	Conventional care + sham VRT, 5 d/w for 2 w.	Global Cognitive MoCA Severe Mild	 16.25±5.5 22.5±2.3	 11.5±7.6	8

CL, Capsule Lenticular; CI, Cognitive Impairment; CGATSE, Computer Game Assisted Task Specific Exercises; Corsi B, Corsi Block Tapping Test Backward; Corsi F, Corsi Block Tapping Test Forward; F, female; FAB, Frontal Assessment Battery; FIM, functional independence measure; GMLT; Groton Maze Learning Task; HS, hemorrhagic stroke; IS, ischemic stroke; M, male; MMSE, Mini Mental State Examination; MoCA, Montreal Cognitive Assessment; NFI, neurobehavioral functioning inventory; OT, occupational therapy; RAVLT, Ray Auditory Verbal Learning Test; Rejoyce, Rehabilitation Joystick for Computerized Exercise; RGS, Rehabilitation Gaming System; SCT, Star Cancellation Test; SST, Set Shift Task; TMT, Trail Making Test; VIRTUE, Virtual Reality for Stroke; VRT, virtual reality training; TSS, time since stroke; WAIS, Wechsler Adult Intelligence Scale IV.
*Converted from MMSE

For PEDro scale-based risk of bias analysis, the results are presented in **Table 1**, where the details of this assessment are presented in **Table 2S** (**Appendix B**). The mean PEDro score obtained herein is 7 (SD 0.81) ranging from 6 to 8, categorized as high quality.

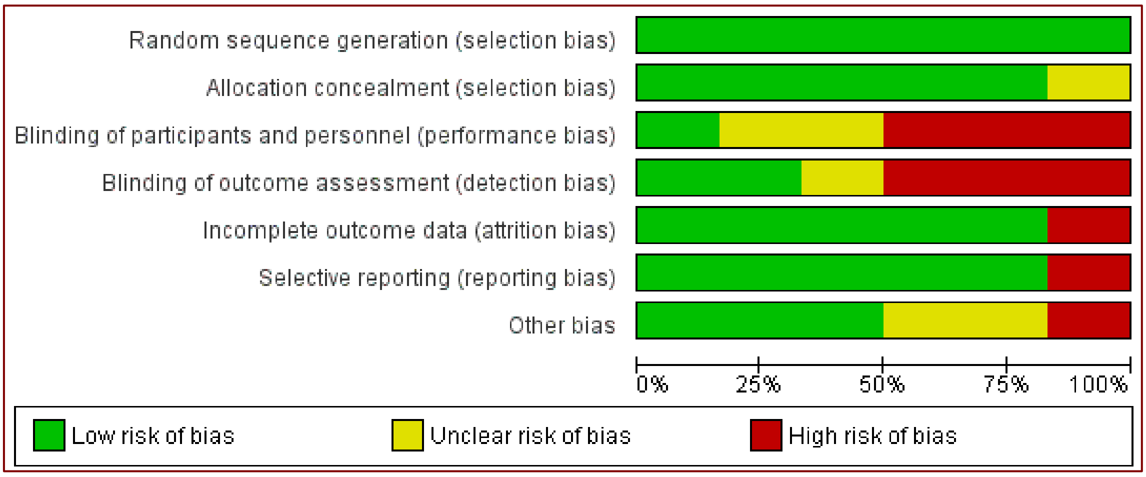


Figure 2. Summarized results of the quality appraisal based on Cochrane 5.2.0. risk of bias tool.

Global cognitive

The results of the random effect meta-analysis of the global cognitive based on MoCA is presented in **Figure 3**. The effect of exergame therapy on global cognitive was assessed in six studies [24–29] according to MoCA score. The effect of exergame therapy on global cognitive favored the experimental group but statistically insignificant (n=6; MD 2.45; 95%CI: -0.28,5.18; p=0.08). The I^2 of this analysis exceeded 50% threshold (86%).

	Experimental			Control				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Chatterjee 2022	16.25	5.5	11	11.5	7.6	7	9.2%	4.75 [-1.75, 11.25]
Chatterjee 2022	22.5	2.3	11	11.5	7.6	7	10.3%	11.00 [5.21, 16.79]
Maier 2017	21.5	0.37	6	23.1	0.8	5	18.9%	-1.60 [-2.36, -0.84]
Maier 2020	21.38	4.11	16	22.21	3.68	16	16.1%	-0.83 [-3.53, 1.87]
Ozen 2021	21.86	5.79	15	19.33	6.12	15	13.0%	2.53 [-1.73, 6.79]
Rogers 2019	24.8	2.6	10	21.4	3.6	11	16.2%	3.40 [0.73, 6.07]
Tereza 2021	25.6	3.54	25	22.9	5.53	25	16.4%	2.70 [0.13, 5.27]
Total (95% CI)			**94**			**86**	**100.0%**	**2.45 [-0.28, 5.18]**

Heterogeneity: Tau² = 10.13; Chi² = 41.68, df = 6 (P < 0.00001); I² = 86%
Test for overall effect: Z = 1.76 (P = 0.08)

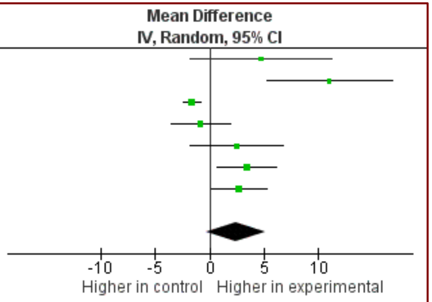


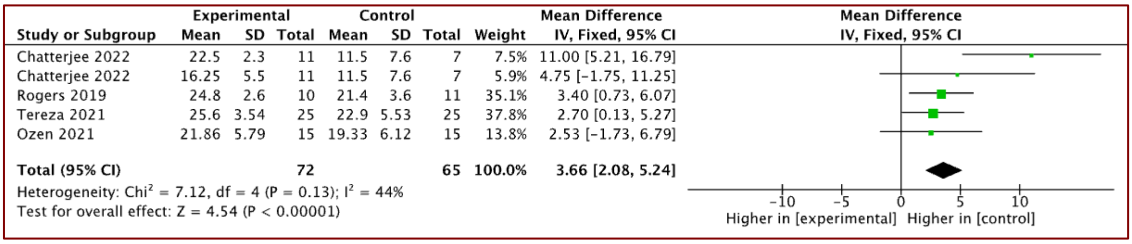
Figure 3. Forest plot of the effects of exergame therapy on global cognitive.

Sub-group analysis for global cognitive

The sub-group analysis was performed based on the time to onset duration of stroke (acute/chronic) to reduce the heterogeneity. The fixed effect was used for the analysis since the heterogeneity has been considered low. The results of this sub-group analysis are presented in **Figure 4**. The first subgroup was based on the participants with acute stroke [26–29] while the second subgroup was based on the participants with chronic stroke [24,25]. Overall, a significantly higher effect was observed in the experimental group among acute stroke patients (n=4; MD 3.66; 95%CI: 2.08, 5.24; p<0.00001). Meanwhile, a significantly lower effect was observed in the experimental group among chronic stroke patients (n=2; MD -1.54; 95%CI: -2.28, -0.81; p<0.0001).

Duta et al. Narra X 2023; 1 (1): e73 - http://doi.org/10.52225/narrax.v1i1.73

Chronic stroke



Acute stroke

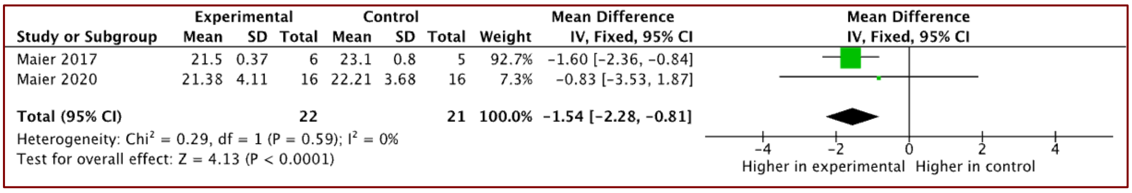


Figure 4. Forest plot of the effects of exergame therapy on global cognitive among acute and chronic stroke patients.

Attention, memory, executive function, and visuospatial ability

Attention, memory, executive function, and visuospatial ability were only reported in two studies participated by chronic stroke patients [24,25]. The results of the random effect meta-analysis for attention, memory, executive function, and visuospatial ability outcomes have been presented in Appendix C. Based on all the used assessment tools, the effects of exergame rehabilitation were not statistically significant as compared to the conventional rehabilitation ($p>0.05$).

Publication bias

Funnel plot were meant to detect the publication bias accurately if only the number of included studies was more than ten, as suggested previously [30,31]. Since only six studies were included in this present review (n<10), the test for publication bias was not feasible.

Discussion

Based on the limited number of evidence retrieved from the systematic review, it is found that exergame-based rehabilitation is significantly more effective to improve cognitive impairment as compared with conventional rehabilitation based on global cognitive scores among elderly patients with acute stroke. Exergames have a dual-task device as a combination of motor activity and simultaneous cognitive training. Physical activity can induce neurogenesis and prolong the duration of cognitive function by increasing cerebral blood flow to the hippocampal dentate gyrus [32]. A previous study has witnessed that VR induces reactivation of the overall frontal cortex to boost cognitive function [33]. Moreover, the cognitive training modulated perception, prediction, and executed goal-oriented movements, which improved cognition by enhancing decision/priority-making (executive functions), visuospatial perception, spatial attention, and memory, such as working memory load and memory-delayed recall [25,34]. However, it is less effective in the case of chronic stroke.

The superior effectiveness of exergame-based rehabilitation has been corroborated by a meta-analysis study on patients with mild cognitive impairment or dementia [35]. Nonetheless, the results obtained herein are contrary to those reported by two meta-analysis studies of patients with stroke-associated cognitive impairment [12,13]. The foregoing studies suggested an insignificant difference between the cognitive function outcomes obtained in experimental (receiving computer- or virtual reality-based rehabilitation) and control groups [12,13]. Each of the two studies had the I^2-value of more than 50% suggesting that the analyzed studies were highly non-homogenous [12,13]. Hence, the difference between this present study and the reported study could be ascribed to the absence of sub-group analysis separating the acute and chronic stroke patients [12,13]. One of the included studies in the previous meta-analysis [12] was participated by chronic stroke patients, contributing to negative standard MD favoring the control group [36]. In line with our present study, the two included studies reporting higher MoCA values in the control group are those participated by chronic stroke patients [24,25]. An explanation for this is the relatively longer neurological sequelae (such as reduced muscle contraction and force generation) experienced by chronic stroke patients as compared to those with acute stroke [37]. This condition becomes a constraint for the chronic stroke patient to fully follow the game instruction, hence less optimal benefit can be gained. Furthermore, the long-term progression of stroke is associated with increased blood barrier brain and impaired mechanisms of clearance by neurotoxic molecules, which leads to neurodegeneration [38]. This situation combined with older age and the long period of stroke is a significant risk factor for rapidly acute decline in global cognition, new learning, verbal memory, and executive function [39,40]. It is worth mentioning that a short training period (6 weeks), which led to adaptation difficulties, might contribute to this less effectiveness of exergame among chronic patients. Physical adaptation to exercise usually occurs after 6–8 weeks [41]. Hence, future studies should be carried in a longer training duration (≥8 weeks).

On the other side, exergames could be implemented in treating patients with stroke, especially in the acute stroke [42]. Exergames are easy for stroke patients to use after receiving instruction and getting familiarized with exergames. Visualization development in exergame is thought to offer more engagement with participants' cognitive attention and their interest to explore exercise tasks [43]. Further, rehabilitative exergame could be carried out at home with hired caregivers. Nonetheless, some concerns on its ethical implications persist, especially among elderly [44]. These include digital addiction, lack of privacy, and security threats [44].

Several limitations should be acknowledged in the methodology of our study that might lead to biased systematic review and meta-analysis. We only included English-written papers and three papers were not available to us in full-texts. However, the present study remains significant owing to the inclusion of a large pool of patients and most updated records.

Conclusion

Exergame-based rehabilitation is more effective than conventional therapy in ameliorating the global cognitive for elderly patients with acute stroke, but contrarily less effective for those with chronic stroke. It is worth noting that the result should be further proven by comparing both subjects (acute versus chronic strokes) under the same study design. We also recommend future studies to thoroughly evaluate the change in cognitive impairment; not only based on MoCA but also on other assessments on attention, memory, language, executive function, and visuospatial ability.

Ethics approval

Not required.

Acknowledgments

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Conflict of interest

All the authors declare that there are no conflicts of interests.

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Underlying data

All data underlying the results are available as part of the article and no additional source data are required. Supplementary files are available on Figshare (https://doi.org/10.6084/m9.figshare.22713460.v1).

How to cite

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References

1. Feigin VL, Stark BA, Johnson CO, *et al.* Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol 2021;20(10):795–820.
2. Gorelick PB. The global burden of stroke: persistent and disabling. Lancet Neurol 2019;18(5):417–8.
3. Chaurasia RN, Sharma J, Pathak A, *et al.* Poststroke cognitive decline: a longitudinal study from a tertiary care center. J Neurosci Rural Pract 2019;10(03):459–64.
4. Al-Qazzaz NK, Ali SH, Ahmad SA, *et al.* Cognitive impairment and memory dysfunction after a stroke diagnosis: a post-stroke memory assessment. Neuropsychiatr Dis Treat 2014;10:1677.
5. Rost NS, Brodtmann A, Pase MP, *et al.* Post-Stroke Cognitive Impairment and Dementia. Circ Res 2022;130(8):1252–71.
6. Cicerone KD, Goldin Y, Ganci K, *et al.* Evidence-based cognitive rehabilitation: systematic review of the literature from 2009 through 2014. Arch Phys Med Rehabil 2019;100(8):1515–33.
7. De Luca R, Leonardi S, Spadaro L, *et al.* Improving cognitive function in patients with stroke: can computerized training be the future? J Stroke Cerebrovasc Dis 2018;27(4):1055–60.
8. Oh Y and Yang S. Defining exergames & exergaming. Proc meaningful Play 2010;2010:21–3.
9. Zheng L, Li G, Wang X, *et al.* Effect of exergames on physical outcomes in frail elderly: a systematic review. Aging Clin Exp Res 2020;32(11):2187–200.
10. Chen CK, Tsai TH, Lin YC, *et al.* Acceptance of different design exergames in elders. PLoS One 2018;13(7):1–22.
11. Mingming Y, Bolun Z, Zhijian L, *et al.* Effectiveness of computer-based training on post-stroke cognitive rehabilitation: A systematic review and meta-analysis. Neuropsychol Rehabil 2022;32(3):481–97.
12. Wiley E, Khattab S and Tang A. Examining the effect of virtual reality therapy on cognition post-stroke: a systematic review and meta-analysis. Disabil Rehabil Assist Technol 2020;17(1):50–60.
13. Zhang B, Li D, Liu Y, *et al.* Virtual reality for limb motor function, balance, gait, cognition and daily function of stroke patients: A systematic review and meta-analysis. J Adv Nurs 2021;77(8):3255–73.
14. Lange B, Flynn S, Proffitt R, *et al.* Development of an Interactive Game-Based Rehabilitation Tool for Dynamic Balance Training. Top Stroke Rehabil 2010;17(5):345–52.
15. de Bruin ED, Schoene D, Pichierri G, *et al.* Use of virtual reality technique for the training of motor control in the elderly. Z Gerontol Geriatr 2010;43(4):229–34.
16. Moher D, Liberati A, Tetzlaff J, *et al.* Research methodes and reporting. BMJ 2009;8:332–6.
17. Page MJ, McKenzie JE, Bossuyt PM, *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;n71.
18. Stoll CRT, Izadi S, Fowler S, *et al.* The value of a second reviewer for study selection in systematic reviews. Res Synth Methods 2019;10(4):539–45.
19. Sharma D, Ulaganathan SP, Sharma V, *et al.* Deep Meta Tool: GUI tool to obtain Mean and Standard Deviation (SD) from Median and Interquartile range (IQR). Res sq 2021; PPR385417.
20. Higgins J, Altman D and Sterne J. Chapter 8: Assessing risk of bias in included studies. Cochrane Handb Syst Rev Interv version 520 (updated June 2017). 2017; Available from: www.training.cochrane.org/handbook. Accessed: 15 Jan 2023
21. Maher CG, Sherrington C, Herbert RD, *et al.* Reliability of the PEDro Scale for Rating Quality of Randomized Controlled Trials. Phys Ther 2003;83(8):713–21.
22. Thorlund K, Imberger G, Johnston BC, *et al.* Evolution of Heterogeneity (I2) Estimates and Their 95% Confidence Intervals in Large Meta-Analyses. Emmert-Streib F, editor. PLoS One 2012;7(7):e39471.
23. The Cochrane Collaboration. Review Manager (RevMan) [Computer program]. Version 5.4. 2020.

24. Maier M, Banuelos NL, Ballester BR, *et al*. Conjunctive rehabilitation of multiple cognitive domains for chronic stroke patients in virtual reality. IEEE Int Conf Rehabil Robot 2017;2017:947–52.
25. Maier M, Ballester BR, Leiva Bañuelos N, *et al*. Adaptive conjunctive cognitive training (ACCT) in virtual reality for chronic stroke patients: a randomized controlled pilot trial. J Neuroeng Rehabil 2020;17(1):42.
26. Rogers JM, Duckworth J, Middleton S, *et al*. Elements virtual rehabilitation improves motor, cognitive, and functional outcomes in adult stroke: evidence from a randomized controlled pilot study. J Neuroeng Rehabil 2019;16(1):56.
27. Ozen S, Senlikci HB, Guzel S, *et al*. Computer Game Assisted Task Specific Exercises in the Treatment of Motor and Cognitive Function and Quality of Life in Stroke: A Randomized Control Study. J Stroke Cerebrovasc Dis 2021;30(9):105991
28. Gueye T, Dedkova M, Rogalewicz V, *et al*. Early post-stroke rehabilitation for upper limb motor function using virtual reality and exoskeleton: equally efficient in older patients. Neurol Neurochir Pol 2021;55(1):91–6.
29. Chatterjee K, Buchanan A, Cottrell K, *et al*. Immersive Virtual Reality for the Cognitive Rehabilitation of Stroke Survivors. IEEE Trans Neural Syst Rehabil Eng 2022;30:719–28.
30. Thornton A. Publication bias in meta-analysis its causes and consequences. J Clin Epidemiol 2000;53(2):207–16.
31. Terrin N, Schmid CH, Lau J, *et al*. Adjusting for publication bias in the presence of heterogeneity. Stat Med 2003 ;22(13):2113–26.
32. Farì G, Lunetti P, Pignatelli G, *et al*. The Effect of Physical Exercise on Cognitive Impairment in Neurodegenerative Disease: From Pathophysiology to Clinical and Rehabilitative Aspects. Int J Mol Sci 2021;22(21):11632.
33. Carrieri M, Petracca A, Lancia S, *et al*. Prefrontal Cortex Activation Upon a Demanding Virtual Hand-Controlled Task: A New Frontier for Neuroergonomics. Front Hum Neurosci 2016;10:53.
34. Zhao Y, Feng H, Wu X, *et al*. Effectiveness of Exergaming in Improving Cognitive and Physical Function in People With Mild Cognitive Impairment or Dementia: Systematic Review. JMIR Serious Games 2020;8(2):e16841.
35. Kim O, Pang Y and Kim J-H. The effectiveness of virtual reality for people with mild cognitive impairment or dementia: a meta-analysis. BMC Psychiatry 2019;19(1):1–10.
36. Oh Y-B, Kim G-W, Han K-S, *et al*. Efficacy of Virtual Reality Combined With Real Instrument Training for Patients With Stroke: A Randomized Controlled Trial. Arch Phys Med Rehabil. 2019;100(8):1400–8.
37. Kuriakose D and Xiao Z. Pathophysiology and Treatment of Stroke: Present Status and Future Perspectives. Int J Mol Sci 2020;21(20):7609.
38. Rost NS, Meschia JF, Gottesman R, *et al*. Cognitive Impairment and Dementia After Stroke: Design and Rationale for the DISCOVERY Study. Stroke 2021;52(8).
39. Lo JW, Crawford JD, Desmond DW, *et al*. Long-Term Cognitive Decline After Stroke: An Individual Participant Data Meta-Analysis. Stroke 2022;53(4):1318–27.
40. Levine DA, Wadley VG, Langa KM, *et al*. Risk Factors for Poststroke Cognitive Decline. Stroke 2018;49(4):987–94.
41. Kraemer WJ, Koziris LP, Ratamess NA, *et al*. Detraining Produces Minimal Changes in Physical Performance and Hormonal Variables in Recreationally Strength-Trained Men. J Strength Cond Res 2002;16(3):373–82.
42. Nguyen A-V, Ong Y-LA, Luo CX, *et al*. Virtual reality exergaming as adjunctive therapy in a sub-acute stroke rehabilitation setting: facilitators and barriers. Disabil Rehabil Assist Technol 2019;14(4):317–24.
43. McDonald MW, Hayward KS, Rosbergen ICM, *et al*. Is environmental enrichment ready for clinical application in human post-stroke rehabilitation? Front Behav Neurosci 2018;12:135.
44. Bhattacharya I, Patil VS and De Sousa A. Ethical Issues in the use of Exergames in the Elderly. Glob Bioeth Enq J 2022;10(2):75–9.