Journal of Stroke and Cerebrovascular Diseases 34 (2025) 108161

Contents lists available at ScienceDirect

Journal of Stroke and Cerebrovascular Diseases

journal homepage: www.elsevier.com/locate/jstroke

Exergames for rehabilitation in stroke survivors: *Umbrella review of meta-analyses*

Carla Sílvia Fernandes [a,b,c,*], Bruno Magalhães [e], Filipe Gonçalves [f], Andreia Lima [g], Mafalda Silva [a], Maria Teresa Moreira [h], Célia Santos [d], Salomé Ferreira [i]

[a] *Research Center for Health Technologies and Services (CINTESIS@RISE), Porto, Portugal*
[b] *Porto Higher School of Nursing, Porto, Portugal*
[c] *ADITGames Association, Póvoa de Varzim, Portugal*
[d] *Research Center for Health Technologies and Services (CINTESIS@RISE), Porto Higher School of Nursing, Porto, Portugal*
[e] *School of Health, University of Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal, Comprehensive Cancer Centre (Porto.CCC) & RISE@CI-IPOP (Health Research Network), Porto, Portugal*
[f] *University of A Coruña, Faculty of Health Sciences, Oza, 15071 A Coruña, Spain; APELA -Associação Portuguesa de Esclerose Lateral Amiotrófica, Oporto, Portugal*
[g] *Research Center for Health Technologies and Services (CINTESIS@RISE), Higher School of Health, Polytechnic Institute of Viana do Castelo, Portugal*
[h] *Health Sciences School - Fernando Pessoa, Portugal; CINTESIS@RISE*
[i] *Higher School of Health, Polytechnic Institute of Viana do Castelo, Portugal*

A R T I C L E I N F O

Keywords:
Exergame
Stroke
Stroke rehabilitation
Rehabilitation

A B S T R A C T

Background: It is essential to explore alternative methods to motivate stroke survivors throughout their lengthy rehabilitation journey. Exergames have emerged as promising tools for rehabilitating this demographic.
Objective: We aimed to synthesize the combined evidence from meta-analyses that assessed the effects of exergames in the rehabilitation of stroke survivors.
Methods: The umbrella review was conducted utilizing several databases, including MEDLINE® (Medical Literature Analysis and Retrieval System Online), CINAHL® (Cumulative Index to Nursing and Allied Health Literature), the Psychology and Behavioral Sciences Collection, SPORTDiscus®, and Scopus®. It included studies published until December 2023 without any restrictions based on publication date.
Results: The analysis included 11 meta-analyses involving approximately 9,615 patients, reflecting a growing adoption of exergames in post-stroke rehabilitation since 2015, focusing on using Nintendo Wii. The analyzed studies varied widely in intervention duration (from 1 to 16 weeks) and were applied across different phases of post-stroke rehabilitation, from the acute to the chronic phase. Significant improvements were observed in balance and upper limb functionality, although there was notable methodological heterogeneity and variability in the results.
Conclusions: This study highlights the value of exergames in the rehabilitation of stroke survivors and recommends future research that adopts rigorous methodological designs with clearly specified intervention stages. It underscores the importance of additional qualitative studies to explore the perspectives of patients and healthcare professionals regarding exergames, aiming to refine rehabilitation strategies and enhance the clinical benefits achieved.

Introduction

The rehabilitation of the person after a stroke is a process that can be long and focuses on ensuring a better quality of life, with greater independence and providing emotional support for both the individual and his family.[1] The rehabilitation period can exceed six months.[2,3] Stroke is one of the leading causes of disability in adults, significantly affecting the lives of individuals and their families, as well as the health and economy of a country, requiring that rehabilitation services be planned and delivered effectively, considering the individual needs and

* Corresponding author at: Rua Dr. António Bernardino de Almeida, 4200-072 Porto, Portugal
E-mail addresses: carlafernandes@esenf.pt (C.S. Fernandes), bruno.magalhaes@netcabo.pt (B. Magalhães), amarialima@ess.ipvc.pt (A. Lima), celiasantos@esenf.pt (C. Santos).

https://doi.org/10.1016/j.jstrokecerebrovasdis.2024.108161
Received 27 June 2024; Received in revised form 21 November 2024; Accepted 25 November 2024
Available online 27 November 2024

preferences of stroke survivors, and utilizing the best resources for effective rehabilitation.[1] Post-stroke rehabilitation is divided into distinct phases: the acute phase, the subacute phase lasting from three to six months, and the chronic phase, which continues throughout the patient's life.[1-3] This process aims to improve quality of life and maximize independence continuously.[3,4]

The conventional rehabilitation method can lead to patients' loss of interest in the therapy as it involves repetitive tasks to be done repeatedly every day.[4,5] The conventional rehabilitation method involves control exercises and training, which are manually conducted between therapists and patients.[1] It is known that high-intensity rehabilitation has more significant gains in health.[5] On the other hand, most conventional therapies include exercises that can be exhausting, demotivating and uncomfortable for the patient.[5,6] Gamification strategies are widely used in rehabilitation services, as they are essential in encouraging patients to participate and feel involved in performing the exercises.[2,4-6] Different types of games are already being used in rehabilitation[5,7], among which we highlight exergames.[8] Exergames, which combine digital games and physical exercise, have become a popular alternative to conventional exercise programs and are increasingly used in health fields.[8-11] Exergames integrate physical activity into a video game environment that requires active body movements to control the game.[12] Exergames have emerged as a popular alternative for post-stroke rehabilitation, combining the benefits of conventional rehabilitation with the growing innovations in digital health, fostering motivation and participation through gameplay.[2,5,9] Conventional rehabilitation can be repetitive and tedious, often leading to a lack of motivation and reluctance to adhere to treatment protocols.[3-6] On the other hand, this type of digital platform enables patients to practice exercises independently while receiving immediate feedback on their performance[2,9]

In rehabilitation after a stroke, Exergames can improve balance[9], functional mobility, lower and upper limbs[9,13] and functional independence[9], among other gains[2,4], making it a complementary resource beneficial for rehabilitation.[9,13] They are a viable strategy for stimulating neurocognitive functions and promoting functional training and movement through user-game interaction.[14]

Exergames gained popularity with the launch of the Nintendo Wii® console in 2006.[14,15.] The user and the game interact through wireless control and a force platform, which converts movements into game commands. In most cases, the user is represented by an avatar.[14-16] Several studies have addressed the therapeutic application of exergames, with positive results in different capacities of healthy individuals and in treating patients with physical disabilities, such as those resulting from stroke or other diseases.[14-17]

The Xbox 360 Kinect® console, released in 2009, has also been used in therapy. This Microsoft® console eliminates the user's direct contact with the hardware. Instead, the movements are captured digitally through an infrared camera, allowing the subject to interact with the virtual environment through their body image. [18.]

Given the substantial number of systematic reviews and meta-analyses that have investigated the effects of exergames on the different rehabilitation outcomes of these patients.[2,3,5,9,16], a synthesis of their results is essential to appraise the available evidence on this topic, thus being able to provide relevant information for health professionals.

A preliminary search of the JBI Database of Systematic Reviews and Implementation Reports, the Cochrane Database of Systematic Reviews, PROSPERO, PubMed and CINAHL revealed no other umbrella review published or in progress. Therefore, an umbrella review will expose the best available evidence, evaluate its quality and provide an up-to-date synthesis to enlighten healthcare professionals.

The objective of the current study is to synthesize the combined evidence from meta-analyses that assessed the effects of exergames in the rehabilitation of stroke survivors.

Materials and Methods

The umbrella review protocol is followed by the framework described by the Joanna Briggs Institute[19]. In addition, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were used throughout the process.[20] This umbrella review protocol has been registered in the Open Science Framework. DOI 10.17605/OSF.IO/MT6EC

Eligibility criteria

The mnemonic for our research question used the PICOT strategy: in adults after a stroke (P), the use of exergames (I) compared to conventional treatment (C) for rehabilitation outcomes (O) and systematic reviews (T).

All review studies with meta-analysis were considered eligible if they used exergames in rehabilitating patients after an episode of stroke in all steps of rehabilitation or context. Only scientific articles indexed in the searched databases and English, Portuguese, French or Spanish publications were considered. As exclusion criteria, we considered all publications whose population is under 18, subject to other forms of treatment, not exclusively using exergames, but different types of games. Unpublished (grey) literature, dissertations or studies in books were excluded.

Information sources

The respective descriptors in English were identified, using appropriate search syntax for each of the databases: MEDLINE® (Medical Literature Analysis and Retrieval System Online), CINAHL® (Cumulative Index to Nursing and Allied Health Literature), Psychology and Behavioral Sciences Collection, Sports® and Scopus®. Combining descriptors/medical subject headings (MeSH), subject headings and subject terms were used for each of the databases, using accessible terms and the "*" tool that boosted the search by creating new variations of the same word. (Table 1) The first author conducted the research, the language of the study was English, and publications were considered until December 2023.

Selection of studies

The results of each search in the different databases were imported into the Rayyan® software. Duplicate references were removed, and the initial selection by title and abstract was conducted independently and anonymously by two investigators. The full texts of the remaining references were obtained to decide whether to include or exclude them in the final study based on their full reading per the previously defined inclusion/exclusion criteria. Discrepancies in the final decision to include or not an article will be discussed with a third investigator to reach a consensus. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) model will be used to organize the information resulting from the article selection process.

Assessment of methodological quality

The methodological quality analysis for this study's systematic reviews and meta-analyses was conducted using the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses.[21] In this umbrella review study, the criteria for evaluation were derived from 11 specific points provided by the JBI manual in the Critical Appraisal Instrument for Research Syntheses in Systematic Reviews and included only moderate to high-quality reviews.[21] Before beginning this evaluation process, it was predetermined that only the studies meeting at least 6 of these criteria would be considered eligible to be part of this review. This approach ensures a rigorous selection, aiming to include works that meet a substantial methodological quality standard.

Table 1
Search Strategy.

MEDLINE®
"(((MM "Cerebrovascular Disorders") OR (MM "Cerebral Hemorrhage") OR (MM "Brain Ischemia") OR (MH "Stroke") OR (MM "Brain Infarction") OR (MM "Cerebral Infarction") OR (MM "Subarachnoid Hemorrhage") OR (MM "Brain Injuries") OR (MH "Brain Damage, Chronic") OR (MM "Carotid Artery Diseases") OR (MH "Cerebral Arterial Diseases+") OR (MM "Intracranial Arterial Diseases") OR (MM "Intracranial Arteriovenous Malformations") OR (MH "Intracranial Embolism and Thrombosis+") OR (MM "Intracranial Hemorrhages") OR (MM "Ischemic Attack, Transient") OR ("cerebral haemorrhage") OR ("cerebrovascular accident*") OR ("cerebral vascular event*") OR ("poststroke") OR ("post-stroke") OR ("after stroke")) AND ((MM "Video Games") OR (MM "Games, Recreational") OR (MM "Play and Playthings") OR (MM "Role Playing") OR (MM "Recreation Therapy") OR ("Game*") OR ("Video Game*") OR ("Virtual game*") OR ("Games Recreational") OR ("Boardgam*") OR ("Experimental Game*") OR ("Board gam*") OR ("Gamification*") OR ("serious game*") OR ("Gameboard*") OR ("Simulation Game*") OR ("Mobile game*") OR ("Computer game*") OR ("Internet game*") OR ("Electronic game*") OR ("Roleplaying") OR ("RPG") OR ("Role playing") OR ("Recreational Therapy") OR ("Play and Plaything*") OR ("didactic* tool*") OR ("Exergam*") OR ("playful")) AND (("systematic review" OR "meta-analysis"))AND ((MH "Systematic Review'') OR (MH "Meta Analysis'') OR (TI "systematic review'') OR (TI "meta analysis'') OR (TI "meta-analysis'') OR (TI "metaanalysis") OR (AB "systematic review'') OR (AB "meta analysis'') OR (AB "meta analysis'') OR (AB "metaanalysis)))"
CINAHL®
"((((MM "Subarachnoid Hemorrhage") OR (MM "Brain Damage, Chronic") OR (MM "Brain Injuries") OR (MH "Stroke+") OR (MM "Carotid Artery Diseases") OR (MM "Intracranial Arterial Diseases") OR (MM "Cerebral Arterial Diseases") OR (MM "Intracranial Embolism and Thrombosis") OR (MM "Intracranial Hemorrhage") OR (MM "Cerebral Ischemia, Transient") OR ("brain ischemia") OR ("cerebrovascular accident*") OR ("cerebral vascular event*") OR ("poststroke") OR ("post-stroke") OR ("after stroke") OR ("brain infarction") OR ("intracranial arteriovenous malformation*") OR ("cerebral haemorrhage")) AND ((MM "Video Games") OR (MM "Games") OR (MM "Play and Playthings") OR (MM "Role Playing") OR (MM "Recreation Therapy") OR ("Game*") OR ("Video Games") OR ("Virtual game*") OR ("Games Recreational") OR ("Boardgam*") OR ("Experimental Game*") OR ("Board gam*") OR ("Gamification*") OR ("serious game*") OR ("Gameboard*") OR ("Simulation Game*") OR ("Mobile game*") OR ("Computer game*") OR ("Internet game*") OR ("Electronic game*") OR ("Roleplaying") OR ("RPG") OR ("Role playing") OR ("Recreational Therapy") OR ("Play and Plaything*") OR ("didactic* tool*") OR ("Exergam*") OR ("playful")) AND (("systematic review" OR "meta-analysis"))AND ((MH "Systematic Review'') OR (MH "Meta Analysis'') OR (TI "systematic review'') OR (TI "meta analysis'') OR (TI "meta-analysis'') OR (TI "metaanalysis") OR (AB "systematic review'') OR (AB "meta analysis'') OR (AB "meta analysis'') OR (AB "metaanalysis)))"
Psychology and Behavioral Sciences Collection
"(((DE "CEREBRAL hemorrhage") OR (DE "CEREBRAL ischemia") OR (DE "TRANSIENT ischemic attack") OR (DE "CEREBROVASCULAR disease") OR (DE "SUBARACHNOID hemorrhage") OR (DE "BRAIN damage") OR (DE "BRAIN injuries") OR (DE "ALTERNATIVE treatment for stroke") OR (DE "STROKE patients – Rehabilitation") OR (DE "CEREBRAL infarction") OR (DE "CAROTID artery diseases") OR (DE "INTRACRANIAL arterial diseases") OR (DE "CEREBRAL arterial diseases") OR (DE "CEREBRAL arteriovenous malformations") OR (DE "BRAIN blood-vessel abnormalities") OR ("cerebrovascular disorder*") OR ("cerebral haemorrhage") OR ("brain ischemia") OR ("cerebrovascular accident*") OR ("cerebral vascular event*") OR ("stroke") OR ("poststroke") OR ("post-stroke") OR ("after stroke") OR ("brain infarction") OR ("intracranial arteriovenous malformations") OR ("intracranial embolism and thrombosis") OR ("intracranial hemorrhages")) AND ((DE "GAMES") OR (DE "GAMES & psychology") OR (DE "GAMES & technology") OR (DE"GAMES – Social aspects") OR (DE "GAMES – Therapeutic use") OR (DE "GAMEBOARDS") OR (DE "VIDEO games") OR (DE "BOARD gamers") OR (DE "BOARD games") OR (DE "ROLEPLAYING games") OR (DE "GAMIFICATION") OR(DE "SIMULATION games") OR (DE "ELECTRONIC artificial life games") OR (DE "ELECTRONIC management games") OR (DE "MOBILE games") OR (DE "COMPUTER games") OR (DE "MOBILE games") OR (DE "INTERNET games") OR ("Game*") OR ("Video Games") OR ("Virtual game*") OR ("Games Recreational") OR ("Boardgam*") OR ("Experimental Game*") OR ("Board gam*") OR ("Gamification*") OR ("serious game*") OR ("Gameboard*") OR ("Simulation Game*") OR ("Mobile game*") OR ("Computer game*") OR ("Internet game*") OR ("Electronic game*") OR ("Roleplaying") OR ("RPG") OR ("Role playing") OR ("Recreational Therapy") OR ("Play and Plaything*") OR ("didactic* tool*") OR ("Exergam*") OR ("playful")) AND (("systematic review" OR "meta-analysis"))AND ((TI "systematic review'') OR (TI "meta analysis'') OR (TI "meta-analysis'') OR (TI "metaanalysis") OR (AB "systematic review'') OR (AB "meta analysis'') OR (AB "meta analysis'') OR (AB "metaanalysis)))"
SPORTS
"(((DE "CEREBROVASCULAR disease") OR (DE "CEREBRAL hemorrhage") OR (DE "BRAIN damage") OR (DE "BRAIN injuries") OR (DE "STROKE") OR (DE "CEREBROVASCULAR disease") OR ("cerebrovascular disorder*") OR ("cerebral haemorrhage") OR ("cerebral ischemia") OR ("brain ischemia") OR ("cerebrovascular accident*") OR ("cerebral vascular event*") OR ("subarachnoid haemorrhage") OR ("poststroke") OR ("post-stroke") OR ("after stroke") OR ("brain infarction") OR ("carotid artery diseases") OR ("intracranial arterial diseases") OR ("cerebral arterial diseases") OR ("intracranial arteriovenous malformation*") OR ("intracranial embolism and thrombosis") OR ("intracranial hemorrhage*")) AND ((DE "VIDEO games – Physiological aspects") OR(DE "VIDEO games") OR (DE "ELECTRONIC games") OR (DE "GAMES") OR (DE "EXERCISE video games") OR (DE "SPORTS in video games") OR (DE "INTERNET games") OR (DE "COMPUTER games") OR (DE "ROLEPLAYING games") OR (DE "VIDEO game consoles") OR (DE "VIDEO gamers") OR (DE "EXERCISE video games") OR (DE "EXERCISE" OR DE "VIDEO games") OR (DE "NINTENDO Wii Fit games") OR (DE "BOARD games") OR ("Game*") OR ("Video Games") OR ("Virtual game*") OR ("Games Recreational") OR ("Boardgam*") OR ("Experimental Game*") OR ("Board gam*") OR ("Gamification*") OR ("serious game*") OR ("Gameboard*") OR ("Simulation Game*") OR ("Mobile game*") OR ("Computer game*") OR ("Internet game*") OR ("Electronic game*") OR ("Roleplaying") OR ("RPG") OR ("Role playing") OR ("Recreational Therapy") OR ("Play and Plaything*") OR ("didactic* tool*") OR ("Exergam*") OR ("playful")) AND ((TI "systematic review'') OR (TI "meta analysis'') OR (TI "meta-analysis'') OR (TI "metaanalysis") OR (AB "systematic review'') OR (AB "meta analysis'') OR (AB "meta analysis'') OR (AB "metaanalysis)))"
SCOPUS
"(((TITLE-ABS-KEY (("cerebrovascular disorder*") OR ("cerebral haemorrhage") OR ("cerebral haemorrhage") OR ("cerebral ischemia") OR ("brain ischemia") OR ("cerebrovascular accident*") OR ("cerebral vascular event*") OR ("subarachnoid haemorrhage") OR ("brain damage") OR ("brain injurie*") OR ("stroke") OR ("poststroke") OR ("post-stroke") OR ("after stroke") OR ("brain infarction") OR ("carotid artery disease*") OR ("intracranial arterial disease*") OR ("cerebral arterial disease*") OR ("intracranial arteriovenous malformation*") OR ("intracranial embolism and thrombosis") OR ("intracranial haemorrhage*")) AND TITLE-ABS-KEY (("Game*") OR ("Video Games") OR ("Virtual game*") OR ("Games Recreational") OR ("Boardgam*") OR ("Experimental Game*") OR ("Board gam*") OR ("Gamification*") OR ("serious game*") OR ("Gameboard*") OR ("Simulation Game*") OR ("Mobile game*") OR ("Computer game*") OR ("Internet game*") OR ("Electronic game*") OR ("Roleplaying") OR ("RPG") OR ("Role playing") OR ("Recreational Therapy") OR ("Play and Plaything*") OR ("didactic* tool*") OR ("Exergam*") OR ("playful")) AND TITLE-ABS-KEY (("systematic review'') OR ("Meta Analysis'') OR ("meta-analysis'') OR ("metaanalysis")))"

Data analysis

New analyses were not conducted on the selected reviews due to the various results and tools used. The overlap of primary studies across different meta-analyses is visually displayed through the Overlapping Graph for Overviewing Reviews (GROOVE) tool. We summarized the studied populations and research designs of each, including meta-analysis, primary outcomes, and methodological quality. We conducted a narrative synthesis of the findings from the included meta-analyses, making an indirect comparison to analyze the effects of interventions and explore interpretations that indicate whether there are viable recommendations for clinical practice or ideas for future research. The effect estimates extracted the results of each comparison presented, with the respective 95% confidence interval (standardized mean differences, mean differences, etc.) and heterogeneity (I2), as reported by the authors.

Results

Fig. 1 displays the PRISMA flowchart outlining the literature search and selection process. A total of 11 meta-analyses met the inclusion criteria and underwent full data extraction and quality assessment.[2,9,13,16,22-28]

Characteristics of the included studies

The Table 2 analysis shows that the 11 studies cover 2015 to 2023. The distribution indicates an increase in interest in and research on using exergames in the rehabilitation of stroke survivors, particularly in recent years, starting in 2021. The reviews encompass studies conducted

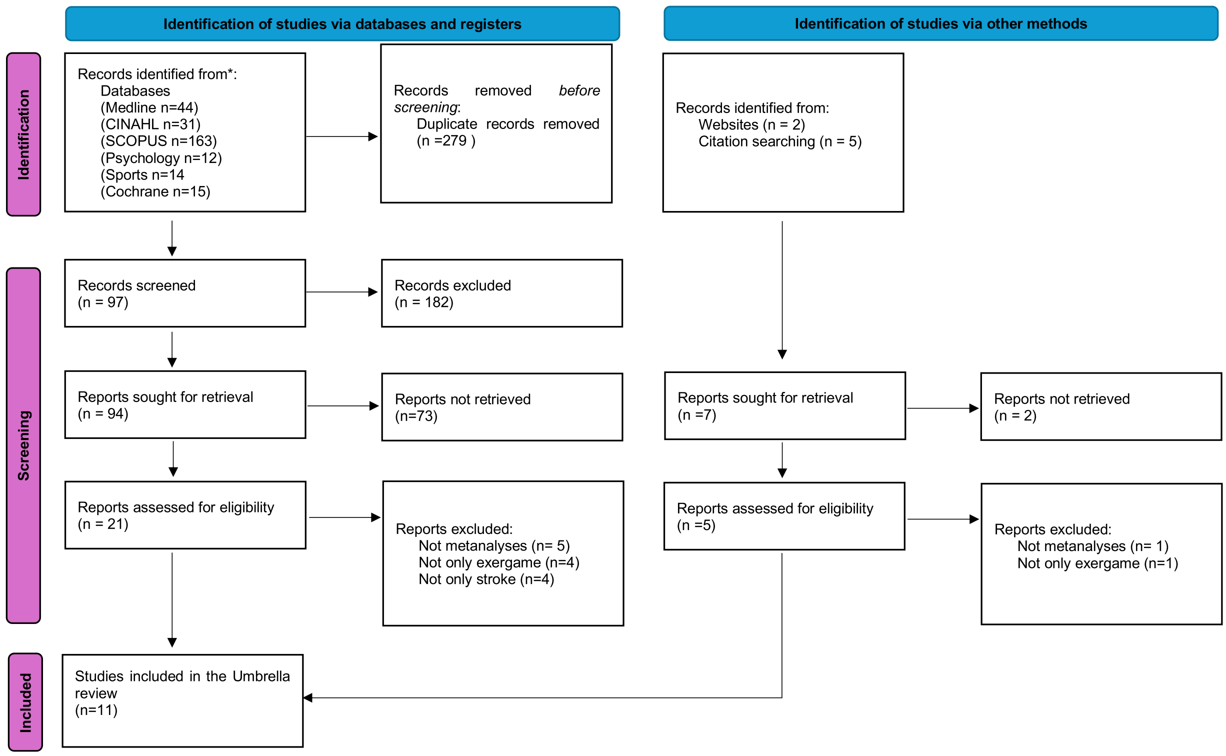

Figure 1. PRISMA 2020 flow diagram.

over this nearly decade-long window, reflecting geographic diversity and a range of objectives in using exergames for stroke rehabilitation. Each study focuses on different aspects of rehabilitation, such as motor function, balance, mobility, and cognitive functions, among others.

Table 3 synthesizes the methodological assessment results of the included studies. The review included all studies; none scored below half of the observed criteria.

The 11 meta-analysis studies include 232 primary studies, of which 138 were utilized in the respective meta-analyses. The degree of overlap is presented in Fig. 2. The Corrected Covered Area (CCA) score was 4.67%, indicating slight overlap. This minimal overlap is significant for the quality of this Umbrella review, as it also emphasizes the large number of works developed on this topic over the last few years and highlights the broad scope of research in this field.

Description of participants

The articles included encompass approximately 9615 participants. The minimum number of participants in the analyzed studies is 166, and the maximum is 1760. As for age, the average age is around 62 years, ranging between 52 and 72 years. In the 11 studies analyzed, including patients from any stage of stroke was the most frequent, demonstrating a comprehensive approach to participant selection. Despite this, a significant emphasis was also placed on selecting patients in the chronic stage of stroke, reflecting a specific interest in long-term recovery after the event (Table 2).

Studies E1[9], E2[16], E5[2], E6[24], E7[21] and E9[26] highlight consistent interest in using exergames in rehabilitation for patients in the chronic phase of stroke. These studies focused exclusively or predominantly on participants in the chronic phase, emphasizing the importance of exploring the long-term effects of rehabilitation interventions for this population.[2,9,16,21,26]

Intervention Characteristics

Regarding the type of exergame used, although the Nintendo Wii is the most mentioned exergame (E1[9], E2[16], E4[23], E6[24], E7[13], E8[25], E9[26], E10[27], E11[28]), the variety of exergames utilized in the interventions is significant, including other popular commercial options from platforms like Xbox (E7[13], E10[27]), and PlayStation (E7[13]). The intervention duration ranges from 1 to 16 weeks, with longer interventions being more frequent (E1[9], E2[16], E3[22], E4[23]; E5[2], E6[24], E8[25], E9[26], E10[27]). The exercise duration in the studies varied significantly, ranging from 20 to 180 minutes per session. Short sessions of 20 to 60 minutes were observed in studies E1[9], E4[21], E6[24], and E9[26], while more extended periods were reported in the study (E7[13]).

Outcomes

Table 4 presents the meta-analyses' outcomes on the included articles, detailing the observed outcomes, the estimated effect with a 95% confidence interval, the degree of heterogeneity (I2), and the P-value. The studies vary in focus, covering aspects such as balance (E1[9], E2[16], E4[23], E6[24], E9[26]) functional independence (E1[9], E2[16], E3[22], E4[23], E10[27]), upper limb motor function (E3[22], E4[23], E5[2], E7[13], E8[25], E11[28]), fall risk (E2[16], E4[23]), hand dexterity (E3[22], E11[28]), quality of life(E3), sensorimotor stroke recovery (E4[23], E10[27]), social participation(E5[2]), mobility, cognitive ability(E10[27], E11[28]), daily living activities (E11[28]), lower limb functional mobility (E1[9]) and emotion(E10[27]). The results show a diversity in the estimated effects, varying in significance and heterogeneity. It is important to note that, for each outcome, various distinct instruments were used, which poses a challenge in aggregating the results. The inability to conduct a meta-analysis of the data due to the variety of instruments used and the heterogeneity of the data suggests that although there is evidence of benefits in certain areas (such as improved balance and motor function, among others), direct comparison and quantitative synthesis of these results are challenging.

Based on the most frequently identified outcomes in studies on using exergames in stroke survivors' rehabilitation, Fig. 3 visually represents the distribution and results of these studies. The results of adequate studies are shown as bars on the right side of the chart (with P-values below 0.05), indicating significant improvements in the evaluations

Table 2
Presentation of Results.

ID	Authors Year Country	Aim	*Characteristics of the Systematic Review"*					*Characteristics of the participants*			*Characteristics of the intervention*		
			Number of Primary Studies	***Meta-analysis***	***Types of included studies***	***Outcomes***	***Period Covered***	***Number***	***Age (mean)***	***Stroke stage***	***Type of Exergame***	***weeks***	***Time***
E1	Chan, et al., 2022[9] Singapore	To evaluate the effectiveness of exergaming on balance, lower limb functional mobility, and functional independence in individuals with chronic stroke**.**	32	27	Randomized controlled trials (RCTs)	Statistically significant small effect sizes favoring exergaming on balance (p=0.004), lower limb functional mobility (p=0.007), and functional independence (p=0.01).	Until January 2021	900	Ranged from 40 to 76.4 years.	Chronic stage, with participants being at least 6 months post-stroke.	Most common Nintendo Wii	1 to 12 weeks.	20 to 60 minutes
E2	Cheok et al., 2015[16] United Kingdom	To investigate the effectiveness of Nintendo Wii compared to no intervention or other exercise interventions in the rehabilitation of adults with stroke.	6	6	Randomized controlled trials (RCTs)	Statistically significant small effect sizes favoring in Wii for the Timed Up and Go test (p=0.05) but not for functional *independence*.	Until July 2014	166	Mean age around 59 years.	Patients with stroke of any stage, primarily chronic stroke.	Nintendo Wii	3 to 12 weeks	5 to 12 hours total
E3	Domínguez-Téllez et al., 2020[22] Spain	To assess the impact of game-based VR interventions on upper limb motor function and quality of life in stroke survivors.	20	15	Randomized controlled trials (RCTs)	Statistically effect Improvement in upper limb motor function (p=0.003) and quality of life (p=0.04).	2008 until 2018	874	Ranged from 54 to 75 years	Stroke survivors without explicit mention of the stroke stage	Various Exergames systems	4 to 12 weeks	30 to 60 minutes
E4	Unibaso-Markaida,& Iraurgi 2021[23] Spain	Systematic review of the use of commercial video games in comprehensive rehabilitation (physical and cognitive) post-stroke.	*40*	*30*	Observational and experimental studies	In observational studies, results favored intervention in terms of functionality (p=0.003) and when measured in the upper limbs (p=0.02). In the experimental studies, results tended to favor the experimental group, only in balance (p=0.02).	2008 until 2020	1149	Ranged from from 46 to 75 years	Patients with stroke of any stage	Most common Nintendo Wii	2 to 12 weeks	20 to 60 minutes
E5	Doumas et al. 2021[2] Belgium	Assess the efficacy of serious games for upper limb (UL) recovery after stroke and investigate the influence of neurorehabilitation principles on game efficacy	51	42	Randomized controlled trials (RCTs)	Statistically effect with Significant improvements in upper limb function (p=0.001), activity (p=0.01), and participation (p=0.005)	Until 2020	1760	Ranged from 49.3 to 76.0 years	Patients with stroke of any stage, mostly chronic stage	Serious games implemented on various technological systems	2 to 12 weeks	Not specified
E6	Ferreira et al, 2018[24] Brazil	Evaluate the effects of interactive video games on functional balance and mobility in poststroke individuals	11	7	Randomized controlled trials (RCTs)	Statistically effect in Functional balance (p=0,01), but no significant improvement was observed in mobility.	2005 until 2016	310	Not specified	Patients with stroke of any stage, mostly chronic stage	Most common Nintendo Wii	4to 12 weeks	20 to 60 minutes
E7	Gelineau et al., 2022[13] France	Assess the effectiveness of upper limb home-based exergaming interventions on activity post-stroke	9	8	Randomized controlled trials (RCTs)	Found no significant difference on upper limb functional with	Until 2021	535	Not specified	Patients with stroke of any stage, mostly chronic stage	Nintendo Wii, Xbox Kinect, PlayStation EyeToy and others	2 to 8 weeks	30 to 180 minutes

(*continued on next page*)

Table 2 (*continued*)

ID	Authors Year Country	Aim	*Characteristics of the Systematic Review"*					*Characteristics of the participants*			*Characteristics of the intervention*		
			Number of Primary Studies	***Meta-analysis***	***Types of included studies***	***Outcomes***	***Period Covered***	***Number***	***Age (mean)***	***Stroke stage***	***Type of Exergame***	***weeks***	***Time***
						exergaming interventions.							
E8	Hao et al., 2023[25] USA	Evaluate the effects of immersive and non-immersive VR on upper extremity functional recovery in stroke patients	20	20	Randomized controlled trials (RCTs)	Statistically effect Upper extremity function (p=0.003) in the following order: head-mounted devices, non-immersive virtual reality systems, Microsoft Kinect, and Nintendo Wii.	Until 2022	813	Not specified	Patients with stroke of any stage, mostly subacute stage	Three types of virtual reality systems, head-mounted devices, non-immersive virtual reality systems, and non-immersive gaming consoles (Nintendo Wii and Microsoft Kinect) were included.	2 to 16 weeks	5 to 48 hours total
E9	Iruthayarajah et al., 2017[26] Canada	To review the effectiveness of virtual reality (VR) interventions for improving balance in individuals with chronic stroke.	20	17	Randomized controlled trials (RCTs)	Significant improvements were found for balance with the Berg Balance Scale-BBS (p<0.001) and Timed Up and Go test-TUG (p<0.001).	Until 2015	469	Ranged from 47.4–to 78.1 years	Chronic (≥6 months post-stroke).	Nintendo® Wii Fit balance board treadmill training and Virtual Reality, and postural training using Virtual Reality	3 to 12 weeks	20 to 60 minutes
E10	Lin et al., 2023[27] China	To assess the effectiveness of virtual reality (VR) games on cognition, mobility, and emotion in elderly stroke patients	29	29	Randomized controlled trials (RCTs) and Pilot Studies	Significant improvements were found for cognitive ability (p=0.03), for mobility (modified Barthel index-MBI p=0.01), Fugl-Meyer assessment- FMA p=0.04), Berg balance scale-BBS p=0.0001, Functional independence measure motor- FIM MOT p=0.0005), and emotion (p=0.02)	2011 until 2022	1311	Ranged from 40 to 74 years	Patients with stroke of any stage	Xbox Kinect, Reh@City, RehabMaster, Nintendo Wii Fit, AmadeoTM, the touch screen, etc.	1 to 12 weeks	15 to 120 minutes
E11	Wang et al., 2022[28] Taiwan	Evaluate the effectiveness of game-based VR systems for upper limb rehabilitation in stroke patients in clinical settings	24	24	Randomized controlled trials (RCTs)	Significant improvements were found for upper limb function (p=0.02) and hand mobility (P=0.013), was not effective for activities of daily living (p=0.117) and cognition(p=0.09	Until 2021	793	Mean age around 72 years	Patients with stroke of any stage	Wii and Kinect devices were commonly used.	1 to 5 weeks	30 to 60 minutes

Table 3
Quality assessment of the included studies by JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses.

ID	Items											Total
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	
E1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	10/11
E2	Y	Y	Y	Y	Y	Y	Y	Y	N	U	U	8/11
E3	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	10/11
E4	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	U	9/11
E5	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	9/11
E6	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	10/11
E7	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	7/11
E8	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	10/11
E9	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	U	9/11
E10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	10/11
E11	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	10/11

Y= Yes; N= No; U= Unclear; NA= Not Applicable

performed. In contrast, outcomes where studies found no significant differences are represented by bars on the left side of the chart (with P-values above 0.05). The most common and effective outcomes include balance (E1[9], E4[23], E6[24], E9[26], E10[27]), and upper limb motor function (E3[22], E4[23], E5[2], E8[25], E11[28]).

Discussion

Principal Findings

The study aimed to synthesize the combined evidence from meta-analyses, highlighting the importance of exploring alternative methods to motivate stroke survivors throughout their long rehabilitation journey. Exergames, which integrate physical exercises with digital games, emerge as promising tools.[29] Different interventions, such as using exergames, are being adopted in rehabilitation, as they act as motivating instruments, making therapies more enjoyable.[30]

Conducting an Umbrella review allowed for the inclusion of extensive research across multiple databases with no date restrictions. This analysis observes that studies conducted with meta-analyses on this focus are recurrent in the last decade, coinciding with the appearance of the first commercial games such as Nintendo®, Xbox®, and PlayStation®, which have revolutionized rehabilitation at various levels, notably among stroke survivors.[22-27]

Our results highlight that the Nintendo Wii was the most frequently used resource. The rehabilitation community has increasingly adopted these tools,[29-31] particularly the Nintendo Wii system, as an accessible resource, with its haptic sensor-based controllers and kinetic force platform (Wii Fit).[31] Commercial exergames can be particularly appealing due to their ease of access and familiarity for many users, potentially complementing rehabilitation without the presence of a healthcare professional.[32] Utilizing these games in rehabilitation leverages the technology available on the market, making it a viable and cost-effective option for many institutions and individuals. Moreover, the variety of games available allows for customizing the rehabilitation experience to meet the specific needs of each stroke survivor, contributing to a more patient-centred approach and potentially increasing the efficacy of the treatment.[29] Although currently, due to technological innovation, many new resources have been developed specifically for each rehabilitation program. Although our analysis highlights the frequent mention of the Nintendo Wii, other exergames were also employed in the interventions, including popular titles from different platforms such as Xbox[13,27] and PlayStation[13], as well as other tools.[2,13,22,27]

This reflects a trend toward using accessible exergames, offering a variety of activities that can be tailored to patient's specific needs and preferences, even though they were not initially designed for this purpose. Exergames can be beneficial for improving long-term outcomes in stroke patients; however, their use should be based on a personalized training prescription, applying progression rules, and conducted under clinical supervision. [33]

Regarding the duration of the interventions, the data point to a variation from 1 to 12 weeks, with a tendency to concentrate around six weeks. This suggests that there is a preferred period that balances efficacy and practicality, allowing participants to experience significant benefits. In terms of rehabilitation programs for stroke survivors, the evidence suggests that "more is better" when it comes to rehabilitation,

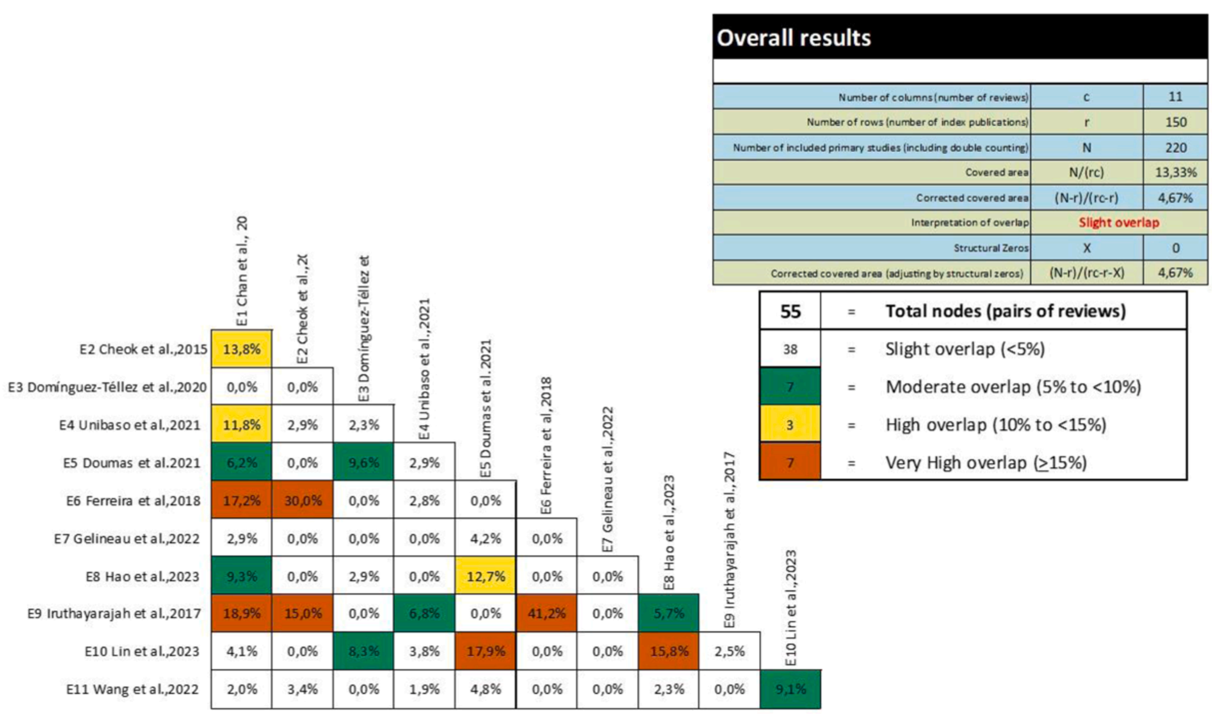

Figure 2. Overall overlap assessment_Groove.

Table 4
Outcomes of included meta-analyses.

Studies ID (Author)	Outcomes	Estimated effect (95% CI)	Heterogeneity (I^2) %	*P* value
E1 Chan et al. 2022[9]	Balance – *Berg Balance Scale (BBS), Functional Reach Test (FRT)* – *Dynamic Gait Index (DGI)* – *Postural Assessment Scale for Stroke* – *Balance Evaluation Systems Test*	0.25 [0.08, 0.41]	0%	0.004
	Lower limb functional mobility – *Timed Up and Go test (TUG)* – *Fugl-Meyer Assessment lower extremity (FMA-LE) subscale* – *Modified Motor Assessment Scale walking item* – *6-minute walk test* – *10-metre walk test*	0.29 [0.08, 0.50]	0%	0.007
	Functional independence – *Functional Independence Measure, FIM*	0.41 [0.09, 0.73]	0%	0.01
E2 Cheok et al., 2015[16]	Balance – *Berg Balance Scale (BBS)* – *Timed Up and Go test (TUG)* – *Postural sway velocity with force plate system*	0.39 [-0.25, 1.04]	85%	0.24
	Fall risk – *Falls Efficacy Scale-International*	0.64 [0.00, 1.28]	67%	0.05
	Functional independence – *Functional Independence Measure (FIM)*	0.27 [-0.38, 0.93]	0%	0.41
E3 Domínguez-Téllez et al., 2020[22]	Upper limb motor function – *Fugl-Meyer Assessment upper extremity subscale* – *Box and Block Test* – *Nine-Hole Peg Test*	1.53 [0.51, 2.54]	92%	0.003
	Hand dexterity – *Box and Block Test* – *Nine-Hole Peg Test*	0.55 [-0.66, 1.76]	95%	0.37
	Functional independence – *Barthel Index* – *Functional Independence Measure (FIM)*	2.37 [-0.25, 4.98]	98%	0.08
	Quality of life – *Stroke Impact Scale* – *EuroQol - 5 Dimensions (EQ-5D)* – *36-Item Short Form Survey*	0.77 [0.05, 1.49]	91%	0.04
E4 Unibaso-Markaida,et al. 2021[23] Observational studies	Balance – *Berg Balance Scale (BBS)* – *Timed Get Up and Go test (TUG)* – *Dynamic Gait Index*	-0.39 [1.23, 0.45]	67%	0.37
	Sensorimotor stroke recovery – *Fugl-Meyer Assessment* – *Wolf Motor Function Test*	-0.45 [-0.74,-0.15]	0%	0.03
	Fall risk – *Falls Efficacy Scale*	0.45 [0.04,0.87]	9%	0.03
	Upper limb motor function – *Wolf Motor Function Test* – *Fugl-Meyer Assessment*	0.41 [0.07,0.74]	0%	0.02
E4 Unibaso-Markaida,et al. 2021[23] Experimental studies	Balance – *Berg Balance Scale (BBS)* – *Dynamic Gait Index (DGI)* – *Functional Reach Test (FRT)* – *Timed Get Up and Go test (TUG)*	0.30 [0.05, 0.55]	0%	0.02
	Sensorimotor stroke recovery – *Fugl-Meyer Assessment (FMA)* – *Wolf Motor Function Test (WMFT)* – *Brunnstrom Approach*	0.30 [-0.01,0.61]	4%	0.06
	Fall risk – *Postural Assessment Scale*	-0.02 [-0.31,0.27]	0%	0.89
	Functional independence – *Functional Independence Measure (FIM)* – *Barthel Index (BTI)*	0.22 [-0.17,0.60]	0%	0.27
E5 Doumas et al. 2021[2]	Upper limb motor function – *Fugl-Meyer Assessment* – *Action Research Arm Test*	0.62 [0.33,0.92]	80%	0.0001

(*continued on next page*)

Table 4 (*continued*)

Studies ID (Author)	Outcomes	Estimated effect (95% CI)	Heterogeneity (I^2) %	*P* value
	– Box and Block Test			
	Upper limb motor activity *– Action Research Arm Test – Box and Block Test – Wolf Motor Function Test*	0.42 [0.12,0.72]	64%	0.006
	Social participation *– Stroke Impact Scale (sub-scale social)*	0.66 [0.29,1.03]	0%	0.005
E6 Ferreira et al, 2018[24]	Balance *– Berg Balance Scale (BBS)*	2.34 [0.45,4.04]	24%	0.01
	Mobility *– Timed Up and Go Test (TUGT)*	-0.51 [-2.66,1.64]	0%	0.64
E7 Gelineau et al., 2022[13]	Upper limb motor function *– Action Research Arm Test (ARAT) – Chedoke Arm and Hand Activity Inventory (CAHAI) – Wolf Motor Function Test (WMFT) – Box and Block Test (BBT) – Grooved Pegboard Test – Nine Hole Peg Test (NHPT)*	-0.05 [-0.24,0.14]	0%	0.62
E8 Hao et al., 2023[25]	Upper limb motor function *– Fugl-Meyer Assessment (FMA)*	1.39 [0.25,2.53]	?	0.003
E9 Iruthayarajah et al., 2017[26]	Balance *– Berg Balance Scale (BBS) – Timed Up and Go Test (TUG)*	0.57 [1.88,3.53]	3%	<0,001
	Mobility *– Berg Balance Scale (BBS) – Timed Up and Go Test (TUG)*	0.63 [1.36,3.06]	66%	<0,001
E10 Lin et al., 2023[27]	Cognitive ability *– General cognition assessments – Mini-Mental State Examination (MMSE) – Montreal Cognitive Assessment (MoCA) – Attention Tests*	-8.79 [-16.50, -1.00]	71%	0,03
	Mobility *– Modified Barthel Index (MBI) – Fugl-Meyer Assessment (FMA) – Berg Balance Scale (BBS) – Functional Independence Measure Motor (FIM MOT)*	0.61 [0.14, 1.08]	75%	0,01
	Sensorimotor stroke recovery *– Fugl-Meyer Assessment (FMA)*	0.47 [0.02, 0.93]	82%	0,04
	Balance *– Berg Balance Scale (BBS)*	0.78 [0.42, 1,15]	83%	<0,001
	Functional independence *– Functional Independence Measure Motor (FIM MOT) – Modified Barthel Index (MBI)*	5.87 [2.57, 9.17]	69%	0,0005
	Emotion *– Assessments of depression and anxiety*	-0.59 [-1.07, -0.11]	75%	0,02
E11 Wang et al., 2022[28]	Upper limb motor function *– Fugl-Meyer Assessment – Action Research Arm Test (ARAT) – Box and Block Test – Wolf Motor Function Test*	0.76 [0.47,1.05]	65%	0,000
	Hand dexterity *– Box and Block Test – Nine Hole Peg Test*	0.81 [0.27, 1.36]	73%	0,003
	Daily living activities *– Barthel Index – Functional Independence Measure (FIM)*	0.93 [0.61, 1.25]	4%	0,000
	Cognitive ability *– Montreal Cognitive Assessment (MoCA) – Mini-Mental State Examination (MMSE)*	1.14 [0.20, 2.08]	77%	0,017

indicating that those with longer duration, time, and intensity, ranging from 3 to 22 months, tend to be more effective.[34]

Based on the comprehensive analysis of the included studies, the main outcomes highlight significant improvements in various key areas of stroke survivor rehabilitation through the use of exergames. Despite the promising results, the heterogeneity of the included studies was visible, with different intervention times and tools, which only made this more descriptive analysis feasible. This points to the need for

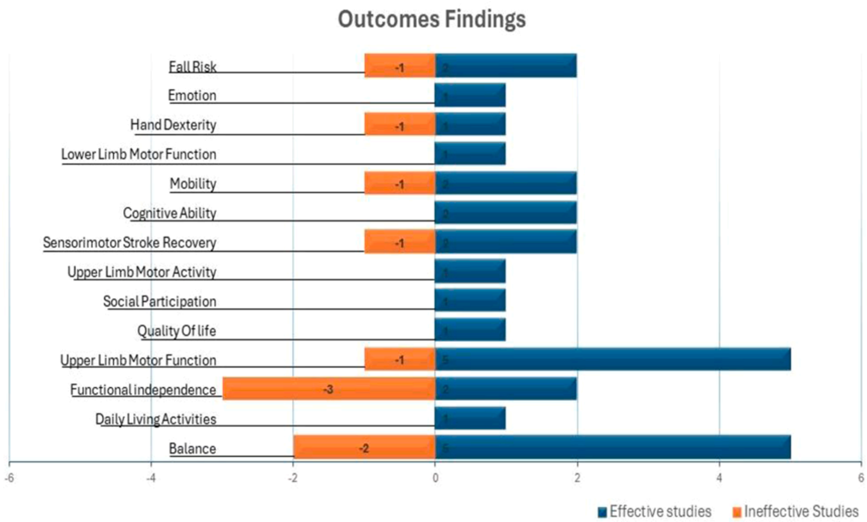

Figure 3. Outcomes Findings.

standardization in future research, allowing for more direct comparisons and robust quantitative syntheses of the benefits of exergames—the description of these detailed results in Table 3 and Fig. 3.

The results show benefits mainly in improving balance and functional mobility of the upper limbs. Some studies reported significant improvements in balance, indicating that exergames can effectively contribute to recovery and postural stability in post-stroke individuals.[9,23,24,26,27] Other studies found improvements in upper limb function [2,22,23,25,28], highlighting the potential of exergames to assist in the recovery of strength, coordination, and manual dexterity[28], essential for performing daily activities.[28] These results are significant because balance and mobility are fundamental for stroke survivors' independence and quality of life.

Among the main outcomes analyzed, it is noteworthy that none of them examined satisfaction, motivation, or user perception, which could positively impact the choice of exergames. In one of the studies mentioned, it was observed that stroke survivors felt motivated to exercise and perform tasks during gaming sessions due to the engagement provided by the games.[35] Similarly, healthcare professionals were also motivated by the competitive aspect of the games. Both groups acknowledged the potential of these games for post-stroke gait rehabilitation, highlighting their ability to adapt to each patient's individual needs and the technology's ease of use.[35]

The results also underscore the versatility and efficacy of exergames as a rehabilitation tool. They offer a holistic approach encompassing physical, cognitive[27,28], and emotional[27] improvements. The ability to adapt games to patients' needs and their engaging and motivational nature makes exergames a valuable addition to rehabilitation.

Analyzing the outcomes can provide valuable insights into the effectiveness and potential benefits of exergames as a form of complementary therapy in rehabilitation for stroke survivors.

Limitations

Throughout the development of this article, several limitations were identified, including the variability of available resources, the variability in intervention duration, and the use of exergames in rehabilitation programs at different stages post-stroke, ranging from the acute to the chronic phase.

Other limitations include the diversity of measurement instruments used in the primary studies, which impacts the consistency of results and poses challenges for conducting robust quantitative data syntheses. Additionally, due to the heterogeneity of the studies, the results must be interpreted with caution.

Moreover, while the studies cover a wide range of outcomes, other areas of potential benefit remain underexplored, such as the influence of exergames on motivation, satisfaction, well-being, and mental health of stroke survivors. These limitations highlight areas for future research and the need for more standardized and inclusive methodological approaches in assessing the impact of exergames on stroke rehabilitation.

Conclusion

This is the first Umbrella Review to systematically synthesize and evaluate the impact of exergame use in post-stroke rehabilitation. This review identified increased adoption of exergames in rehabilitation, with commercial exergames, such as Nintendo, emerging as accessible and widely used resources. The analysis revealed notable variability in terms of time, intensity, duration, and phase of application of the interventions, aspects that warrant further investigation in future studies.

The analysis of intervention outcomes demonstrated significant improvements in critical areas, particularly in balance and upper limb functionality. Despite the heterogeneity and diversity of the included studies, this review highlights the potential of exergames as a valuable tool in stroke survivors' rehabilitation, significantly contributing to the knowledge base on the topic and providing relevant insights for healthcare professionals. Finally, the analysis also underscores the need for more qualitative studies on the subject, including the perspectives of patients and healthcare professionals on the use of exergames.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.
Data Availability Statement
Not applicable.

CRediT authorship contribution statement

Carla Sílvia Fernandes: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Bruno Magalhães:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Filipe Gonçalves:** . **Andreia Lima:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Mafalda Silva:** Writing – original draft, Investigation, Formal analysis. **Maria Teresa Moreira:** Writing – review & editing, Data curation, Conceptualization. **Célia Santos:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Salomé Ferreira:** .

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Not applicable.

Funding Statement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Lloyd A, Bannigan K, Sugavanam T, Freeman J. Experiences of stroke survivors, their families and unpaid carers in goal setting within stroke rehabilitation: a systematic review of qualitative evidence. *JBI Database of Systematic Reviews & Implementation Reports*. 2018;16(6):1418–1453. https://doi.org/10.11124/JBISRIR-2017-003499.
2. Doumas I, Everard G, Dehem S, Lejeune T. Serious games for upper limb rehabilitation after stroke: a meta-analysis. *J Neuroeng Rehabil*. 2021;18(1):100. https://doi.org/10.1186/s12984-021-00889-1.
3. Kennedy C, Bernhardt J, Churilov L, Collier JM, Ellery F, Rethnam V, et al. Factors associated with time to independent walking recovery post-stroke. *J Neurol Neurosurg Psychiatry*. 2021;92(7):702–708. https://doi.org/10.1136/jnnp-2020-325125.
4. Mubin O, Alnajjar F, Jishtu N, Alsinglawi B, Mahmud AA. Exoskeletons With Virtual Reality, Augmented Reality, and Gamification for Stroke Patients' Rehabilitation: Systematic Review. *J Med Internet Res*. 2019;21(9). https://doi.org/10.2196/12010. N.PAG.
5. Mubin O, Alnajjar F, Al Mahmud A, Jishtu N, Alsinglawi B. Exploring serious games for stroke rehabilitation: a scoping review. *Disability & Rehabilitation: Assistive Technology*. 2022;17(2):159–165. https://doi.org/10.1080/17483107.2020.1768309.
6. Al-Whaibi RM, MS Al-Jadid, ElSerougy HR, Badawy WM. Effectiveness of virtual reality-based rehabilitation versus conventional therapy on upper limb motor function of chronic stroke patients: a systematic review and meta-analysis of randomized controlled trials. *Physiotherapy Theory & Practice*. 2022;38(13):2402–2416. https://doi.org/10.1080/09593985.2021.1941458.
7. Fernandes CS, Magalhães B, Goncalves F, Nogueira PC, Santos C. The Use of Gamification in Patients Undergoing Hip Arthroplasty: Scoping Review. *Games Health J*. 2021;10(3):147–157. https://doi.org/10.1089/g4h.2020.0210.
8. Fernandes CS, Magalhães B, Lima A, Nóbrega P, Silva M, Santos C. Impact of Exergames on the Mental Health of Older Adults: A Systematic Review and GRADE Evidence Synthesis. *Games Health J*. 2022;11(6):355–368. https://doi.org/10.1089/g4h.2021.0229.
9. Chan KGF, Jiang Y, Choo WT, Ramachandran HJ, Lin Y, Wang W. Effects of exergaming on functional outcomes in people with chronic stroke: A systematic review and meta-analysis. *J Adv Nurs*. 2022;78(4):929–946. https://doi.org/10.1111/jan.15125.
10. Fernandes CS, Magalhães B, Gomes JA, Santos C. Exergames to improve Rehabilitation after Anterior Cruciate Ligament Injury: Systematic review and GRADE evidence synthesis. *Int J Orthop Trauma Nurs*. 2022;44. https://doi.org/10.1016/j.ijotn.2021.100917.
11. Fernandes CS, Magalhães B, Gomes JA, Lima A, Santos C. Exergames to improve rehabilitation after knee arthroplasty: a systematic review and grade evidence synthesis. Europ J Physiother 2022. doi: 10.1080/21679169.2022.2126518.
12. Mat Rosly M, Mat Rosly H, Davis OAM GM, Husain R, Hasnan N. Exergaming for individuals with neurological disability: A systematic review. *Disabil Rehabil*. 2017; 39:727–735. https://doi.org/10.3109/09638288.2016.1161086.
13. Gelineau A, Perrochon A, Robin L, Daviet J-C, Mandigout S. Measured and Perceived Effects of Upper Limb Home-Based Exergaming Interventions on Activity after Stroke: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*. 2022;19(15). https://doi.org/10.3390/ijerph19159112.
14. Garcia-Munoz C, Casuso-Holgado MJ. [Effectiveness of Wii Fit Balance board in comparison with other interventions for post-stroke balance rehabilitation. Systematic review and meta-analysis]. *Rev Neurol*. 2019;69(7):271–279. https://doi.org/10.33588/rn.6907.2019091.
15. Pessoa TM, Coutinho DS, Pereira VM, Ribeiro NP de O, Nardi AE, Silva AC de O e. The Nintendo Wii as a tool for neurocognitive rehabilitation, training and health promotion. *Comput Human Behav*. 2014;31:384–392.
16. Cheok G, Tan D, Low A, Hewitt J. Is Nintendo Wii an Effective Intervention for Individuals With Stroke? A Systematic Review and Meta-Analysis. *J Am Med Dir Assoc*. 2015;16(11):923–932. https://doi.org/10.1016/j.jamda.2015.06.010.
17. Tripette J, Murakami H, Ryan KR, Ohta Y, Miyachi M. The contribution of Nintendo Wii Fit series in the field of health: a systematic review and meta-analysis. *PeerJ*. 2017;5:e3600. https://doi.org/10.7717/peerj.3600.
18. Bonnechère B, Jansen B, Omelina L, Sholukha V, Van Sint Jan S. Patients' follow-up using biomechanical analysis of rehabilitation exercises. *International Journal of Serious Games*. 2017;4(1). https://doi.org/10.17083/ijsg.v4i1.121.
19. Aromataris E, Fernandez R, Godfrey CM, Holly C, Khalil H, Tungpunkom P. Summarizing systematic reviews: methodological development, conduct and reporting of an umbrella review approach. *Int J Evid Based Healthc*. 2015;13(3): 132–140, 1097/XEB.0000000000000055.
20. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372. https://doi.org/10.1136/bmj.n71. n71PMID: 33782057.
21. Aromataris E, Fernandez R, Godfrey C, Holly C, Kahlil H, Tungpunkom P. Summarizing systematic reviews: methodological development, conduct and reporting of an Umbrella review approach. *Int J Evid Based Healthc*. 2015;13(3): 132–140.
22. Domínguez-Téllez P, Moral-Muñoz JA, Salazar A, Casado-Fernández E, Lucena-Antón D. Game-Based Virtual Reality Interventions to Improve Upper Limb Motor Function and Quality of Life After Stroke: Systematic Review and Meta-analysis. *Games Health J*. 2020;9(1):1–10. https://doi.org/10.1089/g4h.2019.0043. PMID: 32027185.
23. Unibaso-Markaida I, Iraurgi I. Commercial videogames in stroke rehabilitation: systematic review and meta-analysis. *Top Stroke Rehabil*. 2022;29(8):551–567. https://doi.org/10.1080/10749357.2021.1943798.
24. Ferreira V, Carvas N, Artilheiro MC, Pompeu JE, Hassan SA, Kasawara KT. Interactive Video Gaming Improves Functional Balance in Poststroke Individuals: Meta-Analysis of Randomized Controlled Trials. *Eval Health Prof*. 2020;43(1):23–32. https://doi.org/10.1177/0163278718784998.
25. Hao J, He Z, Yu X, Remis A. Comparison of immersive and non-immersive virtual reality for upper extremity functional recovery in patients with stroke: a systematic review and network meta-analysis. *Neurol Sci*. 2023;44(8):2679–2697. https://doi.org/10.1007/s10072-023-06742-8.
26. Iruthayarajah J, McIntyre A, Cotoi A, Macaluso S, Teasell R. The use of virtual reality for balance among individuals with chronic stroke: a systematic review and meta-analysis. *Top Stroke Rehabil*. 2017;24(1):68–79. https://doi.org/10.1080/10749357.2016.1192361.
27. Lin C, Ren Y, Lu A. The effectiveness of virtual reality games in improving cognition, mobility, and emotion in elderly post-stroke patients: a systematic review and meta-analysis. *Neurosurg Rev*. 2023;6(1):167. https://doi.org/10.1007/s10143-023-02061, 46.
28. Wang L, Chen JL, Wong AMK, Liang KC, Tseng KC. Game-Based Virtual Reality System for Upper Limb Rehabilitation After Stroke in a Clinical Environment: Systematic Review and Meta-Analysis. *Games Health J*. 2022;11(5):277–297. https://doi.org/10.1089/g4h.2022.0086.
29. Gopaul Urvashy, Omar Zaliha Binti, Bayley Mark, Schwertfeger Julie, Cheng Hsiao-Ju, Faieta Julie, Lee Chang Dae. What Do I Need to Know About Exergames to Improve Recovery at Home After My Stroke? *Arch Phys Med Rehabil*. 2024. https://doi.org/10.1016/j.apmr.2023.12.006. January 19.
30. Henrique PPB, Colussi EL, De Marchi ACB. Effects of Exergame on Patients' Balance and Upper Limb Motor Function after Stroke: A Randomized Controlled Trial. *J Stroke Cerebrovasc Dis*. 2019;28(8):2351–2357. https://doi.org/10.1016/j.jstrokecerebrovasdis.2019.05.031.
31. Deutsch JE, Brettler A, Smith C, Welsh J, John R, Guarrera-Bowlby P, et al. Nintendo Wii Sports and Wii Fit Game Analysis, Validation, and Application to Stroke Rehabilitation. *Top Stroke Rehabil*. 2011;18(6):701–719. https://doi.org/10.1310/tsr1806-701.
32. Chen Y, Zhang Y, Guo Z, et al. Comparison between the effects of exergame intervention and traditional physical training on improving balance and fall prevention in healthy older adults: a systematic review and meta-analysis. *J NeuroEngineering Rehabil*. 2021;18:164. https://doi.org/10.1186/s12984-021-00917-0.
33. Huber SK, Held JPO, de Bruin ED, Knols RH. Personalized Motor-Cognitive Exergame Training in Chronic Stroke Patients-A Feasibility Study. *Front Aging Neurosci*. 2021;13, 730801. https://doi.org/10.3389/fnagi.2021.730801.
34. Wei L, Shang W, Nan Y, Liu Y, Yang J, Yang K. An Evidence Map of Clinical Practice Guideline Recommendations on Stroke Rehabilitation. *Am J Phys Med Rehabil*. 2024. https://doi.org/10.1097/PHM.0000000000002413.
35. Moan ME, Vonstad EK, Su X, Vereijken B, Solbjør M, Skjæret-Maroni N. Experiences of Stroke Survivors and Clinicians With a Fully Immersive Virtual Reality Treadmill Exergame for Stroke Rehabilitation: A Qualitative Pilot Study. *Front Aging Neurosci*. 2021;13, 735251. https://doi.org/10.3389/fnagi.2021.735251.