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REVIEW

Rehabilitation applied with virtual reality improves functional capacity in post-stroke patients. A systematic review and meta-analysis

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KEYWORDS
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Abstract Virtual reality (VR) is emerging technologies in the field of rehabilitation of post-stroke patients. The aim of this study was to systematically explore the effects of VR rehabilitation program on functional capacity of stroke patients. We conducted a systematic review and meta-analysis. The searches were carried out in the PubMed/Medline, Web of Science, PEDro and OTSeeker to October 2024. Methodological quality was assessed using the Downs and Black scale and the Version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2) was used to assess risk of bias. A total of 4 studies met the inclusion criteria. The type of VR intervention varied among studies using Wii Fit, ARMEO Spring 1.1, Rehabilitation Gaming System and ArmAble^{TM}. The meta-analysis indicated that the VR group showed statistically significant improvement in functional ability versus control group. The methodological quality mean was moderate quality level. VR interventions seem to be a promising therapeutic system for functional capacity rehabilitation in people with post-stroke.

PALABRAS CLAVE
Lesión cerebral adquirida;
Función;
Independencia;
Neurológico;
Neuroplasticidad

La rehabilitación aplicada con realidad virtual mejora la capacidad funcional en pacientes post-ictus. Una revisión sistemática y un metaanálisis

Resumen La realidad virtual (RV) es una tecnología emergente en el campo de la rehabilitación de pacientes que han sufrido un ictus. El objetivo de este estudio fue explorar sistemáticamente los efectos del programa de rehabilitación con realidad virtual sobre la capacidad funcional de los pacientes con accidente cerebrovascular. Realizamos una revisión sistemática

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y un metaanálisis. Las búsquedas se realizaron en Pubmed/Medline, Web of Science, PEDro y OTSeeker hasta octubre de 2024. La calidad metodológica se evaluó mediante la escala de Downs y Black, y la versión 2 de la herramienta Cochrane de riesgo de sesgo para ensayos aleatorios (RoB 2) se utilizó para evaluar el riesgo de sesgo. Un total de 4 estudios cumplieron los criterios de inclusión. El tipo de intervención de realidad virtual varió entre los estudios que utilizaron Wii Fit, ARMEO Spring 1.1, Rehabilitation Gaming System y ArmAble™. El metaanálisis indicó que el grupo de RV mostró una mejora estadísticamente significativa en la capacidad funcional frente al grupo de control. La media de calidad metodológica fue de nivel de calidad moderado. Las intervenciones de realidad virtual parecen ser un sistema terapéutico prometedor para la rehabilitación de la capacidad funcional en personas que han sufrido un accidente cerebrovascular.

Introduction

Stroke ranks third as a cause of mortality and represents the most predominant clinical syndrome; it is one of the leading causes of significant disability in adults worldwide causing significant impairments in the functional capacity of those affected.[1] There has been a notable decrease in mortality rates among people who suffer strokes in recent decades. This could be attributed to the wide range of rehabilitation treatment alternatives that exist today to address cases of acute stroke. Although mortality has decreased, the numbers of people with neurologically impaired individuals living with considerable disabilities have rigorously increased.[2] Regardless of stroke etiology (i.e. haemorrhagic, ischemic) clinical sequelae are devastating causing impairment of cognitive, social and motor function, that situation results in a greater demand for rehabilitation services, emphasising its utmost importance.[3] Sensitive and motor impairments are common among stroke patients, generating several alteration deficits.[4] These symptoms may cause a reduction in functional capacity described as the ability to perform daily activities.

The rehabilitation of stroke patients is a critical aspect of post-stroke recovery, as it aims to restore lost functional abilities and improve the overall quality of life. According to this perspective, current clinical practice for neurorehabilitation relies on promoting movement learning and plasticity.[5] This type of rehabilitation has the focus on reducing the impact of disease on loss of function and to improve functional independence. Neuroplasticity has been described as the ability to carry out brain reorganization processes by developing new neural connections in the healthy hemisphere adjacent to the injured hemisphere or in the uninjured hemisphere to take over the lost function.[6] Recent literature suggests that to improve the efficacy of rehabilitation intervention is necessary to include the principles of motor learning and enriched environment in a feasible clinical approach. According to motor learning, intensive, repetitive, and fandom practice of functional activity might be required to recuperate neural structures involved in learning process and motor control. Despite advances in rehabilitation techniques, functional recovery following a stroke reins is limited for many patients, underscoring the need for novel and effective therapeutic approaches. A significant boost to facility neuroplasticity during neurorehabilitation intervention, came from the implement of novel methods like virtual reality (VR).[7]

VR rehabilitation program is an innovative form to simulate different environments and situations through a computer that makes it possible for the patient to ''interact'' with a multitude of contexts, objects and people with the render virtual scenario.[8] It has widely become an emerging tool to evaluate and treat several chronic neurological conditions. VR systems involve employing a computer–user interface that simulates a scenario, environment, or action permitting patients to engage through several sensory canals.[8] It allows creating customised rehabilitation programs by applying immersion in computer-generated environments, providing realistic feedback, and improving motivation and engagement in patients.[9] In addition, it has been shown that there are improvements in physical function, balance and gait thanks to VR, positively contributing to both emotional well-being and improving quality of life in terms of health.[9–13] VR has been shown to be effective for rehabilitation in chronic conditions such as chronic and degenerative disorders[14,15]; it is still emphasized that the existing literature is insufficient and further investigation is required.

The scientific evidence supporting the efficacy of VR rehabilitation programs remains inconsistent. While some studies report significant improvements others show minimal or no effect. These discrepancies could be due to the rapid advancement of VR technology, therefore it is crucial to update and synthesize the available evidence to better understand the effectiveness of VR rehabilitation programs for improving functional capacity in stroke patients.

Over the years, countless studies[16–20] have explored this topic, nevertheless to our knowledge no comprehensive systematic review and meta-analysis have yet been conducted to provide a clear and conclusive evaluation of VR rehabilitation's impact on functional capacity outcome. Given that there are discrepancies about the use of VR technology in stroke patients, which limits the clinical decision-making by health professionals as well the continuous progress of this, it is considered relevant, substantiated and necessary to carry out a systematic review of the literature available. By updating and synthesizing existing evidence, we aim to systematically explore the effects of VR rehabilitation programs on functional capacity of stroke patients, in order to provide valuable insights that can guide clinical practice, inform future research, and ultimately contribute to better rehabilitation outcomes for stroke survivors. For that, we formulated the following research question: in stroke patients, how does a VR rehabilitation program compare to conventional rehabilitation (without VR) or no intervention in improving functional capacity according to evidence from randomized controlled trials?

Methods

Design and registration

This systematic review follows the updated guideline for the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA)[21] and the Cochrane[22] recommendations. This review was registered in the International Prospective Register of Systematic Reviews (PROSPERO Registration: CRD42023469043).

Eligibility criteria

The criteria for inclusion and exclusion in this review were determined in accordance with the PICOS principles (population (P), intervention (I), comparison (C), outcome (O), and study design (S)), which facilitates the studies selection process to enable the extraction of the most relevant studies. The inclusion criteria were as follows:

- Population (P): stroke survivors aged 18 years or older.
- Intervention (I): VR/videogame therapy was considered according to the definition (utilizing computer technology to establish and sustain an environment while representing the user's physical presence within it, enabling the user to engage and interact with the environment) provided by the MeSH term.
- Comparison (C): conventional rehabilitation, placebo or waist list. Conventional rehabilitation refers to any therapeutic approach used in patient recovery, excluding VR/video game therapy.
- Outcome (O): functional capacity. According to previous literature,[23] functional capacity refers to a person's ability, under controlled conditions, to perform tasks and activities that are necessary or desirable in their lives.
- Study design (S): randomized control trials were included in this systematic review.

Search strategy

The searches were carried out in four databases: PubMed/Medline, Web of Science, PEDro and OTSeeker to October 2024. The search strategy integrated controlled vocabulary terms and freely chosen words found in the title or abstract related to the specified concepts of VR, rehabilitation, neurorehabilitation, and stroke. After checking and validating our PubMed/Medline search strategy using the capture-recapture technique as well as evaluating retrieval of known items, we use in other databases the search strategy translated, modifying the controlled vocabulary as appropriate. We also explored the reference list and performed citation searching of included studies to find other possibly relevant studies. The search strategy was created according to the recommendations of our librarians. MeSH terms, natural terms and Boolean operators were combined in the search equation (Appendix 1).

Selection process

Database search results according to inclusion criteria were imported into Mendeley Desktop Software. Duplicated and following study designs were excluded: systematic reviews, meta-analysis, book chapters, conference papers, qualitative studies and abstracts, retrospective, cross sectional, observational, case reports, case series and studies and pilots' studies all of which lack reported results. The rest of the abstracts were screened to exclude articles comparing two virtual reality groups and with no control groups. A comprehensive review was conducted on the full texts of the remaining articles to verify their compliance with the inclusion criteria. Two investigators independently assessed articles for eligibility for inclusion.

Data extraction and management

Data on participants, interventions, outcome measures and results were extracted by two reviewers independently for each version of the review. The information was recorded on a data extraction form.

Study risk of bias assessment

The assessment of bias risk (RoB) was conducted using the Cochrane Collaboration RoB 2.0 tool.[22] This tool encompasses five domains: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported results. For each judgment of bias risk, the response options include: (1) low risk of bias; (2) some concerns; and (3) high risk of bias.

Methodology quality assessment

The evaluation of the methodological quality of the incorporated studies was conducted utilizing the Downs and Black scale (see Table 1).[24] This tool consists in a checklist of 27 items owed into five subscales according to the reporting, the external validity, the bias, the confounding and the power. The final question underwent a modification according to previous studies, changing from a 5-point scoring system to a binary scale or 0 or 1. A score of 1 was assigned if the item was reported in the study and 0 was

Table 1 Methodological quality of the included studies.

Authors (year)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Total 28
Morone et al. (2014)	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0	0	1	1	20/27
Taveggia et al. (2016)	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	21/27
Ballester et al. (2017)	1	1	1	1	0	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	0	0	1	19/27
Sulfikar Ali et al. (2024)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	27/27
Sultan et al. (2023)	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	22/27
Huang et al. (2024)	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	23/27

assigned when the question addressed was not reported. The score ranges from 0 to 28 points, categorising studies as ''excellent'' (24–28 points), ''good'' (19–23 points), ''fair'' (14–18 points), or ''poor'' (less than 14 points).[24]

Meta-analysis

The synthesis and analysis of the chosen articles' data were carried out utilizing the Review Manager (RevMan) 5.4.1 software, developed by the Cochrane Collaboration.[22] According to Cochrane Collaboration,[21] a meta-analysis was performed when a minimum of three or more articles compared the effects of VR rehabilitation program over the control group reported post-intervention means and standard deviations (SD) for the outcomes of this study, functional ability. If only confidence intervals (CIs) or standard error (SE) were present, we calculated SD (using the Review Manager calculator). For studies lacking sufficient information, authors were contacted via email in order to obtain these data.

The overall mean effect sizes were investigated through the application of either fixed-effects models or random-effects models. The I^2 statistical heterogeneity test was used to assess statistical heterogeneity. Fixed-effects models were applied when I^2 values were below 50%. The results of the meta-analysis comparing the VR intervention with control group treatment were presented using forest plots. Forest plots were visually scrutinized to pinpoint potential outlier studies. Outliers were removed using a sensitivity analysis.

Results

In total $n = 196$ articles were included after the first electronic database research. After removing duplicates, a total of $n = 162$ articles were subjected to a thorough review, resulting in $n = 78$ articles remaining for evaluation. After title and abstract review, $n = 8$ articles were selected for full text reading. Finally, a total of 6 articles[25–30] fulfils the inclusion criteria and were included into this review. Fig. 1 illustrates the flowchart depicting the various stages of the study selection process.

Table 2 summarizes study characteristics ordered chronologically from most to least recent and following alphabetical order, including number of participants, age, sex, and rehabilitation intervention description, instrument to evaluate functional capacity and results, post intervention and follow up.

Records included in this systematic review consisted of $n = 6$ randomized controlled trials including a total of 340 patients with stroke, 173 patients were examined in the experimental group and 167 in the control group. The mean age of the participants in the experimental group ranged from 58 to 73 and from 61 to 68 years in the control group. A total of five studies[25–28] reported participant sex, with the majority of participants being female. The six studies[25–30] examined the effect of VR rehabilitation programs compared to conventional intervention.

VR rehabilitation program was administered for 20–60 min per session, excluding the length of warm-ups, cold-downs, and stretching if the breakdown was provided. The frequency of intervention ranged from

Table 2 Studies characteristics included in this systematic review.

Study author (year)	Participants				Intervention			Functional capacity measure instrument	Results
	n total	Gender (women)	Age (years) mean ± SD or range	Time since stroke	EG	CG	Duration and frequency		
Morone et al. (2014)	50	NR	18–85 EG: 58.36 ± 9.62 CG: 61.96 ± 10.31	From 3 weeks to 2 months	Balance training with Wii Fit + Conventional therapy	Conventional therapy focuses on balance	EG: 12 s; 20 m; 3t/w; 4 w CG: 12 s; 20 m; 3t/w; 4 w	BI	Significant differences improvement intragroup after intervention for both groups ($p \leq 0.001$) Statistically significant differences between groups in favor to EG post intervention ($p < 0.001$) and 1-month follow up ($p < 0.001$).
Taveggia et al. (2016)	54	EG: NR CG: NR	18–80 EG: 73 ± 10 CG: 68 ± 13	Between 0.5 and 12 months	Robotic technology and VR using ARMEO Spring (1.1) + Conventional therapy based on the Bobath concept (1.2)	Conventional therapy based on the Bobath concept	EG: 30 s; (1.1) 30 m + (1.2) 30 m; 5t/w; 6 w CG: 30 s; 60 m; 5t/w; 6 w	FIM	No significant improvement intragroup after intervention for both groups. Statistically significant differences between groups in favor to EG post intervention ($p = 0.009$) and 1-month follow up ($p = 0.037$).
Ballester et al. (2017)	35	EG: 9 (53%) CG:12 (67%)	45–85 EG: 65.05 ± 10.33 CG: 61.75 ± 12.94	More than 12 months after the stroke	VR-based system for motor rehabilitation	Conventional therapy (general exercises)	EG: 26 m 40 s EG; sessions ranged between 1 to 3 per day; 5t/w; 3 w; CG: 20 m; min 1 s/d; 5t/w; 3 w	BI	No significant improvement intragroup after intervention for both groups. No significant differences between groups after intervention and 2-month follow up

Table 2 (*Continued*)

Study author (year)	Participants				Intervention			Functional capacity measure instrument	Results
	n total	Gender (women)	Age (years) mean ± SD or range	Time since stroke	EG	CG	Duration and frequency		
Sulfikar Ali et al. (2024)	120	EG: 14 (21.85%) CG: 15 (26.7%)	EG: 54.4 ± 11.7 CG:57.7 ± 10.9	From 22.5 to 30 days	Gamified upper limb training with ArmAble^{TM}	Upper limb task-based training that included daily function tasks	EG: 12 s; 45–60 m; 6t/w; 2 w CG: 12; 45–60 m; 6t/w; 2 w	FM-UE	Significant improvement intragroup ($p < 0.001$) and between group ($p < 0.001$) after intervention in favor of EG group. Significant differences between groups 6 weeks follow up ($p = 0.003$)
Sultan et al. (2023)	41	EG:20 CG:21	EG: 58.6 ± 3.3 CG:58.1 ± 4.3	More than 3 months after the stroke	Exergaming by Xbox Kinect	General exercises comprising balance training, upper limb strengthening, and core strengthening	EG: 24 s; 30 m; 3t/w; 8 w CG: 24 s; 30 m; 3t/w; 8 w	FIM	Significant improvement intragroup ($p < 0.001$) and between group ($p < 0.001$) after intervention in favor of EG group (Cohen's $d > 1.0$)
Huang et al. (2024)	40	EG:20 (50%) CG: 20 (50%)	EG: 63.3 ± 14.3 CG: 65.1 ± 6.1	Within the last month	Conventional therapy + Immersive VR (imVR)	Conventional occupational therapy and physiotherapy	EG: 15 s; 60 m; 5t/w; 3 w CG: 15 s; 60 m; 5t/w; 3 w	BI	Significant improvement intragroup (Zp < 0.001) and between group ($p = 0.048$) after intervention in favor of EG group. Significant differences between groups 12 weeks follow up ($p = 0.019$)

Abbreviations: ARAT: action research arm test; BI: Barthel Index; CG: control groups; EG: experimental group; FIM: Functional Independence Measure; FM-UE: Fugl-Meyer Assessment-Upper Extremity; NR: no reported; VR: virtual reality.

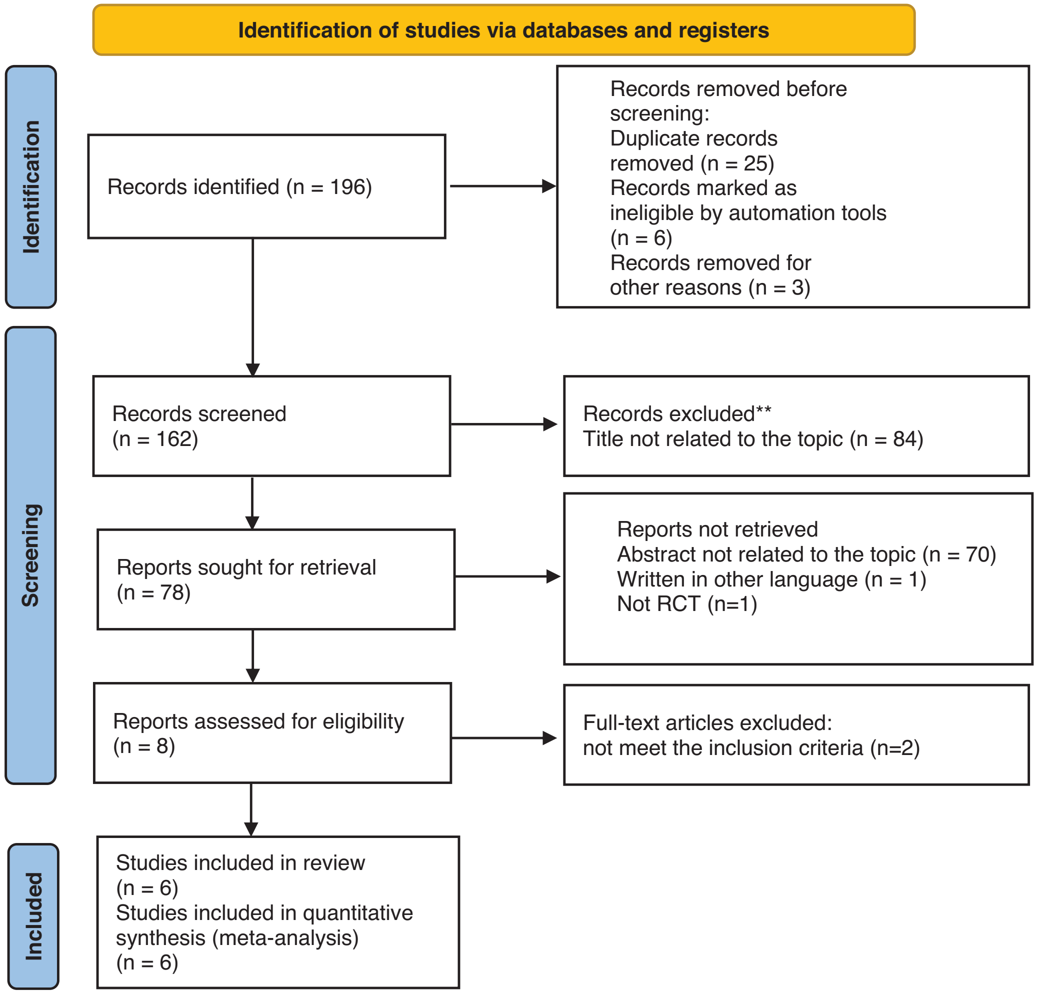

Figure 1 Flow diagram of literature selection in this systematic review.

two to five days a week, and the total duration of the interventions ranged from 3 to 8 weeks. The rehabilitation intervention varied from a total of 12–30 sessions between studies. The type, duration an frequency of VR intervention varied among studies included in this systematic review. Different devices were used for rehabilitation across the studies, including various systems such as: ArmAble™,[25] Rehabilitation Gaming System,[26] Wii Fit,[27] ARMEO Spring 1.1,[28] Immersive Virtual Reality,[29] and Xbox Kinect.[30] The instruments used to assess function capacity among the RCT included in this systematic review were Barthel Index,[26,27,29] Functional Independence Measures[28–30] and Fugl-Meyer Assessment-Upper Extremity.[25]

The interventions for the control group were described such as conventional treatment. However, just two interventions focused on general exercises,[26,30] other on balance exercises,[27] other implement a conventional treatment focuses on Bobath principles,[28] other applied occupational therapy and physiotherapy[29] and the last one[25] implement occupational therapy tasks at home, which consisted of horizontal and vertical stacking and unstacking of plastic cups, using left and right hand consecutively to match the movements trained during the task. The overall intervention effect was large for functional capacity (SMD 0.26; 95% CI: 0.04–0.48, $p = 0.02$). The level of heterogeneity was considerable ($I^2 = 88\%$). Fig. 2 illustrates the meta-analysis for functional capacity. A sensitivity analysis was carried out due to the strange data presented by Sulfikar Ali et al. and Sultan et al. obtained a reduction of the level of heterogeneity ($I^2 = 36\%$) and a significant effect in favour of experimental group (SMD 0.83; 95% CI: 0.52–1.14, $p < 0.001$).

The mean Downs and Black scale score was 22 out 28, which corresponds with a moderate quality level (see Table 1). All studies presented similar scores. Studies did not meet the criteria of blinding the subjects and therapist as this does not seem possible with respect to treatment. In addition, blinding of assessors was not reported. Therefore, a negative score given for this item.

The risk of bias assessment for each study included in the analysis is shown in Fig. 3. The method used for randomisation process generation was reported in 5 of the 6 studies,[25,27–30] while one study presented risk of bias assessment mainly relate to bias due to deviations from the intended intervention.[26] Only one study was judged with some concerns in relation to missing outcome data.[26] All included studies were judged as having a ''low risk of bias'' in term of ''measurement of the outcome''.[25–30] Only

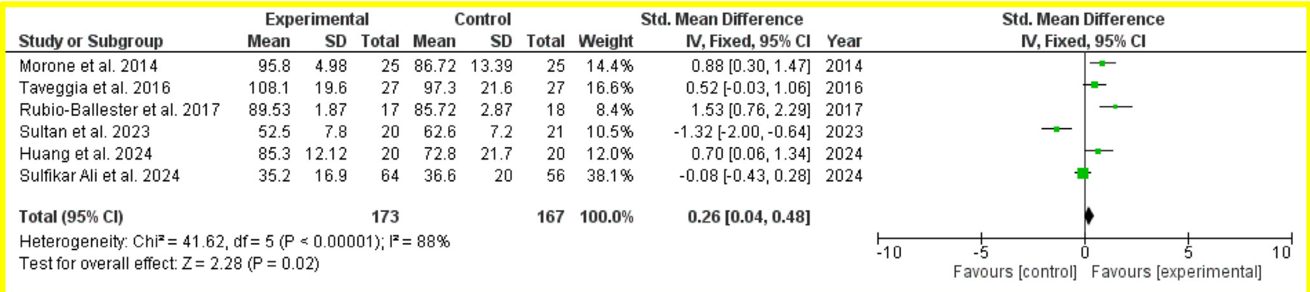

Figure 2 Forest plot of effects of virtual reality on functional capacity.

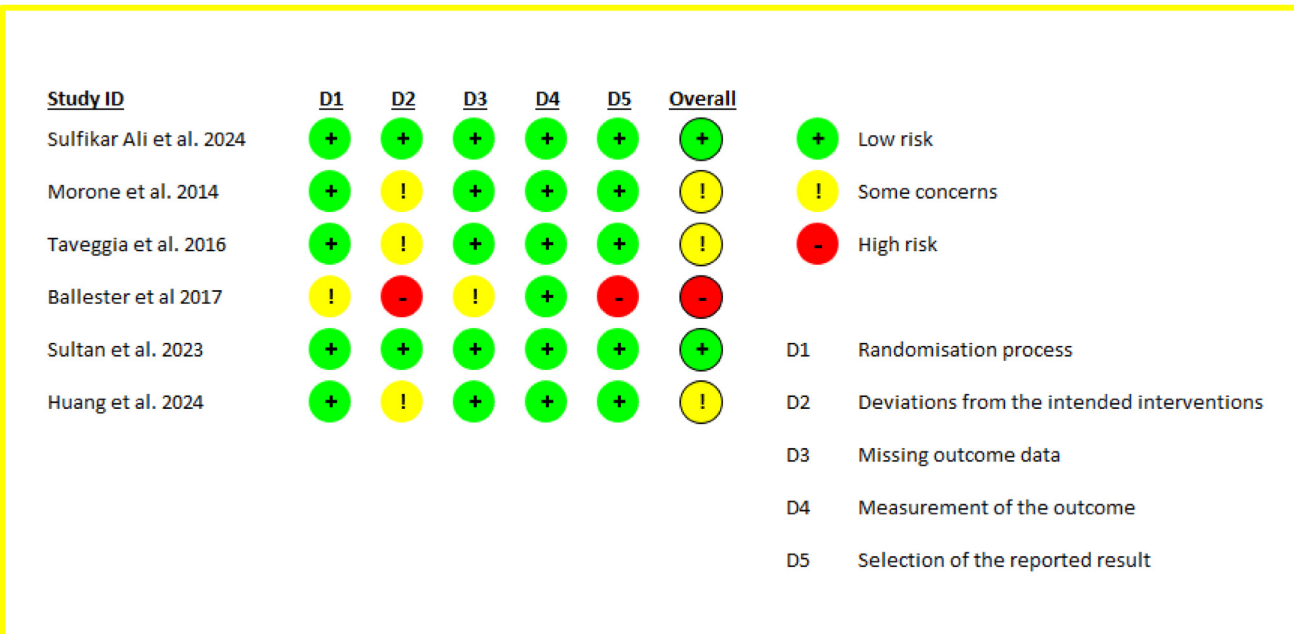

Figure 3 Analysis of the risk of bias in accordance with Cochrane Collaboration guideline.

one study showed high risk of bias due to selection of the reported results.[26]

Discussion

The aim of this study was to systematically explore the effects of VR rehabilitation programs on functional capacity of stroke patients. The entirety of 6 RCTs[25–30] integrated this systematic review and all of them were included in the meta-analysis. Relying on the combined data of the collected studies, VR rehabilitation programs in comparison with control groups, which received different conventional rehabilitation programs, showed statistically significant positive effects in favour of EG on functional capacity. It is relevant to mention that no study, included in this systematic review and meta-analysis, refers to adverse and/or detrimental effects arising from VR rehabilitation programs. The control groups underwent conventional rehabilitation programs denominated post-stroke care, including in-person conventional exercise, with an equivalent duration of intervention time (active control), or received routine care without supplementary intervention (passive control).

Although VR systems were not originally designed for rehabilitation purposes, extensive research and collaboration among neurorehabilitation teams and users have led to significant developments. VR rehabilitation programs has become a new tool widely employed across rehabilitation of neurological conditions.[8,31] VR is an interactive technology that has emerged in recent years as a promising tool for neurorehabilitation in comparison with traditional rehabilitation interventions.[32] It can offer an interactive simulated context, which mostly includes feedback in auditory and visual effects that mimics the real world and engages stroke patients in task-oriented, repetitive, and intensive training. Previous systematic reviews and meta-analyses have evidence that VR technology is showing promise as a way to improve health outcomes such as cognitive, sensitive and motor function in stroke patients.[7,33] Conventional or usual intervention may become tedious, leading to decreased motivation and treatment adherence over time, while VR rehabilitation program may provide a more exciting, personalised, richer environment and engaging approach to intervention than traditional rehabilitation. Therefore, VR is a beneficial form of intervention to rehabilitate and train patients with stroke. The outcomes of this analysis align with the conclusions drawn from earlier research, substantiating that VR compared with conventional rehabilitation approaches, significantly improve function ability. Functional capacity recovery after brain damage is heavily dependent on motor learning and experience-dependent neuroplasticity, stimulating dendritic sprouting, fostering the formation of new synapses, modifying existing synaptic connections, and organizing neurochemical construction.[33] It could also be argued that most VR interventions rely on readily available, off-the-shelf games that are not specifically designed for stroke patients.[34] While this can be advantageous in terms of accessibility for a broader range of patients, it may also mean that the interventions lack the specificity and customization needed for stroke rehabilitation.

Individuals experiencing a stroke encounter brain damage that alters learning processes, stemming from shifts in both neuronal and non-neuronal connectivity in response to reorganization and cell death.[5,7] The neuroplasticity process can occur due to numerous causes, so its nature and scope may vary. Neuroplasticity refers to the capacity of the central nervous system to adapt both functionally and structurally in reaction to experiences. It summarises the dynamic capacity for change in the nervous system throughout life, encompassing the interplay between two phenomena: synaptic pruning and Hebbian neural interactions.[5] The present comprehension of neural plasticity holds relevance for rehabilitation, and these insights have been applied in the context of stroke rehabilitation. Based on extensive clinical studies within the field, VR has been identified as a catalyst for experience-dependent neural plasticity and functional recovery. To maximize effectiveness, it is recommended to employ repetitive, intensive, and task-specific practices that are salient to the individual. In addition, training environments could be enriched thanks to VR rehabilitation programs, thereby providing an explanation for how VR rehabilitation programs might impact neuronal plasticity. An enriched environment has the capacity to promote neuronal plasticity linked to the experience in stroke, showing its behavioural, cellular and molecular effects.

Previous studies have reported that VR rehabilitation leads to higher levels of satisfaction and motivation.[35,36] The enthusiasm of participants during the experimental intervention plays a crucial role in enhancing their motivation, fostering greater engagement, positive effects of rehabilitation and encouraging sustained effort throughout the process. This could also be considered a strength of VR-based interventions, as the immersive nature of the experience may shift participants' focus away from their physical limitations and toward the enjoyment of the game.

As no previous studies have explored the impact of VR interventions on functional capacity in stroke, this study is crucial as it aims to fill a significant gap in the literature. By investigating this area, it could provide valuable insights into the effectiveness of VR interventions, potentially offering new rehabilitation strategies that could improve functional outcomes for stroke survivors. Moreover, the findings could guide future research and clinical practitioners, paving the way for more targeted and personalized interventions that better address the needs of stroke patients.

Limitations

This study is not exempt from limitations. First, the number of RCTs of included and sample size are limited due to the strict eligibility criteria established and the search strategy. It should be mentioned as a significant limitation that the search strategy was conducted to search exclusively within the titles, which may have restricted the comprehensiveness and scope of the results obtained. This limitation may have led to the exclusion of relevant studies that did not clearly convey their content in the titles and abstracts, thereby reducing the number of studies included. Nevertheless, the topic remains highly relevant, and it is essential to continue conducting studies to gain a deeper understanding of how VR determines functional capacity in stroke patients. Second, the VR rehabilitation programs are very diverse from each other, from the time and frequency to the outcome evaluation scales adopted in the studies. Comparing results between studies was very challenging due to this variety. Consequently, it has not been possible to firmly conclude about the benefits of this VR rehabilitation program compared to conventional rehabilitation programs, despite the fact that studies provide findings on improvements in functional capacity after the intervention.

Although our analysis has reported positive results, another important aspect to consider is that all measures used in the studies are subjective. This could be seen as a limitation, as incorporating objective measures might lead to more accurate and reliable results.

Furthermore, the samples of the included trials are relatively small, so we estimate low certainty in the measures of effect and statistical power. Moreover, the methodological quality of the included studies is relatively low, with a moderate overall quality level. The studies, while offering valuable insights, highlight the need for further research with more rigorous methodologies to draw stronger conclusions. For future research, we consider that it would be interesting to conduct studies with more than 25 participants per group.

Conclusion

This study on the efficacy of VR rehabilitation programs applied to the neurorehabilitation of patients with stroke highlights the positive effects of VR to conventional intervention on functional capacity.

VR devices offer a range of benefits that position them as a promising option for physical intervention when compared to conventional methods. These advantages range from avoiding long waiting lists to saving on treatment costs, being attractive, affordable and motivating for the user, etc. More clinical and research studies are needed on the use of VR in stroke patients to guide future clinical practice based on these new rehabilitation opportunities.

Implications for rehabilitation

- VR systems integrate basic and important aspects for driving neuroplasticity (i.e. intensity, repetition, task-oriented training and enriched environment) among stroke patients.

- Rehabilitation programs were applied using different VR systems.
- The duration and intensity of the rehabilitation programs using VR are relevant aspects in its effectiveness.
- Rehabilitation programs ranged from 3 to 6 weeks of duration. It suggests that improving functional capacity in stroke patients is possible in a short period.

Authors' contributions

Conceptualization: ANO, MCV, JMN and AOR
Methodology: AOR, ACP and MCV
Formal analysis: AOR and ACP
Investigation: ACP, JRB, ANO, ICM, and MCV
Data curation: AOR and ICM
Writing – original draft preparation: AOR, ANO and ACP
Writing – review and editing: ACP, ANO, JMN, ICM, JRB, AOR, MCV. All authors have read and agreed to the version of the manuscript.

Ethical considerations

International Prospective Register of Systematic Reviews: PROSPERO Registration: CRD42023469043.

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Conflicts of interest

The authors certify that there are no conflicts of interest with any financial organization regarding the material discussed in the manuscript.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version available at https://doi.org/10.1016/j.rh.2025.100907.

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