Virtual rehabilitation effectiveness in the body balance and motor skills of individuals with neuromotor deficit: a systematic review

Efetividade da reabilitação virtual no equilíbrio corporal e habilidades motoras de indivíduos com déficit neuromotor: uma revisão sistemática

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Abstract

The physical capabilities are reduced in individuals with neuromotor damage. The balance and motor skills are affected by diseases in the nervous system. Virtual reality (VR) has been used to balance recovery and motor function these individuals, but its effectiveness is not fully known. The aim of this study was to identify and analyze studies that investigated the effectiveness of virtual technology in the rehabilitation of the body balance and motor skills of individuals with neuromotor deficits. We included clinical trials and / or randomized controlled trials published in English and Portuguese between 2001 and 2011, wich used with VR exercises as therapy for individuals of both genders, aged 45 years or more with neurological disorders. The following databases were consulted: Medline, BVS, SciELO and PEDro. Studies found in the references were also considered for further reviews. The PEDro scale was used to evaluate the scientific quality of articles. Studies with a minimum of 6 points on this scale were included and analyzed, totalling of seven studies. The mean effect size for the virtual rehabilitation body balance (0.50 ± 0.35) and motor skills (0.52 ± 0.34) were better to other interventions (0.17 ± 0.16 and 0.25 ± 0.22 respectively). VR proved to be effective in the rehabilitation of the body balance and motor skills of individuals with neuromotor deficits although the amount of evidence is still limited. Despite the positive effect shown the method should still be used with care and also studied in subjects with other conditions.
Keywords: Rehabilitation; Physical exercise; Virtual technology.

Resumo

As capacidades físicas são reduzidas em indivíduos com prejuízo neuromotor. O equilíbrio e a motricidade são afetados por enfermidades no sistema nervoso. A realidade virtual (RV) tem sido utilizada para a recuperação do equilíbrio e função motora desses indivíduos, mas sua efetividade é pouco conhecida. O objetivo do presente estudo foi identificar e analisar estudos que investigaram a efetividade da tecnologia virtual na reabilitação do equilíbrio corporal e habilidades motoras de indivíduos com déficit neuromotor. Foram incluídos ensaios clínicos e/ou experimentos controlados e randomizados publicados em inglês e português entre 2001 e 2011, que utilizaram como terapia exercícios com RV para indivíduos de ambos os gêneros, com enfermidades neurológicas e idade igual ou superior a 45 anos. As bases de dados consultadas foram: *Medline*, BVS, *PEDro* e *SciELO*. Também foram considerados estudos encontrados nas referências de outras revisões. Para avaliação da qualidade científica dos artigos utilizou-se a escala *PEDro*. Estudos com o mínimo de 6 pontos nessa escala foram incluídos e analisados, totalizando sete estudos. As médias do tamanho do efeito da reabilitação virtual para o equilíbrio corporal (0,50 ± 0,35) e para as habilidades motoras (0,52 ± 0,34) foram superiores às de outras intervenções (0,17 ± 0,16 e 0,25 ± 0,22 respectivamente). A RV mostrou-se efetiva na reabilitação do equilíbrio corporal e habilidades motoras de indivíduos com déficit neuromotor, mas a quantidade de evidências ainda é limitada. Apesar do efeito positivo apresentado, o método deve ser utilizado com atenção e também pesquisado em sujeitos com outros quadros clínicos.
Palavras-chave: Reabilitação; Exercício físico; Tecnologia virtual.

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• Recebido: 01/09/2011
• Re-submissão: 10/11/2011
17/02/2012
27/03/2012
• Aceito: 29/03/2012

INTRODUCTION

Changes in body balance and motor skills in individuals with nervous system injuries have been studied for years[1, 2]. The reduction in sensory information due to neurological injuries results in a decrease in one's ability to control body balance[3], whereas motor skills are mainly affected by cortical activity disorders and lack of use of impaired limbs[4, 5]. In addition, the aging process translates into worse neuromotor skills[6]. The amount and frequency of specific exercises promote an increase in motor development[1] and activities involving body mass support improve body balance[7-9].

Since the 1990s[10, 11], motor therapies and physical training using virtual reality (VR) have been researched. This intervention has been applied to rehabilitation with innumerable integrated resources, thus distinguishing types of treatment. Among such resources associated with extrinsic feedback, the following stand out: robotics[12] (devices used by individuals to receive tactile stimuli), telereabilitation[13] (computers installed at home for residents to train with visual stimuli, while being monitored and guided by researchers in their laboratory) and immersion[14] (individuals are placed in a set environment where they receive visual and auditory feedback).

Physical exercise benefits have been achieved with virtual reality to improve physical fitness[15], whereas, in rehabilitation, virtual environments have been used as an alternative in the treatment of individuals having stroke sequelae with motor deficit and/or impaired body balance[13, 16, 17]. Important changes in the cortical activity pattern seem to occur in post-stroke individuals after the execution of movements in a virtual environment[18]. This improvement in motor performance can be maintained in post-stroke individuals engaged in virtual rehabilitation programs, because motor learning transfer from a virtual environment to a real environment has been effective[19]. With regard to body balance, significant improvements in walking after virtual reality training have been shown[20]. All these changes, apparently positive in neuromotor performance, seem to occur due to neuroplasticity mechanisms[5, 18, 21], in which healthy neurons perform the functions of impaired neurons[5].

In addition to the low cost and viability in the use of virtual training[9], the amount of sensory information provided by these systems appears to be a strong element for the acquisition of body balance and improvement in motor function[13, 22]. These variables are essential for the execution of activities of daily living (ADLs), especially in individuals with brain impairment[23, 24]. The external visual feedback provided by the virtual environment promotes an increase in the performance of these variables[9, 13]. However, there are reports that the use of some of these systems without adequate guidance can cause orthopedic injuries[25-27] and apparently does not change cortical activity in healthy individuals[28], apart from inconclusive motor function results being obtained[12].

Due to divergent information about this theme, confusing study designs and procedures found in the literature and the growing clinical application of virtual rehabilitation, a broad review of this subject is required to make a more conscious decision about interventions performed with this new method. Consequently, the present systematic review aimed to identify and analyze the studies that investigated the effectiveness of the use of virtual technology in body balance and motor skill rehabilitation in individuals with neuromotor deficit.

METHODS

Type of study

The present study was a systematic literature review, based on methodological procedures of assessment of the articles included, revealing their qualitative and quantitative aspects.

Study search strategy

Researchers analyzed original articles on the effectiveness of virtual technology through visual feedback in body balance and motor skill rehabilitation in individuals with neuromotor deficit, published in English and Portuguese between 2001 and 2011 and found in the following databases: National Library of Medicine (Medline), *Biblioteca Virtual em Saúde* (BVS) with integrated search sources (LILACS, IBECS, Medline, CidSaúde, DESASTRES, HISA, HOMEOINDEX, MedCarib, REPIDISCA, PAHO, WHOLIS, LIS and Cochrane), Physiotherapy Evidence Database (PEDro) and Scientific Electronic Library Online (SciELO). Combinations of descriptors and terms and their respective synonyms in English or Portuguese were used for each database. The following synonyms were obtained after being identified in the *Descritores em Ciências da Saúde* (DeCS – Health Sciences Descriptors): virtual reality, virtual rehabilitation, games for health, postural balance, body balance, balance, motor skill, functional skill, motor function, functional autonomy, activities of daily living and routine activities. Only the terms "postural balance", "balance" and "routine activities" were translated into English with the DeCS platform. After this procedure was performed, the synonyms referring to translated words were identified in the Medical Subject Headings (MeSH). Additionally, the following terms were included in the search: Wii gaming, Wii Balance Board, Wii Fit Plus, Nintendo Wii and exergames. Whenever the database allowed an age range to be selected, researchers chose "between 45 and 80 years". The study search strategy was described in TABLE 1. A total of 63 studies were retrieved from the databases used. In addition, studies identified in the lists of references of other reviews and of studies on this theme were also included, totaling ten studies. A total of 73 articles were included in the present review. The entire procedure was performed by a single researcher.

Criteria for the inclusion of studies

The following were taken into consideration to be included in this review: clinical trials and/or randomized controlled trials that used virtual reality systems as therapy or training, in which participants were older than 45 years of age and had a neurological disorder that caused a reduction in body balance and motor skills.

Criteria for the selection of studies

Selection began with the verification of coherence between the title and objective of each study, followed by the reading of abstracts. The following articles were excluded: those in which the abstract did not clearly state that the study dealt with the effectiveness of virtual technology through visual feedback in body balance and motor skill rehabilitation in individuals with neuromotor deficit and/or those that did not clearly describe the methodological procedures and the main results. After reading the titles and abstracts, the PEDro scale criteria[29] were used to assess methodological quality. The assessment of these studies was performed by an inde-

Figure 1 **Search strategy in the databases.**

Databases	Search strategy	Number of studies found
Medline	Title words – 1st Search: *Wii gaming OR Wii balance board OR Wii fit plus OR Nintendo Wii OR virtual reality OR virtual rehabilitati on OR games for health OR exergames OR Wii*	1,696
	2nd Search*: anterior AND postural balance OR balance, postural OR postural equilibrium OR equilibrium, postural OR balance OR musculoskeletal equilibrium OR equilibrium, musculoskeletal*	20,816
	3rd Search: *previous AND activities of daily living OR activities, daily living OR activity, daily living OR daily living activities OR daily living activity OR living activities, daily OR living activity, daily OR ADL.*	384
	4th Search: *previous* AND *delimiters of type of study*: *Randomized Controlled Trials, Clinical Trials, Controlled Clinical Trials;* *Year:* 45-64 *years*; =65 *years*; =80 *years* *Species: Humans* *Sex: males AND females*	19
BVS	Fields: title; clinical aspect; main subject; limits; year of publication; type of study Title words: *Wii gaming; Wii Balance Board; Wii Fit Plus; Nintendo Wii*; *virtual rehabilitation; virtual reality; games for health; balance; postural balance; body balance; functional skill; motor skill; motor function; functional autonomy; activities of daily living; routine activities.*	19
PEDro	Fields: only title; method; year of publication; sub-discipline Title words: *Wii gaming; Wii Balance Board; Wii Fit Plus; Nintendo Wii*; *virtual rehabilitation; games for health; exergames; postural balance; balance, postural; postural equilibrium; equilibrium, postural; balance; musculoskeletal equilibrium; equilibrium, musculoskeletal; activities of daily living; activities, daily living; activity, daily living; daily living activities; daily living activity; living activities, daily; living activity, daily; ADL.*	17
SciELO	Fields: title; clinical aspect; main subject; limits; year of publication; type of study Title words: *Wii gaming; Wii Balance Board; Wii Fit Plus; Nintendo Wii*; *virtual rehabilitation; games for health; exergames; postural balance; balance, postural; postural equilibrium; equilibrium, postural; balance; musculoskeletal equilibrium; equilibrium, musculoskeletal; activities of daily living; activities, daily living; activity, daily living; daily living activities; daily living activity; living activities, daily; living activity, daily; ADL*	8

pendent (blinded) evaluator (a physiotherapist) who did not participate in the review. The PEDro scale is comprised of 11 criteria, which are considered when an article is given a score, although the first criterion is only maintained to characterize the Delphi[30] list. Consequently, the PEDro scale provides a score of ten points in which the scoring criteria were adopted by consensus of the specialists. The scale helps to identify randomized or quasi-randomized controlled trials, contributing to the analysis of the scientific content of information by researchers. Each criterion was equal to one point. Whenever a criterion was met, one point was given; otherwise, no points were given. The scale criteria were as follows: 1) Eligibility criteria specification; 2) Random distribution of individuals into groups; 3) Blind distribution of individuals; 4) Homogeneity of groups with regard to the initial response variable; 5) Blind participation of individuals; 6) Blind treatment; 7) Blind assessment; 8) Experimental mortality of up to 15%; 9) Complete execution of the proposed treatment; 10) Inter-group comparison; and 11) Results in terms of the mean, standard deviation and significance level.

However, studies with a treatment or training intervention did not meet criteria 5 and 6 of the original scale, when scores were given for only eight criteria. Consequently, a cut-off value of six points (75% of eight criteria) was established, so that this study could be selected for the analyses.

RESULTS

Of the 73 articles included in this study, only seven were selected for the analysis (FIGURE 1), with scores that varied between six and eight points. Studies were grouped into a database. The main data collected from the articles were the mean and standard deviation values of variables associated with body balance and motor skills, in addition to the significance level (P-value) between the intra- and inter-group comparisons. The calculation of the intra-group effect size[31] was used to analyze the effects of interventions on each group of each article. Subsequently, the mean effect size of all groups was calculated. Results were organized according to the variable studied and assessment instrument (TABLES 1, 2 and 3). Studies that showed a significant intra- and inter-group improvement for at least one variable associated with motor skills or body balance were considered to be effective.

Of all seven studies that assessed motor skills, four[16, 17, 32, 33] only showed significant intra-group improvement, whereas the three others[13, 20, 22] showed a significant increase in performance among groups. According to the scientific rigor of the

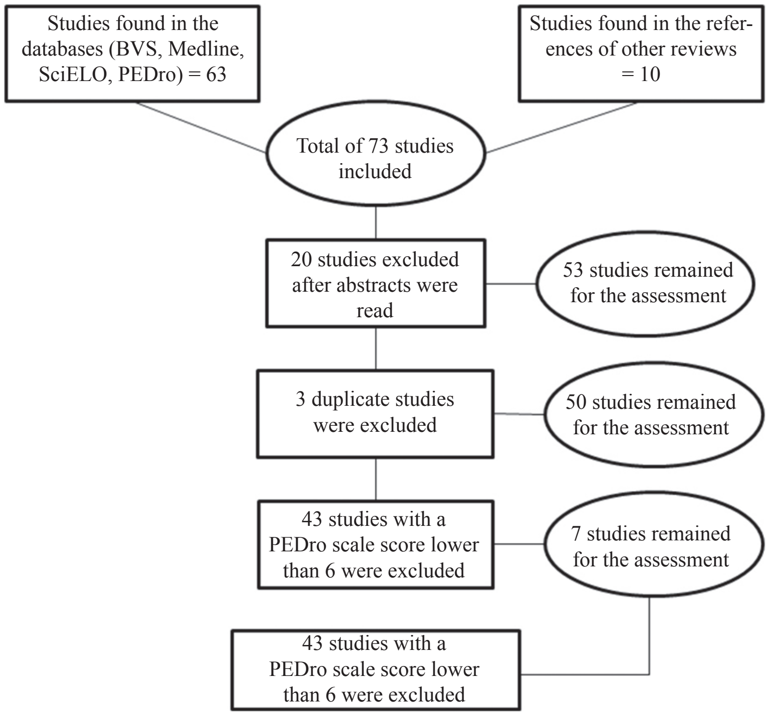

Figure 1 **Flow chart of the studies selected.**

Table 1 **Intra-group effect size (motor skills observed in clinical tests) of the studies selected.**

Author/Year	Sample	Age (years)	Test	Pre- (M ± SD)	Post- (M ± SD)	*Follow-up*	$_{Intra}$ES
Lam (2006)[33]	VR = 20	70 ± 15	*MTRS*	38.4 ± 15.8	49.1 ± 15.5*		0.67
	C = 16	70 ± 15		25.0 ± 19.8	34.6 ± 17.1*		0.48
	VR		*MTRSE*	61.0 ± 33.0	72.3 ± 26.2*		0.34
	C			30.5 ± 39.4	51.3 ± 32.9*		0.52
Piron (2009)[13]	VR = 18	66 ± 7	*FMUE*	48.5 ± 7.8	53.6 ± 7.7* #	53.1 ± 7.3	0.65
	C = 18	64 ± 7		47.3 ± 4.6	49.5 ± 4.8*	48.8 ± 5.1	0.47
Saponsnik (2010)[17]	VR = 11	55‡	*WMFT*	29.5s‡	19.8s‡	19s CI -10.5 (-19.3; -1.8)	-
	C = 11	67‡		39.7s‡	37.4s‡	25.7s CI -14 (-32.1; 4.1)	-
Kim (2009)[20]	VR = 12	52 ± 8	*MMAS*	3.9 ± 0.5	4.7 ± 0.6§ #		1.63
	C = 12	52 ± 8		4.1 ± 0.3	4.1 ± 0.3§		0
Gil-Gomez (2011)[32]	VR = 9	47‡	*STp*	6.7 ± 3.5	7.6 ± 4.0		0.24
	C = 8	47‡		6.5 ± 2.3	7.5 ± 2.4*		0.43
	VR		*STn*	9.3 ± 2.8	10.5 ± 3.0		0.41
	C			8.1 ± 1.7	9.5 ± 3.3*		0.77
	VR		*TST*	15.3 ± 9.6	13.5 ± 9.6		0.19
	C			14.8 ± 9.4	12.1 ± 4.9		0.28
	VR		*1MWT*	31.9 ± 12.4	42.6 ± 20.4		0.86
	C			31.1 ± 13.5	36.3 ± 15.3*		0.38
	VR		*10MT*	15.4 ± 8.2	13.4 ± 10.6		0.24
	C			14.5 ± 10.9	14.0 ± 9.0		0.04
	VR		*TUG*	20.9 ± 15.1	18.6 ± 13.4		0.15
	C			24.0 ± 14.8	19.5 ± 10.9*		0.3
	VR		*30SST*	7.5 ± 4.1	9.0 ± 4.7		0.34
	C			6.8 ± 3.5	8.5 ± 3.1*		0.46
Total VR ES							0.52
Total C ES							0.38

*M ± SD – mean ± standard deviation; IntraES – Intra-group effect size; FMUE - Fugl-Myer Upper Extremity; WMFT - Wolf Motor Function Test; Tre. - treadmill; MMAS - Modified Motor Assessment Scale; MTRS - MTR Skills; MTRS - MTR self-efficacy rating scale; STp - Stepping Test paretic; STn - Stepping Test non-paretic; TST - Timed Star Test; 1MWT - 1-Minute; Walking Test; 10MT- 10-m Walking Test; TUG - Time "up and go" Test; 30SST - 30-s Sit-to-stand Test; VR - Virtual Reality group; C – Group without virtual reality; ł - standard deviation value not informed; Total ES - mean intra-group ES of studies; * intra-group P-value < 0.05; # inter-group P-value < 0.05; § intra-group P-value not shown.*

Table 2 **Intra-group effect size (motor skills observed with the kinematic analysis) of the studies selected.**

Author/Year	Sample	Age (years)	Test	Pre- (M ± SD)	Post- (M ± SD)	*Follow-up*	$_{Intra}$ES
Mirelman (2010)[16]	VR = 9	62ł	GS (m/s)	0.65ł	0.81ł *	0.7 ± 0.1*	-
	C = 9	62ł		0.67ł	0.68ł	0.6 ± 0.2	-
Yang (2008)[22]	VR = 11	55 ± 1	GST (m/s)	0.6 ± 0.3	0.8 ± 0.3* #	0.8 ± 0.3*	0.53
	C = 9	61 ± 9		0.7 ± 0.5	0.7 ± 0.6	0.7 ± 0.7	0.03
	VR		TR (min)	23.1 ± 19.1	16.9 ± 18.3* #	15.7 ± 19.2*	0.32
	C			22.5 ± 26.0	20.6 ± 24.6*	19.9 ± 23.6*	0.07
Kim (2009)[20]	VR = 12	52 ± 8	GS (m/min)	48.6 ± 20.4	64.0 ± 22.6§ #		0.75
	C = 12	52 ± 8		44.4 ± 10.1	46.7 ± 13.0§		0.22
	VR		GP (p/min)	71.1 ± 13.8	82.4 ± 20.1* #		0.81
	C			73.2 ± 21.6	73.5 ± 21.9		0.01
	VR		TS (s)	0.9 ± 0.1	0.8 ± 0.1* #		0.38
	C			0.9 ± 0.2	0.9 ± 0.2		0
	VR		LS (cm)/AC	31.5 ± 7.6	35.6 ± 9.0* #		0.52
	C			30.9 ± 4.8	31.5 ± 6.2		0.12
Total VR ES							0.55
Total C ES							0.07

*M ± SD – mean ± standard deviation; GS – gait speed; GST – gait speed on treadmill; TR –time of route; GP – gait pace; TS: time of step; LS – length of step; Intra ES – Intra-group effect size; VR – Virtual Reality group; C – Group without virtual reality; ł - Standard deviation value not informed; Total ES – mean Intra ES of the studies; * intra-group P-value < 0.05; # inter-group P-value < 0.05; § intra-group P-value not shown.*

Table 3 **Intra-group effect size (clinical tests for body balance) of the studies selected.**

Author/Year	Sample	Age (years)	Test	Pre- (M ± SD)	Post- (M ± SD)	*Follow-up*	$_{Intra}$ES
Kim (2009)[20]	VR = 12		*BBS*	44.42±5.99	51.17±4.02§ #		1,12
	C = 12			46.67±3.75	48.25±4.22		0,42
Gil-Gomez (2011)[32]	VR = 9		*BBS*	41.22±10.57	45.44±8.62* #		0,39
	C = 8			45.38±7.35	46.88±6.15*		0,2
	VR		*BBA*	10±2	10.33±2.18		0,16
	C			11±1.31	11.13±1.13*		0,09
	VR		*ARTst*	24.13±7.70	27.25±10.38* #		0,4
	C			25.44±9.33	25.63±9.74*		0,02
	VR		*ARTsit*	34.83±11.92	37.78±12.34		0,24
	C			40.06±6.89	40.13±7.66		0,01
Total VR ES							0.46
Total C ES							0.17

*M ± SD – mean ± standard deviation; RV – Virtual Reality group; C – Group without virtual reality; Intra ES – Intra-group effect size; BBS - Berg Balance Scale; BBA - Brunel Balance Assessment; ARTst – Anterior Reach Test Standing; ARTsit – Anterior Reach; Test Sitting; Total ES – Mean Intra ES of the studies; * P < 0,05 intra-grupos; # Inter-group P-value < 0.05; § Intra-group P-value not shown.*

methodological design of these studies and their results, virtual rehabilitation was considered to be effective to recover the motor skills of individuals with neuromotor deficit.

With regard to body balance, three studies[20, 22, 32] selected in this review showed a significant improvement in performance, revealing the effectiveness of virtual rehabilitation in the recovery of body balance in individuals with neuromotor deficit. It should be emphasized that some of the data from one of the studies[22], which used self-administered questionnaires as instruments, were not included in any of the tables. However, significant results for the improvement in intra- (P-value<0.05) and inter-group body balance control (P-value<0.05) were taken into consideration.

DISCUSSION

Extrinsic visual feedback, which enables individuals with motor impairments to make neuromuscular self-adjustments, is a strategy that has been used for a long time[34] and it could have been one of the most important factors to motivate pioneering researchers in the area of virtual rehabilitation. The results of the present study showed that the use of virtual technology through visual feedback in body balance and motor skill rehabilitation in individuals with neuromotor deficit was effective to recover those with neurological impairments. An important factor to be considered is that these results show what has been occurring with regard to such theme in recent years. However, some of the studies selected in this review are not entirely clear[16, 33], as they have unexplained methodological designs and do not correctly show the application of the statistical analysis and significance levels found in the comparisons[20]. Additionally, one of the studies[17] attributed a positive result to virtual rehabilitation without performing inter-group statistical analysis. These researchers obtained positive results for motor function recovery both in the group that received virtual reality treatment and in the group that received traditional physiotherapy. Although the results appear to be more positive for virtual rehabilitation, the absence of statistical tests to compare groups cannot be neglected, which would show the superiority of one intervention over the other.

Encouraging results with the use of virtual reality in the rehabilitation of gait have been found by Mirelman et al[16]. An increase in gait speed and the power generated by the ankles was identified. However, researchers did not report that an inter-group statistical comparison was made to show the differences, nor were intra-group significance levels for the power of ankles shown. By comparing the mean values of the variables presented, an improvement in the group that used virtual reality as a resource can be identified. Nonetheless, despite being promising, the results would be more consistent if the comparison of responses between the groups tested was shown, in addition to the significance levels for both comparisons (intra- and inter-groups). Another extremely important factor to report post-intervention responses in a more reliable way is the explanation about the differences between groups in the pre-intervention period, which would strengthen the final results in case the null hypothesis was rejected.

Although few studies clearly show the procedures and explanations for the results, Piron et al[13] revealed high scientific content in their study design, performing a blind randomized controlled trial. Moreover, authors showed the mean values and standard deviation of each variable studied and the significance level found for all intra- and inter-group comparisons. In this study, the improvement in motor function was achieved after a four-week period of training with a weekly frequency of five sessions, each lasting one hour. The amount of training can be essential for the result obtained, as the massification of activities with the repetition and intensity of tasks led to better motor development. This effect is expected, as the repetition and intensity of tasks increase the perspective of motor learning[1]. However, there was no retention of the effect in the reassessment, one month after the training ended, although the variable showed values that were very similar to the post-intervention period in both groups. As the data analyzed originated from an ordinal variable and the statistical analysis performed was not parametric, some information may have been lost, explaining the non-significant difference found one month after the intervention ended.

Other data that deserve attention were found in a recent study conducted by Gil-Gomez et al[32], using the eBaViR system, which was tested at a different time by the same group of researchers[9] for the assessment and training of body balance. This study was blind randomized controlled trial, showing researchers' care for scientific rigor. The virtual training results seem to be effective for static body balance. However, the use of virtual reality was not efficient for dynamic body balance. Researchers argue that the tests used for dynamic body balance assessment may not be sufficiently sensitive to detect the expected changes. The superiority of the traditional therapy over virtual therapy was evidenced in these tests. Based on a general analysis, virtual reality therapy was more effective in only two tests out of eleven in this study. Despite the design quality and number of tests performed, this study did not show a more sensitive body balance measure, as would be the case of a force platform. Likewise, Yang et al[22] assessed body balance and the ability to walk with a scale and a questionnaire. Although this study showed the effectiveness of virtual rehabilitation, it should be noted that the application of a more sensitive measuring instrument in the assessments could lead to significantly better results for the variables studied, in addition to increasing the consistency of information.

An interesting proposal for the use of virtual technology is the training of instrumental motor skills, as performed by Lam et al[33] with post-stroke individuals who underwent a program that simulated routine tasks. However, when assessing the responses, both the group that trained with virtual reality and the group that watched a psycho-educational video showed an improvement, despite the lack of difference between groups. All information obtained reveals a new perspective for the training of such skills, although unfortunately it does not support the effectiveness of virtual technology treatment, when compared to the traditional method.

Important results were found by Kim et al[20], who investigated changes in body balance and motor function in post-stroke individuals. Researchers observed an improvement in body balance control, better motor test performance and an increase in gait speed, apart from positive changes in other variables associated with gait. However, although this study showed good virtual rehabilitation results, the significance level found in the intra-group analyses was not clear. Despite significance values having been shown in the comparisons between groups, describing the α value in the intra-group comparisons could provide better support for the statements about the effects obtained from the intervention performed.

The main physiological explanation for the improvement in the performance of the variables studied is the cortical reorganization, which occurred during the execution of induced movements, resulting in the mechanism of neuroplasticity[5]. This phenomenon is optimized when a certain type of extrinsic feedback is given[35]. The visual information provided by virtual reality seems to be closely associated with the increase in performance in individuals with neurological impairment and it is the main responsible for motor control improvement[18, 21, 35]. Considering the fact that this type of therapy requires systematic movements, executed three times per week on average with sessions lasting between 30 and 60 minutes each, researchers of this study speculate that important chronic neural adaptations occur due to training, such as the increase in neurotrophic factors (BDNF, VEGF and IGF-1)[36]. Such factors play a key role in chemical signaling for neurogenesis and angiogenesis, which could increase cognitive and motor performances. However, none of the studies included in the present study investigated these mechanisms, so that this is just an assumption.

The discoveries about body balance and motor skills in individuals who have undergone virtual reality-oriented task programs seem to be promising. Nonetheless, aiming to confirm the statements about the effectiveness of virtual rehabilitation, many adjustments need to be made in future studies, preventing positive results from being attributed to the method, when in fact errors may have occurred. Such errors could have been those made in the selection of participants (previous experience with virtual rehabilitation, for instance) or failures in the familiarization procedures, resulting in contamination due to a learning effect.

It should be emphasized that the present systematic review gathered the studies published during a period of ten years, thus guaranteeing a broad and objective approach to this theme. In addition, the assessment of studies performed by an independent researcher reduced the possibility of bias in the findings. However, the adoption of a cut-off point (PEDro scale score ≥ 6) in the assessment of articles did not consider items that may have limited the inclusion of certain studies, such as the lack of application of statistical analysis between groups.

In conclusion, virtual rehabilitation is a useful technique, both for motor function and body balance recovery in individuals with neuromotor impairment, in addition to enabling motivational aspects. Nonetheless, despite this positive effect for motor function and body balance, the methodological limitation of certain studies clearly shows the need for advances in this field of research. Thus, the method must still be used with caution and studied in groups of individuals with other clinical conditions.

Authors' contributions

Renato Sobral Monteiro Junior – Theme conception, construction of the text, formulation of the objective, study search strategy, synthesis and analysis of the studies.

Elirez Bezerra da Silva – Formulation of the objective, study search strategy, synthesis of the studies, methodological adjustments and review of the manuscript.

Acknowledgements

Authors would like to thank Cíntia Pereira de Souza for her participation in the blind assessment of the articles included in the review.

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