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Review article

The effects of using virtual reality in the rehabilitation of stroke patients: Systematic review

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Abstract

Introdution: Stroke causes several alterations, the more frequent are motor, physical and psychological. Since rehabilitation takes time and can become monotonous, the use of virtual reality can act as a stimulating way to involve the patient in the treatment, seeking to develop its functionality. Objective: The objective of this study was to verify in the available literature the effects of using virtual reality in the treatment of the sequelae of the Stroke, to gain functionality in the upper limbs. Methods: This literature review was based on the PICO strategy, carried out in the databases Lílacs, Pubmed, Scielo and PEDro, using the keywords "physiotherapy AND virtual reality OR exergame OR exergaming AND stroke AND upper limbs". Complete articles were published in English, Portuguese and Spanish, available and dated between 2015 and 2020, excluding those that were review articles, incomplete and that did not address the topic. Results: As a result, the search found 1,035 articles, of which only 14 met the imposed criteria. Most studies have shown that the use of virtual reality through games has proved to be an efficient resource in the functional rehabilitation of patients with stroke. Presenting itself as a competent complementary to physiotherapeutic treatment in improving fine motor skills, motor behavior of the limbs and cognitive performance, these gains directly influenced the gain in functionality of the samples. Conclusion: The use of virtual reality is useful to assist in the treatment and reduction of sequelae in the upper limbs of patients with stroke, as it promotes greater functional gain, range of motion and improves the dexterity of both the most and the least compromised hand.

Keywords: Physiotherapy; Virtual reality; Stroke; Upper limbs.

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Introduction

In general, the stroke occurs due to blood irrigation problems, either in an ischemic form when it is caused by a localized vascular occlusion, or in a hemorrhagic form that occurs when a brain blood vessel ruptures with blood leakage, either way, both will culminate in the reduction of oxygen and glucose in brain regions. Some factors such as sedentary lifestyle, obesity, hypertension, atherosclerosis and other heart diseases can increase the likability of a person to develop the stroke, as it occurs due to blood irrigation problems, either in an ischemic forcing one of the types of stroke.[1-3]

In addition, stroke can cause muscle, somatosensory, psychological, cognitive and social damage. One of the most common sequelae, however, is hemiplegia, which causes difficulties in performing simple daily activities, as well as care, treatments and functional independence of that individual. Although the treatment of post-stroke patients is multidisciplinary, physiotherapy acts directly and, in general, both in reducing motor and/or sensory impairments, through the gain of ROM and muscle tone, as well as in cognitive, through the increase of balance and proprioception. When specifically related to the upper limbs, it is possible to obtain greater coordination, manual dexterity, develop motor learning, as well as improve the execution of arm movements as a whole. All exercises aiming at gaining functionality. The patient's lack of adherence to conventional therapeutic approaches, however, negatively influence the recovery of this individual.[4-8]

Furthermore, in order to make physiotherapy services more attractive, making them less repetitive or monotonous, the virtual world can promote greater patient interaction in therapy by inserting him in an environment that arouses his motivation and pleasure when exercising. Virtual Reality (VR) works as a computer system that allows the creation of an artificial environment, through which, the user can not only feel inside this environment, but also interact with it in real time, promoting a comprehensive experience by stimulating various senses such as sight, touch and hearing, mostly at the same time.[9-11]

In view of the various applicability of VR, it can be differentiated according to the way that the user interacts with the virtual environment and with the equipment used, being classified into immersive VR and non-immersive VR, or just Augmented Reality (AR). Immersive VR aims to isolate the individual from the real world, so that a special equipment is needed to block the individual to the real environment, causing their senses to be stimulated only by the computer system, through glasses, helmets, special gloves. On the other hand, in Augmented Reality the user is not isolated from the real environment, it is just an enrichment of the real world with virtual objects, in real time allowing the use of more accessible equipment, such as a computer, mouse, smartphone. There is still Mixed or Mixed Reality, which is the combination of the two types. However, the most used ones associated with therapies with different objectives are the Nintendo-Wii®, PlayStation® and Xbox 360 kinect, both of AR, in which the games were not designed for patients with motor problems. However, they provide a great improvement in motor function as they require the practice of specific activities that involves a greater number of repetitions. Hence, conventional Physiotherapy science added to the dynamism and playfulness of VR can generate better results.[12-16]

Bearing in mind that in addition to being an alarming public health problem, stroke can cause several sequelae, physiotherapy seeks to reduce general impairments through the use of VR that can increase patient compliance. It may also help he/she to gain functionality in a more playful way. The objective of this work is to search the available literature and critically analyze the effects of using VR on the gain of motor functionality in the upper limbs of stroke patients.

Materials and methods

It is an integrative review whose bibliographic survey was carried out on the bases: Lilacs, Scielo, PUBMED and PEDro. The PICO strategy was used, the acronym PICO stands for P (Problem), I (Intervention), C (Control) and O (Results). In this work, C (Control) does not apply, because there was no comparison of two interventions. Thus, the guiding question was: Is there any evidence that the use of VR can help improve the functionality of the upper limbs of patients with stroke? In addition, the keywords were: virtual reality, physiotherapy, stroke, cerebrovascular accident, stroke, virtual reality, physiotherapy, whose combinations used were "virtual reality AND stroke", "use of virtual reality in stroke", "physiotherapy and the use of virtual reality AND stroke "," physiotherapy and virtual reality and stroke ", exergame OR exergaming OR virtual reality AND upper limbs. To be included in this review, the studies identified by the search strategy should consist of research that used virtual reality in patients with stroke sequelae aiming at gaining functionality in upper limbs published in the last 5 years (2015-2020), as well as articles in Portuguese, English and Spanish and available in full. PEDro Scale was also applied to verify and show the quality of the selected studies in order to improve the conclusions about the study, in addition to excluding review articles, reports or case series, as well as studies whose sample was not an adult population.

Results

A total of 1,035 articles were found, 93 of which were selected for a careful evaluation and of these, 79 did not fit the eligibility criteria, thus, only 14 were included in the research, and of these 92.85% of them used not immersive VR, while only 7.15% of them used immersive VR. As for the types of study: 14.29% were of the controlled and randomized type; 14.29% of the blind, controlled, randomized and multicentric type; 14.29% described only as experimental; 21.43% of the blind, controlled and randomized type, and among the 35.70% of them, there are studies of varied types, such as double blind clinical trials, double blind pilot studies; blind, simple and randomized and randomized, parallel and multicentric group. As for the objectives of the studies, 57.15% of them sought to gain functionality in the secondary outcome, with 42.85% seeking it in the primary outcome. Thus, the articles used aimed at gains: cognitive (14.29%); independence (14.29%); motor function (57.15%); sensory function (7.15%); manual dexterity, gross (14.29%); range of movement (21.43%); motor learning (14.29%); adherence and motivation (50%) and feasibility and security (21.43%). (Figure 1)

The information presented in the included articles was summarized in the following topics: author/year, type of study and sample, intervention, analyzed variables, outcomes, results and PEDro Scale (see Tables 1 to 6).

Discussion

According to the studies found, the use of VR games provided the improvement of motor physical function[17-20] and sensory function of the most compromised hand,[17] as well as of gross manual dexterity,[21] active range of motion[18] for shoulder flexion,[22,23] also developing motor learning,[19,21] and in addition to the functional improvements, improvement in treatment adherence and motivation during conventional therapy can be demonstrated.[24-27] However, some studies emphasize that the achievement of these improvements may not have happened due to the exercises performed in VR therapy, but because of the greater adherence promoted by virtual games, compared to conventional therapy, because it makes it more inviting and diversified.[22,26,27]

The smallest sample of selected articles was 10 participants and the largest was 65, with the remaining studies ranging from 20 to 30 individuals, with few dropout rates among them, however, the results were similar and VR therapy was, generally applied in association with conventional therapy, known as "mixed therapy".[17,21,19] In addition, some studies have added, in addition to conventional physiotherapy, occupational therapy as well. And in these, the VR influence scores on cognitive development and motor learning were higher, highlighting the importance of treating patients with stroke in a multidisciplinary way.[18,23,25,29,28]

As for the duration of the sessions, they ranged from 30 to 45 minutes. One of the studies left the session time open, as the VR device would be installed in the patient's

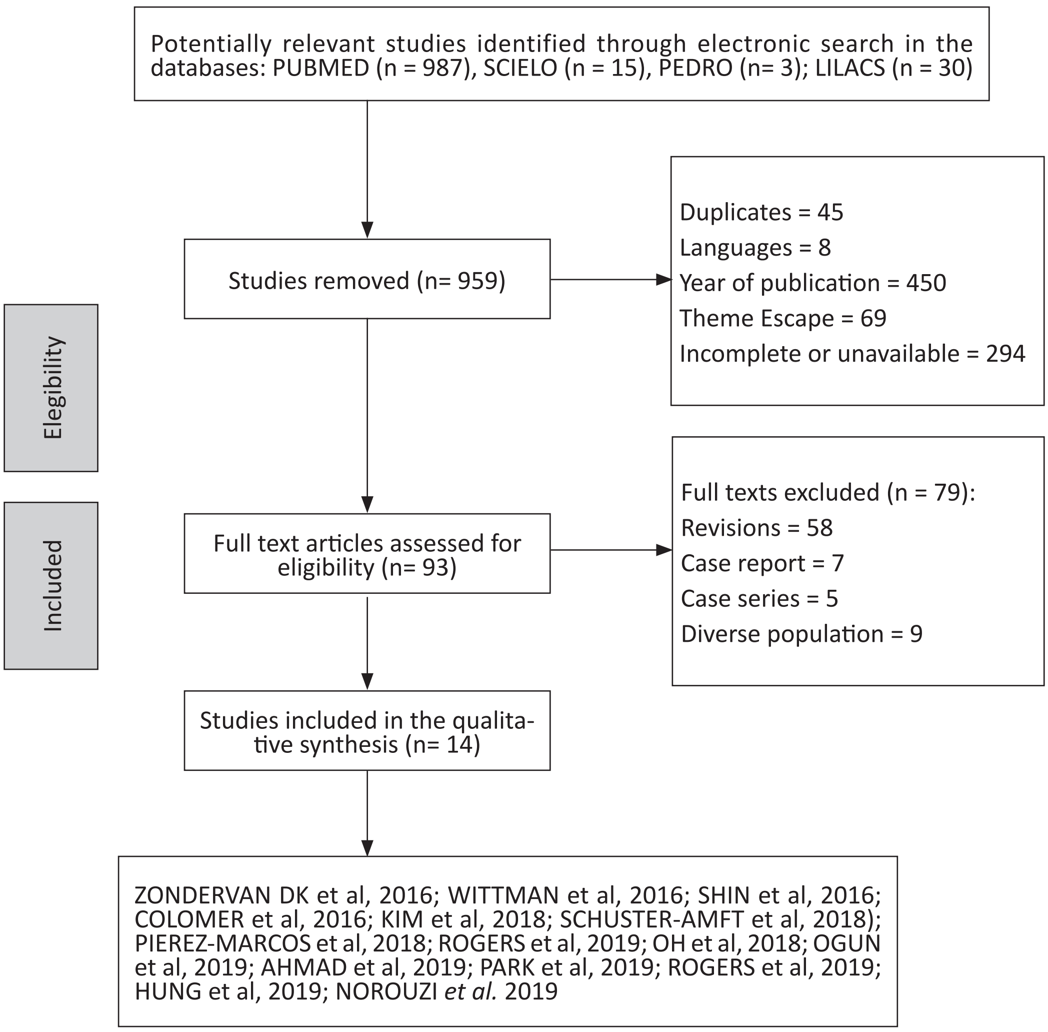

Figure 1. Flowchart of article selection
Authorship: The authors (2020)

Table 1. Selected studies that used virtual reality in patients with stroke to gain functionality

AUTHOR	SAMPLE	INTERVENTION	VARIABLES ANALYZED	OUTCOMES	RESULTS	PEDro SCALE
WITTMAN et al, 2016	Clinical Trial 11 participants using conventional therapy plus VR at home.	It was used: ArmeoSenso, based on RA, comprises a motion capture system based on wearable IMUs (MotionPod 3, Movea Inc.), for motion tracking, added to a computer with an all-in-one touch screen (Inspiron 2330, Dell Inc). Therapy: The game Metheoros, works with arm movements, while Slingshot works with targeting, demanding precision and resistance. Period: The patients themselves decided on the frequency and time dedicated to therapy, however the average was 40 minutes, during the 6 weeks that the study lasted.	Fugl-Meyer assessment of the upper extremity (FMA-UE), the Wolf Motor Function Test (WMFT) used to assess arm function, training intensity and trunk movement.	Primary outcome: Feasibility and safety of the application of VR without supervision, observe the patient's adherence to therapy, Verify the applicability of VR as home therapy. Secondary outcome: improvement in compensatory patterns and functionality.	There was a good adherence to home therapy, functioning as a complement to conventional therapy. In addition to being safe and feasible, it enabled daily monitoring of therapy, detection of maladaptive motor patterns, such as trunk movements during reach, improving the patient's functionality.	2
ZONDERVAN DK et al, 2016	Clinical, Blind, Controlled and Randomized Trial 17 participants separated into MusicGlove group and group with conventional table exercises.	It was used: AR was implanted through MusicGlove and a laptop with the pre-installed software. Therapy: Requires the user to practice functional grasping movements by touching the sensor on the tip of the thumb according to the video game musical tune that displays scrolling notes on a screen. Period: There were 3 sessions, once a week, for 3 weeks, with a minimum duration of 3 hours.	Movement Quality Test and Motor Activity Log Use Quantity Test Box and Blocks (BBT) test to measure the ability of upper limbs.	Primary outcome: Adherence, feasibility of applying VR therapy at home and motivation in therapy. improved grip movements, functionality. Secondary outcome: Improved grip movements, quality of movement, motor function.	MusicGlove therapy is feasible and effective for therapy at home, in addition to promoting adherence to therapy, it was also observed that there was no great difference between the group that used MusicGlove and the group with conventional exercises, both showing an increase in functionality and in quality of hand movement in daily activities	5

Table 1. Selected studies that used virtual reality in patients with stroke to gain functionality (continued)

SHIN et al, 2016	Blind, Controlled and Randomized Study. 46 participants, divided into: group with SmartGlove and group with conventional therapy.	It was used: AR was implanted through RAPAEL Smart Glove ™ (Neofect, Yong-in, Korea), a biofeedback system designed for upper extremity rehabilitation in stroke survivors, added to a glove-shaped sensor device and an application software. Therapy: Games to catch butterflies or balls, squeeze oranges, fish, cook, clean the floor, pour wine, paint fences and turn pages. Period: There were 20 sessions, during 4 weeks, lasting 30 minutes.	Fugl-Meyer (FM) assessment, changes in the Jebsen-Taylor hand function test (JTT), Stroke Impact Scale (SIS).	Primary outcome: Improvement of motor function. Secondary outcome: Gain in range of motion (ROM) and functionality	VR-based rehabilitation can be more effective than rehabilitation to improve the function of the distal upper extremity, range of motion and quality of life of the patient.	5
COLOMER et al, 2016	Experimental Study. 30 subjects with treatment divided into phase 1, conventional therapy and phase 2, VR-based therapy.	It was used: AR was implanted through a table system with multitouch interaction of tangible objects, Kinect ™ depth sensor (Microsoft®, Redmond, WA, USA) and an EB-1720 projector (Epson®, Suwa, Japan). Therapy: The games required daily tasks, such as grating carrots or dialing numbers, it was necessary to obtain certain measures of precision and speed in the movements to advance the phase. Period: There were 30 sessions, 2 to 3 times a week, lasting 30-45 minutes.	Motricity Index, Fugl-Meyer Rating Scale (FMA), Modified Ashworth Scale, Box and Block Test (BBT)	Primary outcome: clinical efficacy and acceptance of the intervention. Secondary outcome: gross manual dexterity, motor learning and promotes gain in functionality.	AR proved to be effective and motivating for the rehabilitation of upper extremity motor skills, manual dexterity and functionality in chronic stroke patients.	3

Table 1. Selected studies that used virtual reality in patients with stroke to gain functionality (continued)

KIM et al, 2018	Double Blind, Controlled and Randomized Study 23 individuals separated into: group with system based on Kinect, and group with false virtual reality.	It was used: Three types of AR-based programs were developed: “Push Museum”, “Apple Run” and “Fruit Market”. These programs were made using the Unity three-dimensional (3D) game engine (Unity Technology Inc., San Francisco, CA). The Push Museum uses the Microsoft Kinect sensor (Microsoft Corporation, Redmond, WA) and its software development kit (SDK). Therapy: games aimed at functional rehabilitation of upper limbs Period: There were 10 sessions, during 10 working days, lasting 30 minutes.	Fugl-Meyer (FMA) assessment Accelerometers were used to measure hemiparetic movements of the upper limbs during therapy.	Primary outcome: improvement of arm movements, motor function and functionality. Secondary outcome: improved adherence and motivation in therapy.	The functional gain and adherence to VR was good and the VR system induced more arm movement and similar activity compared to conventional therapy, which suggests its usefulness as an additional adjuvant therapy during stroke rehabilitation.	6
SCHUSTER-AMFT et al, 2018	Randomized Study, Parallel and Multicentric Group. 20 separate patients and group using VR + conventional therapy and group using conventional therapy only	Used: The YouGrabber® device (now renamed Bi-Manu Trainer) based on RA, designed for rehabilitation of upper limbs in people with stroke. Therapy: Manipulation of virtual objects. Period: There were 16 sessions, 4 times a week, for 4 weeks, lasting 45 minutes.	Box and Block Test (BBT), for dexterity monitoring. Chedoke-McMaster arm and hand activity inventory Stroke Impact Scale (SIS)	Primary endpoint: manual dexterity Secondary outcome: bilateral functionality	The use of a training system based on virtual reality, can be a safe training option that helps in the functional gains, bilaterally, and mainly of manual dexterity, there were no significant differences between the groups.	4

Table 1. Selected studies that used virtual reality in patients with stroke to gain functionality (continued)

PIEREZ-MARCOS et al, 2018	Double blind pilot study. 10 patients using VR in addition to conventional therapy	We used: The MindMotion ™ PRO system (MindMaze SA, Switzerland), table version, based on RA, composed of a 3D motion tracking camera (MindMaze SA) that quantifies the angle of the joints, and a touch screen with a built-in computer. Therapy: Included games that require functional tasks such as: pointing, reaching and learning virtual objects. Period: There were 10 sessions, twice a week, for 5 weeks, lasting 1 hour.	Motor function test (Fugl-Meyer assessment for upper extremity; FMA-UE) Functional Independence Measure (FIM).	Primary outcome: evaluate the rehabilitation dose and the training intensity that VR offers. Secondary outcome: gain in functionality, active ADM, strength, functional independence, motivation and acceptance of technology.	A VR system could provide high doses of rehabilitation and, mainly, intensive training aimed at gaining ROM and functional gains in chronic stroke survivors.	2
OH et al, 2018	Controlled and Randomized Study. 31 individuals using VR in addition to conventional therapy	It was used: Joystim, based on RA, was used with a three-dimensional manipulator with a monitor, a conventional computer and real instruments with three degrees of freedom, imitating knobs, buttons, steering wheels, among others. Therapy: 9 modules were given, with 9 basic tools, with 9 games that used the aforementioned instruments. Period: There were 18 sessions, 3 times a week, for 6 weeks, lasting 30 minutes.	Manual muscle test, modified Ashworth scale; upper scale of the Fugl-Meyer (FMA) engine; Box and Block (BBT), 9-hole test (9-HPT); Montreal-Korean Cognitive Assessment.	Primary outcome: Improvement of motor function, gain of elbow flexion and functionality of the upper limb. Secondary outcome: Improved adherence and motivation in therapy.	VR can encourage and motivate patients to undergo rehabilitation training with task-oriented exercises, which are considered to be the most beneficial for motor function, ROM and upper limb cognitive function.	4

Table 1. Selected studies that used virtual reality in patients with stroke to gain functionality (continued)

ROGERS et al, 2019	Pilot, Controlled and Randomized Study. 21 individuals divided into: group using conventional therapy + VR and in the other only conventional therapy	It was used: The Elements system, was added to the AR games and executed through a tangible object, suitable for the task, a 42 inch touchsceen LCD panel, with built-in CPU Therapy: Performing tasks such as lifting or sliding your hand, placing objects on selected targets, performance metrics (speed and accuracy) Period: There were 12 sessions, during 4 weeks, lasting 30-40 minutes, added to 3 hours a day of conventional therapy.	Box and Blocks Test (BBT); Montreal Cognitive Assessment and selected CogState subtests; Set Shift Task (SST); Montreal Cognitive Assessment (MoCA)	Primary outcome: Improvement of physical motor function. Secondary outcome: Improvement of cognitive function, and gain of functionality	Elements using goal-oriented upper limb movement tasks improves functionality as it facilitates motor and cognitive recovery after stroke.	5
OGUN et al, 2019	Pilot, Blind, Controlled, Randomized and Multicentric Study. 65 subjects using conventional VR + therapy	It was used: Immersive VR was implanted through a device that functioned as a 3D glasses that covered eyes and ears, coupled to the Leap Motion device. Therapy: Games to grab and handle objects with movement and stability of the arm and forearm. Period: There were 3 sessions, 3 times a week for 6 weeks, lasting 30 minutes.	Action Research Arm Test (ARAT); Functional Independence Measure (FIM); Fugl-Meyer Upper Extremity Scale (FMUE); Self-Care Skills Performance Assessment (PASS).	Primary outcome: Improvement of physical motor function and motor learning. Secondary outcome: Gain functionality, independence and self-care	The use of VR promoted the improvement of motor learning and caused a significant evolution in all tests of functionality, independence and self-care.	5

Legend: Virtual Reality (VR); Activities of Daily Living (AVD's); 9-hole test (9-HPT); MusicGlove (glove instrumented with sensors at the fingertips); Fugl-Meyer scale of the upper extremity (FMA-EU); Box and Blocks Test (BBT); ArmeoSenso (virtual reality system that captures movements based on wearable sensors); Wolf Motor Function Test (WMFT); RAPAEL Smart Glove ™ (Neofect, Yong-in, Korea, a biofeedback system designed for rehabilitation of the distal upper extremity in stroke survivors); Jebsen-Taylor test (JTT); Stroke Impact Scale (SIS); MindMotion ™ PRO (VR-based motor rehabilitation system developed for functional training of the upper limb after brain injury); Avatar (doll that simulates the person inside the game); Jintronix (movement-based rehabilitation system); Kinect (device that captures movements through depth sensors); Exergames (electronic games that capture and virtualize users' real movements); Scratch (is a programming language that allows the creation of stories, animations, games and other productions); PC (computers in general); CyWee Z (game controller); Leap Motion (device that captures movements through infrared sensors); Joystim (real instrument in neurorehabilitation); Bi-Manu Trainer (VR training system); Slingshot (type of game used for AR).

Authorship: The authors (2020).

home, and aimed not only to verify the effect of VR, but also the patient's adherence to therapy and, as a result, the study showed that the games were used for a minimum of 8 minutes and a maximum of 41 minutes, and patients who used VR therapy for less time were in the chronic phase of the stroke. This information highlights that the adherence to therapy is greater in patients with more acute sequelae,[30] which is related to another study in which they applied VR therapy for 60 minutes and found that after the initial 10 minutes, patients with chronic stroke show fatigue, as well as have reduced the quality of movement.[19] Such observation suggests that therapy with the use of VR in patients with chronic sequelae, showing less adherence, should still be administered for less time to avoid fatigue in patients.

To really verify the gains obtained with VR, studies used several scales and tests scientifically validated, among them the Fugl-Meyer Assessment (FMA), which stands out as the best known,[17,18,19,23,22,25,28,30] Stroke Impact Scale (SIS),[17,18,23,28,29] Functional Independence Measure (FIM),[19,22] Box and Block Test (BBT),[20,21,24-26,28,29], Wolf motor function test (WMFT),[17,23,27,30] Self-Care Skills Performance Assessment (PASS)[19] and the Pittsburgh Participation Scale (PPS).[27] However, the scales in which the intervention generated the best results were PASS, FMA and BBT, while in the others, the results obtained were not very significant. Yet, one of the studies did a one-month follow-up and the functional and cognitive benefits were being maintained only with conventional therapy.[20]

Most articles used VR games as a means to obtain motor and cognitive functionality, however some of the articles emphasized that in addition to functionality gains, VR systems can work as a means of avoiding compensatory movements in or near the segment being worked on, as well as more distal segments where the therapy is being applied, such as the trunk.[21,30] This is in line with studies that have worked with VR, both immersive and non-immersive, in which they reported that these systems, by providing visual feedback in real time, can favor self-correction aiming at reducing excessive movements or deviating from normal.[19,28]

Only one study used immersive VR using 3D glasses and obtained several functional gains and mainly motor learning.[19] However, the vast majority of studies used non-immersive VR using equipment such as ArmeoSenso,[30] Jintronix®,[28] Kinect2Scratch®[27] and also acquired significant gains, not only in terms of functionality but also in terms of adherence to treatment, this is probably due to ease of application, as well as, because it does not require very specific equipment, and some authors stated its safety and applicability at home,[26,30] aiming mainly to continue the treatment already acquired in the hospital or clinic, because, in addition to demonstrate to be a low-cost therapy,[24] it can still be applied without the therapist, only with initial instructions, this would be useful for patients who live in areas very distant from the Rehabilitation Centers, however frequent follow-ups are necessary to ascertain the evolution of the treatment.[21,24]

However, in all the articles presented, VR was used associated with conventional treatments, thus, the gains obtained are related both to the efficiency of application and adherence to VR therapy, as well as to the methods used in conventional therapy, which were not strictly applied. detailed in most of the articles. Despite the diversity of methodologies and duration of interventions, the biggest and most common gains obtained were from motor functionality of the most compromised hand, ROM, coordination and manual dexterity. Therefore, further research is needed, with a better description of the forms and applications of conventional therapies, as well as studies that standardize only one type of technology or game, describing and characterizing, even in the methodology, the type of VR used, whether immersive, non-immersive or mixed, to achieve clearer results on the effects of VR in the treatment of sequelae of the upper limbs of a patient with stroke.

Final considerations

The results of this review showed that VR is efficient in terms of gaining motor functionality of the upper limbs as it provides, as main effects, gain in range of motion, improved dexterity, motor function and function, both in the hand and in the less compromised patients. In addition, VR proved to be a differential in therapy, because in addition to allowing the patient to continue rehabilitation at home, it can also encourage not only adherence to conventional therapy, but induce several functional, sensory, cognitive and psychological gains. Furthermore, through VR games, regardless of their type, the patient is encouraged to seek self-correction due to the feedback, mainly visual, provided by them. It is also possible to use VR more comprehensively, aiming to perceive some compensatory movements of other segments of the body in which the therapy is not being applied, such as the trunk, and to seek to correct or reduce them. However, VR effects proved to be more relevant and noticeable in less compromised patients.

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