Game-Based Virtual Reality Interventions to Improve Upper Limb Motor Function and Quality of Life After Stroke: Systematic Review and Meta-analysis

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Abstract

Stroke is the main cause of disability in adulthood. Recent advances in virtual reality (VR) technologies have led to its increased use in the rehabilitation of stroke patients. A systematic review and meta-analysis of randomized controlled trials (RCTs) was conducted to determine the effectiveness of game-based reality on upper limb (UL) motor function and quality of life after stroke. In March 2018, a search of the following databases was performed: PubMed, PEDro, Web of Science, Scopus, The Cochrane Library, and Medline at EBSCO. The selection criteria were all RCTs published in English or Spanish during the past 10 years. The PEDro scale was used to evaluate the methodological quality of the studies. A total of 20 clinical trials were included in the systemic review, of which 15 contributed information to the meta-analysis. Favorable results were found for VR interventions on UL motor function (Fugl-Meyer Assessment for upper extremity, standardized mean difference [SMD]=1.53, 95% CI [0.51–2.54]) and quality of life (functional independence measure, SMD=0.77, 95% CI [0.05–1.49]). The results demonstrate the potential benefits of VR interventions on the recovery of UL motor function and on quality of life after stroke.

Keywords: Virtual reality, Stroke, Physical therapy, Meta-analysis

Introduction

CEREBROVASCULAR DISEASES ENCOMPASS a set of clinical neurological manifestations, which are caused by an intracranial or extracranial vascular alteration (arterial or venous).¹ Among these conditions, cerebrovascular accidents, also known as strokes, are considered the leading cause of neurological disability in adults.² Stroke represents the most common cause of physical disability in adults and the second most common cause of dementia.¹ Further, most survivors experience motor disorders, associated with a reduction in quality of life³ and the ability to perform activities of daily living (ADL).⁴

Neurorehabilitation involves a set of methods that aim at recovering neurological functions that were lost or diminished as a result of a brain or spinal damage.¹ Although virtual reality (VR) started gaining popularity in the late 1980s and 1990s, VR technologies have only recently begun to be de-

veloped and studied over the past decade as a possible tool for evaluation and treatment within this discipline.⁵ In addition to technological improvements in the systems, the drastic reduction in the cost of the devices, together with the widespread availability of high-speed internet connection, have led to an increase in their use.⁶ Accordingly, VR has reinvented itself in some technological areas, especially in videogames. These types of games have become popular across different commercial platforms, such as PlayStation, Xbox, Mac and PC.⁷

VR consists of the use of a user-computer interface that enables the real-time simulation of an environment, scenario, or activity, allowing the user to interact through multiple sensory canals.^{8,9} Currently, VR represents a multidisciplinary tool in clinical medicine, which is used in many applications including pain management, assessment of neurocognitive impairment, training of medical techniques, and physical rehabilitation.¹⁰ According to the research literature, VR is

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useful in visual, auditory, tactile, and motor learning applications; it has a positive effect on personal motivation, and it has also been applied to improve post-stroke motor skills.¹¹ Research in this field has not only been limited to stroke rehabilitation; for example, one study used VR systems to evaluate motor levels after stroke.¹²

The term “virtual reality” includes a large number of technological devices and systems with different characteristics, which can be divided into two groups according to the level of patient immersion¹³: (i) immersive systems, where users are fully integrated into the virtual environment with multisensory input through head-mounted displays, large screen projection, and VR caves; and (ii) semi-immersive or non-immersive systems, where a computer screen displays the environment, such as videogame consoles. These systems can also be combined with the use of treadmills, bionic gloves, and/or robot exoskeletons, which provide greater feedback to the user. VR devices allow for the creation of game-based interventions, in which it is possible to manipulate the content, duration, intensity, and feedback to create an adequate exer-

cise prescription. Management of these training characteristics is closely related to recovery, reorganization, and neuroplasticity after stroke.² Moreover, the main advantage of VR interventions over conventional treatment is that patients see it as a fun exercise game rather than treatment, leading to improvements in motivation and treatment adherence.⁹

Interventions with VR have also been demonstrated to improve functional mobility in children with cerebral palsy¹⁴ and in older adults.¹⁵ Likewise, its application has been evidenced in the re-training of walking and balance, as well as in the rehabilitation of upper limbs (UL) and lower limbs.¹¹ However, there is not yet enough evidence for the effect of VR on traumatic brain injuries.¹⁶

Considering the current literature, more than a decade ago, in 2007, Henderson et al.¹³ concluded that the scientific evidence on VR in stroke rehabilitation was limited. Later, in 2014, Lohse et al.³ stated that VR therapy represents a significant advantage over conventional therapy in terms of body function and activity results, in addition to greater benefits of VR versus conventional therapy in relation to

FIG. 1. Information flow diagram of the different phases of the systematic review.

TABLE 1. MAIN CHARACTERISTICS OF THE STUDY INTERVENTIONS

Study	Group interventions	VR games	Participants	Average age (years-SD)	Frequency	Session duration (minutes)	Intervention duration (weeks)	Outcome measure	Measuring instrument	Results	PEDro score
Broeren et al. ⁵	CG: Conventional therapy IG: Conventional therapy + semi-immersive VR	Haptic 3D games to manipulate virtual objects	N=22 CG: 11 IG: 11	68.0 (12.5) 67.0 (12.5)	3	45	4	1. Motor function 2. Executive function and attention 3. Kinematic parameters	1. BBT, ABILHAND 2. TMT-B (Trail Making Test, part B) 3. Kinematic 3D analysis	Favorable results in UL motor function in training sessions.	5
Housman et al. ³⁹	CG: Conventional therapy IG: VR-based therapy + Exoskeleton	Games based on manipulating virtual objects	N=36 CG:18 IG:18	56.4 (12.8) 54.2 (11.9)	3	60	9	1. Motor function 2. Movement quality	1. FMA-UE, ROM 2. MAL (Motor Activity Log)	Favorable results in both groups on FMA-UE, ROM y MAL.	5
Piron et al. ⁴⁰	CG: Conventional therapy IG: VR home-based telerehabilitation	Games based on performing virtual tasks	N=36 CG:18 IG:18	64.4 (7.9) 66.0 (7.9)	5	60	4	1. Motor function 2. Spasticity	1. FMA-UE, ABILHAND 2. Ashworth	Favorable results in both groups. Significant improvements on FMA-UE in IG.	7
Kwon et al. ⁹	CG: Conventional therapy IG: Conventional therapy + Immersive VR (IREX)	Games based on interacting with virtual environments and objects	N=26 CG:13 IG:13	57.9 (12.3) 57.1 (15.4)	5	30	4	1. Motor function 2. Quality of life	1. FMA-UE, MFT (Manual Function Test) 2. MBI	No statistically significant difference was found between the groups.	5
Jo et al. ⁵⁰	CG: Conventional therapy IG: Conventional therapy + immersive VR (IREX)	Games based on interacting with virtual environments and objects	N=29 CG:14 IG:15	63.7 (8.8) 64.0 (7.1)	5	60	4	1. Motor function 2. Visual perception and processing time.	1. WMFT 2. MVPT (Motor-free Visual Perception Test)	No statistically significant difference was found between groups on WMFT. Statistically significant difference was found on MVPT between groups.	5
Sin et al. ²³	CG: Conventional therapy IG: Conventional therapy + semi-immersive VR with Xbox Kinect	Commercial games based on Xbox Kinect	N=35 CG:17 IG:18	75.5 (5.5) 71.7 (9.4)	3	30	6	1. Motor function 2. Manual dexterity.	1. Active ROM, FMA-UE 2. BBT	Statistically significant difference was found between groups in active ROM, FMA-UE and BBT.	6
Subramanian et al. ⁴⁸	CG: Similar real therapy IG: 3D immersive VR (CAREN)	Games based on interacting with virtual environments and objects	N=25 CG:13 IG:12	60.0 (11.0) 62.0 (9.7)	3	–	4	1. Motor function 2. Arm use. 3. Kinematics parameters	1. FMA-UE, WMFT, RPSS (Reaching Performance Scale for Stroke) 2. MAL-AS 3. Kinematic 3D analysis	No statistically significant difference was found between groups in kinematics, arm motor impairment, activity level, and arm use.	7

(continued)

TABLE 1. (CONTINUED)

Study	Group interventions	VR games	Participants	Average age (years-SD)	Frequency	Session duration (minutes)	Intervention duration (weeks)	Outcome measure	Measuring instrument	Results	PEDro score
Thielbar et al. ²⁹	CG: Intensive therapy IG: Intensive therapy with mechatronic VR (AVK)	Games based on interacting with a virtual Keypad	N=14 CG:7 IG:7	59.0 (7.0) 54.0 (7.0)	3	–	6	1. Motor function	1. JTT, ARAT, FMA-UE, finger function	Statistically significant difference was found between groups in FMA-UE, JTT, and finger function.	6
Kiper et al. ⁴	CG: Conventional therapy IG: Conventional therapy + VR feedback gloves	Games based on interacting with virtual environments and objects	N=44 CG:21 IG:23	65.5 (14.2) 63.1 (9.5)	5	60	4	1. Motor function 2. Quality of life 3. Kinematic parameters	1. FMA-UE 2. FIM 3. Kinematic 3D analysis	Statistically significant difference was found between groups on FMA-UE, FIM and kinematics parameters.	5
Rand et al. ⁴⁹	CG: Conventional therapy IG: Semi-immersive and non-immersive VR with Xbox Kinect, PlayStation 2&3	Commercial games based on Xbox Kinect, Sony Play Station 2 EyeToy, Sony Play Station 3 Move, and SeeMe VR system	N=29 CG:14 IG:15	62.5 (–) 57.0 (–)	2	60	12	1. Motor function	1. Number of movements, acceleration, and movement intensity.	Statistically significant difference was found between groups at number of intentional movements	4
Zheng et al. ²⁷	CG: RTMS therapy + immersive VR IG: L-F RTMS therapy + immersive VR	Games based on interacting with virtual environments and objects	N=108 CG:53 IG:55	66.2 (13.1) 65.4 (13.5)	6	–	4	1. Motor function 2. Quality of life	1. FMA-UE, WMFT 2. MBI 3. SF-36	Statistically significant difference was found between groups on FMA-UE, WMFT, and MBI.	10
Shin et al. ²⁵	CG: Conventional therapy IG: Conventional therapy + semi-immersive VR	Games based on interacting with virtual environments and objects	N=32 CG:16 IG:16	54.6 (13.4) 53.3 (11.8)	5	60	4	1. Quality of life 2. Depression 3. Motor function	1. HRQOL and SF-36 2. Hamilton 3. FMA-UE	No statistically significant difference was found in both groups after intervention	6
Ballester et al. ⁴¹	CG: Functional therapy IG: Semi-immersive VR (RGS, Xbox Kinect)	Games based on interacting with virtual environments and objects	N=18 CG:9 IG:9	54.8 (12.0) 63.4 (9.4)	5	30	6	1. Motor function 2. Quality of life 3. Depression	1. FMA-UE and Chedoke 2. MBI 3. Hamilton	Statistically significant difference was found between in both groups after 6 months, and IG also at 12 months follow-up.	5
Lee et al. ⁴³	CG: Conventional therapy IG: Immersive VR (VRBT)	Games based on interacting with virtual environments and objects	N=18 CG:8 IG:10	73.1 (8.9) 69.2 (5.5)	3	30	6	1. Motor function	1. JTHFT, BBT, GPT (Grooved pegboard test), dynamometer	Statistically significant difference was found between groups in UL motor function (JTHFT, BBT, GPT, upper extremity muscle strength, and grip strength).	6

(continued)

TABLE 1. (CONTINUED)

Study	Group interventions	VR games	Participants	Average age (years-SD)	Frequency	Session duration (minutes)	Intervention duration (weeks)	Outcome measure	Measuring instrument	Results	PEDro score
Choi et al. ⁵¹	CG: Conventional therapy IG: Mobile game-based VR	Mobile games using a smartphone and a Tablet PC	N=24 CG:12 IG:12	72.1 (9.9) 61.0 (15.2)	5	30	2	1. Motor function 2. Quality of life 4. Depression	1. FMA-UE, Brunnström, MMT 2. MBI, EQ-5D 3. BDI	Statistically significant difference was found between groups in FMA-UE, Brunnström, and MMT.	8
Saposnik et al. ²⁶	CG: Recreational activities IG: Conventional therapy + non-immersive VR with Nintendo Wii	Commercial games based on Nintendo Wii	N=121 CG:62 IG:59	62.0 (12.0) 62.0 (13.0)	5	60	2	1. Motor function 2. Quality of life 3. Kinematics parameters	1. WMFT, BBT, SIS, dynamometer. 2. SIS, MBI, FIM, and Modified Rankin Scale 3. Kinematic analysis with RPSS	No statistically significant difference was found between groups after intervention.	7
Shin et al. ⁴²	CG: Conventional therapy IG: VR with biofeedback bionic gloves (SmartGlove)	Games based on interacting with virtual environments and objects	N=33 CG:14 IG:19	59.8 (13.0) 57.2 (10.3)	3	30	4	1. Motor function 2. Quality of life	1. FMA-UE, JTT, PPT (Purdue pegboard test) 2. SIS	Statistically significant difference was found between groups in FMA-UE, JTT, and SIS.	8
Kong et al. ³⁰	CG: Conventional therapy IG: Non-immersive VR with Nintendo Wii	Commercial games based on Nintendo Wii	N=68 CG:35 IG:33	55.8 (11.5) 58.1 (9.1)	4	60	3	1. Motor function 2. Quality of life	1. FMA-UE, ARAT. 2. FIM, SIS	No statistically significant difference was found between groups after intervention.	5
Taveggia et al. ²⁴	CG: Conventional therapy IG: Conventional therapy + VR system with an exoskeleton (Armeo Spring)	Games based on performing virtual tasks in virtual environments	N=54 CG:27 IG:27	68.0 (13.0) 73.0 (10.0)	5	30	6	1. Motricity 2. Spasticity 3. Pain 4. Quality of life.	1. MI 2. Ashworth 3. VAS 4. FIM	Statistically significant difference was found in all parameters in both groups.	7
Brunner et al. ²⁸	CG: Conventional therapy IG: Conventional therapy + VR system + bionic gloves (YouGrabber)	Games based on interacting with virtual environments and objects	N=102 CG:52 IG:50	62.0 (-) 62.0 (-)	4	60	4	1. Motor function 2. Quality of life	1. ARAT, BBT 2. FIM	No statistically significant difference was found between groups after intervention.	8

FMA-UE, Fugl-Meyer Assessment for the Upper Extremities; BBT, Box and Block Test; MBI, Modified Barthel Index; FIM, Functional Independence Measure.

TABLE 2. STUDY GROUPS AND SUBGROUPS INCLUDED IN THE META-ANALYSIS

G	Studies	Outcome	Measuring instrument
1	Broeren et al., ⁵ Housman et al., ³⁹ Piron et al., ⁴⁰ Kwon et al., ⁹ Sin et al., ²³ Thielbar et al., ²⁹ Kiper et al., ⁴ Rubio et al., ⁴¹ Lee et al., ⁴³ Saposnik et al., ²⁶ Shin et al., ⁴² Kong et al., ³⁰ Brunner et al. ²⁸	UL Motor Function	FMA-UE BBT
2	Kwon et al., ⁹ Zheng et al., ²⁷ Rubio et al., ⁴¹ Saposnik et al., ²⁶ Kiper et al., ⁴ Kong et al., ³⁰ Taveggia et al., ²⁴ Brunner et al. ²⁸	Quality of life	BARTHEL FIM

treatment participation. These authors also stated that research in this field was limited. De Rooij et al.¹⁷ conducted a meta-analysis in 2016 that showed benefits on gait and balance from VR interventions in conjunction with conventional therapy. More recently, in 2017, a Cochrane review carried out by Laver et al.¹⁸ showed favorable results of VR in addition to conventional therapy on UL motor function, but that VR was comparable to conventional therapy. Considering this, our study aimed at analyzing the current scientific evidence of VR therapy for the recovery of the UL motor function and quality of life after stroke.

Methods

The present review was conducted and reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews and meta-analyses.¹⁹

Search strategy

A search of the literature was performed in March 2018, using the following databases: PubMed, PEDro, Web of Science, Scopus, The Cochrane Library, and Medline EBS-CO. Boolean search terms included the following: “stroke,” “virtual reality,” “virtual reality exposure therapy,” and “physical therapy modalities.” In PubMed, the searches were performed by using MeSH descriptors.

Eligibility criteria

The following inclusion criteria were established: (i) articles published in the last 10 years (2007–2018) to obtain the most relevant and updated research; (ii) English or Spanish language; (iii) randomized controlled trials (RCTs) as the study design; (iv) adult patients with stroke; (v) intervention based on games with immersive, semi-immersive, and non-immersive VR systems, simulating virtual environments using computers, video consoles, mobile apps and VR glasses; (vi) outcomes related to motor function of UL and

quality of life. We excluded studies that combined participants with stroke with those with other kinds of conditions, which did not report the results separately.

Study selection and data extraction

First, we carried out a search combining keywords in different databases. Potentially relevant articles were identified after reading the title and abstract, and duplicated articles were eliminated. Subsequently, an exhaustive verification of compliance with the inclusion criteria was carried out to obtain the articles included in the present systematic review.

Two reviewers (D.L.A. and P.D.T.) actively participated in the process of selecting studies, reviewing and systematically extracting data from each study. A third reviewer (A.S.) participated in achieving consensus in case of different decisions. The following information was extracted from each article included in the review: authors, type of intervention, number of subjects, frequency of sessions per week, length of each session, total duration of the intervention, outcome measures, measurement instrument, and results obtained.

Assessment of risk of bias

The PEDro scale was used to evaluate the methodological quality of the RCTs included in the meta-analysis.²⁰ It consists of 11 items related to the domains of selection, performance, detection, information, and attribution bases.²¹ A study with a score of 6 or more is considered as evidence level 1 (6–8 is good, 9–10 is excellent), and a study with a score of 5 or less is considered as evidence level 2 (4–5 is acceptable, <4 is poor).²²

Statistical analysis

A meta-analysis was applied to compare changes in the effect size (pre- and post-intervention) between the intervention group (IG) and the control group (CG). Only meta-analyses with greater than or equal to four RCTs included

FIG. 2. Forest plot for FMA-UE. FMA-UE, Fugl-Meyer Assessment for the Upper Extremities.

FIG. 3. Forest plot for BBT. BBT, Box, and Block Test.

were considered to increase the confidence in our findings. For the meta-analysis, the standardized mean difference was calculated along with the 95% confidence interval (CI), and the significance level was set at $P < 0.05$. Heterogeneity was determined by the chi-square test and the I^2 statistic. When homogeneity was observed, a fixed-effect model was used. In the case of heterogeneity, a random-effects model was used. The results were presented in Forest plots. All statistical analyses were carried out by using the statistical software Review Manager (RevMan) 5.3 (The Cochrane Collaboration, The Nordic Cochrane Centre).

Results

As illustrated in Figure 1, the database searches were carried out by using the aforementioned combination of keywords, which retrieved a total of 230 documents. After the removal of duplicates, 93 articles were screened for eligibility. After the selection process, a total of 20 studies were included in the review, of which 15 were included in the meta-analysis for the statistical comparison. The entire selection process in the corresponding phases is detailed in Figure 1.

Risk of bias

The methodological quality of the included studies was generally high (average total PEDro score = 6.25, range 4–10). The score obtained as well as the detailed characteristics of each study are shown in Table 1.

Data extraction

A total of 874 subjects (CG, $n = 434$; IG with VR, $n = 440$) participated in the included studies. Regarding participant age, the highest mean age among the CG belonged to the study by Sin and Lee,²³ with 75.5 years, whereas the highest among the IG belonged to the study by Taveggia et al.,²⁴ with 73.0 years. The lowest ages for CG and IG appeared in the study by Shin et al.,²⁵ with 54.6 and 53.3 years, respec-

tively. Considering the number of participants, three studies stand out with samples composed of more than 100 subjects: Saposnik et al.,²⁶ Zheng et al.,²⁷ and Brunner et al.²⁸ The remaining studies recruited between 14²⁹ and 68³⁰ subjects, with a similar distribution of subjects between CG and IG. Table 1 shows the main characteristics of the interventions carried out in the different studies.

Study groups and subgroups included in the meta-analysis

Table 2 shows the characteristics of the different groups created for the meta-analysis. The physical outcomes analyzed in the studies were considered for the creation of these groups. Accordingly, two groups were established: (i) UL motor function and (ii) quality of life. Moreover, different subgroups were created depending on the instrument used to measure the outcomes. In this way, the UL motor function group and the quality of life group were each further divided into two subgroups.

The results of the meta-analysis are presented in Figures 2–5. In the UL motor function group, two different instruments were used: Fugl-Meyer Assessment for the Upper Extremities (FMA-UE), and Box and Block Test (BBT). The FMA-UE scale is a widely used evaluation system for hemiplegic patients that measures stroke-related motor impairment.³¹ It includes different items that assess movement, coordination, and reflex action from the shoulder to hands,³² and it has been confirmed to have high validity and reliability.³³ For FMA-UE, the overall result of the meta-analysis was favorable. On the other hand, the BBT is used to measure gross manual dexterity. It consists of asking the patient to move as many small wooden blocks as possible from one box to another in 1 minute.³⁴ The overall result of the meta-analysis was not conclusive.

Finally, the quality of life group was assessed by using two instruments: Modified Barthel Index (MBI), and Functional Independence Measure (FIM). The MBI is a scale to measure the degree of functional independence, with scores ranging

FIG. 4. Forest plot for the quality of life. MBI, Modified Barthel Index.

FIG. 5. Forest plot for the quality of life. FIM, Functional Independence Measure.

from 0 to 100.³⁵ The overall result in the meta-analysis was not conclusive. The FMI is a scale to measure the severity of the patient's disability.³⁶ The overall result was favorable.

Discussion

The aim of this systematic review and meta-analysis of RCTs was to analyze the efficacy of different types of VR on improving UL motor function and quality of life after stroke.

VR-based systems have many advantages over other interventions, making them a potential physical intervention tool. These advantages include their low cost, easy portability, and compatibility with other systems, in addition to the increased motivation of participants through the use of games, and the ability to provide direct feedback to the patient.³⁷ Moreover, the application of VR through home-based interventions could be effective in stroke rehabilitation.³⁸

Regarding the specific technologies used by different studies that obtained favorable results, the following were employed: an innovative exoskeleton,^{24,39} VR telerehabilitation system,⁴⁰ IREX immersion VR systems,^{9,27} Xbox Kinect,^{23,41} keyboard with VR,²⁹ VR combined with gloves,^{4,28,42} Nintendo Wii,^{26,30} and virtual surfaces.⁴³ All of these technologies share common characteristics, such as the interaction of the user with a virtual environment by playing games, in which the subject acts in a similar way to reality, depending on the level of immersion used. In this way, the higher the immersion is, the less contact they have with the external physical world, thereby enhancing the user's attention. It is important to note the negative effect of attention problems, which are the most prominent neuropsychological issue after stroke,⁴⁴ on learning. Therefore, the use of immersive VR systems, which helps the user focus their attention on the task entirely, could confer great advantages in the recovery of deficits.

The statistical analysis carried out in the present review revealed favorable results of VR intervention on the motor function of UL, especially in the full FMA-UE. Our results are consistent with those of Laver et al.,¹⁸ who reported that VR interventions could be effective when used in conjunction with conventional therapy for improving UL motor function and ADL after stroke. However, it would be interesting to analyze which specific components of therapy make it possible to achieve these positive effects. Along these lines, therapy through VR includes four components that could work together to ensure success: intensive therapy, motivating therapy through exercise games, stimulation of motor learning, and positive feedback between the stimulus and the response.⁴⁵

The findings on quality of life highlight the potential benefits of VR interventions after stroke. According to the International Classification of Functioning, Disability and

Health (ICF),⁴⁶ participation restrictions could be influenced by activity limitations, which can be influenced by impairments at the functional level and by body structure. However, there is not always a direct relationship between these three domains.⁴⁷ We can suggest that the improvements in UL function revealed in the present review could improve the participation in ADL and, consequently, lead to improvements in quality of life. Further, the improvements obtained in the FIM scale could be related to those obtained in the FMA-UE scale, as there is known to be a correlation between both instruments.³² Following the line of research proposed by Lohse et al.,³ we encourage researchers to state which domains of the ICF scale they intend to improve through the intervention.

Finally, according to Pietrzak et al.,¹⁶ emphasis should be placed on the need for incorporating videogames based on VR systems into stroke rehabilitation, in addition to making the service easier to use for therapy centers and home-based treatments. Moreover, therapists could design individualized VR games based on the patient's clinical features, by changing the duration, intensity, and difficulty level, and also by providing different types of feedback and positive reinforcements.³⁸

Although this article presents relevant information, some limitations need to be addressed. One limitation was related to the great variety of VR interventions, all of which are grouped under the same term or keyword. Further, acute and chronic strokes were not analyzed separately. Some studies^{25,48-51} were not included in the meta-analysis as they did not provide the data collected before or after the intervention. Another limitation was the different measuring instruments. It was not possible to statistically compare different studies because different versions of the same scale or different measuring units were used.

Conclusions

According to the results obtained, we can conclude that VR seems to be effective for the improvement of motor function of UL and quality of life after stroke.

This study can be helpful in clinical practice through the use of videogames based on VR systems and as a preliminary step for the realization of new studies on the subject, as well as by providing constructive criticism to improve the methodology of future interventions. It will be necessary to conduct clinical trials that use larger sample sizes and greater homogeneity in terms of the device used, the frequency and the intensity of the interventions, as well as trying to identify which specific factors of therapy have a greater weight in achieving a positive outcome.

Author Disclosure Statements

No competing financial interests exist.

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