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Combining the benefits of tele-rehabilitation and Virtual Reality-based balance training – a systematic review on feasibility and effectiveness.

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Combining the benefits of tele-rehabilitation and Virtual Reality-based balance training – a systematic review on feasibility and effectiveness.

Purpose: A motivational surrounding is desirable in stroke rehabilitation considering the need to train repetitively to improve balance, even after discharge from rehabilitation facilities. This review aims to investigate if it is feasible to combine VR which allows exercising in game-like environments with tele-rehabilitation in a community-dwelling stroke population.

Methods: Literature searches were conducted in five databases, e.g. PubMed and the Cochrane Library. Randomised and non-randomised controlled trials investigating feasibility and effectiveness of VR-based tele-rehabilitation were included. Based on the risk of bias and study design, methodological quality is ranked according to the GRADE guidelines.

Results: Seven studies (n=120) were included, of which four are RCTs. Evidence regarding therapy adherence and perceived enjoyment of VR, as well as a cost-benefit of tele-rehabilitation emphasizes feasibility. Equal effects are reported comparing this approach to a therapist-supervised intervention in the clinical setting on balance and functional mobility.

Conclusions: Tele-rehabilitation could be a promising tool to overcome burdens that restrict accessibility to rehabilitation in the future. VR can increase motivation allowing longer and more training sessions in community-dwelling stroke survivors. Therefore, combining the benefits of both approaches seems convenient. Although evidence is still sparse, functional improvements seem to be equal compared to a similar intervention with therapist-supervision in the clinic, suggesting that for cost-efficient rehabilitation parts of therapy can be transferred to the homes.

Keywords: Stroke; Rehabilitation; Tele-rehabilitation; Virtual Reality; Balance

Introduction

Half of the stroke survivors leave rehabilitation facilities in a wheelchair[1] leaving those patients with persistent walking disabilities which restrict them from participating in society[2, 3, 4]. This is a major economic and ethical burden for our society since stroke is the leading cause of adult disability[5]. Even more, because of demographic changes the incidence is considered to increase dramatically[6]. Considering rather disappointing mobility outcome after stroke[1, 7], this increase will inevitably lead to a chronically dependent and disabled stroke population. Consequently, gait recovery remains a prioritized rehabilitation goal, even in the chronic phase[3] and there is a considerable need for effective as well as affordable and accessible long-term rehabilitation.

A Cochrane review found that repetitive task training is able to improve balance and walking ability irrespective of time post-stroke[8]. This emphasizes the need to engage the community-dwelling stroke population in exercises to improve functional mobility and counteract deconditioning. However, the long-term need for professional supervised rehabilitation is often restricted by transportation and rehabilitation costs as well as logistic difficulties[9, 10]. Therefore, home-based rehabilitation programs seem appropriate. This implicates that (a part of) therapy would be transferred from the clinical setting to the patient's home environment[11]. The concept of tele-rehabilitation, which is based on transfer of information through communication-networks such as the internet or telephone, can be used to observe and assess patients during training from remote[12]. The fact that these therapeutic sessions could take place in the patient's own environment, with minimal supervision of a physiotherapist, means that the financial and logistic burden could be overcome.

The use of virtual reality (VR) might be of interest in tele-rehabilitation considering the need of repetitive task-training[8]. VR provides a motivational, yet safe, surrounding to exercise which might lead to enhanced adherence to therapy[13]. Indeed, VR-based rehabilitation has been found to be feasible and effective in patients after stroke[13, 14], e.g. by the use of the Nintendo Wii[15] which is affordable and accessible suggesting its potential for home-based training. Despite progression in the utilization of VR-systems for stroke rehabilitation[13], the usefulness of VR-based training in tele-rehabilitation remains largely unknown. As a hypothesis, we suggest VR-based interventions in the home-setting to have equal effects as a similar or conventional intervention in the clinical setting on balance and mobility, however with advantages in terms of accessibility, perceived enjoyment and cost-benefits. Therefore, the aim of this review is to investigate these items on feasibility together with effectiveness of home-based VR tele-rehabilitation on balance and functional mobility.

Methods

This systematic review was conducted according to the PRISMA guidelines to guarantee high-quality reporting[16].

Literature search

The literature search was conducted in various databases including PubMed, Web of Science, the Physiotherapy Evidence Database (PEDro), Rehab Data and the Cochrane Library. The following search terms (and synonyms) were used: “stroke” and “virtual reality” and “tele-rehabilitation” or “home-based” and “balance”. An adapted search strategy was developed for different databases (see appendix). References of obtained systematic reviews with overlapping research questions were hand-searched for relevant studies. A final update of the literature search was conducted at 04/01/2018.

Study selection

At first, studies were screened on title and abstract by two independent researchers (XC, JVS). During a consensus meeting, the scores were cross-checked and if necessary, a third researcher (WS) was consulted. Included studies were then screened on full-text in a similar way. To be included, the studies had to fulfil the following inclusion criteria:

(1) Adult stroke survivors (>18 years);

(2) screen-based VR, to include those VR-applications which are accessible to a broader stroke population as a casual television- or computer-screen is used;

(3) balance training, including repetitive task training in upright postures, e.g. weight-shifting during bipedal stance;

(4) Training in the home-setting without physical presence of a therapist;

(5) Use of tele-rehabilitation methods, hereby no restrictions were set-up as this review aims to discover and discuss different methods to remotely stay in contact with the patients;

(6) Outcome measures on balance and/or gait ability and consequently unrelated measurements on upper limb motor functions and activities of daily living are excluded;

(7) Published in English, Dutch, German or French. Reviews and meta-analyses were excluded.

Methodological quality

The PEDro scale was used to score randomized-controlled trials (RCTs)[17]. Case control studies were scored using the Newcastle Ottawa Scale (NOS)[18] as it is an easy and convenient tool for quality assessment of non-randomized studies. Case series were scored using the National Heart, Lung, and Blood Institute (NIH) checklist as recommended by the United States National Institutes of Health[19]. The risk of bias assessment was conducted by two independent researchers. During a consensus meeting, the scores were cross-checked and if necessary, a third researcher (WS) was consulted. A classification on risk of bias is proposed here: A score of 8-9 on the PEDro scale was considered as low risk of bias, since blinding of participants and practitioners is difficult due to the nature and setting of the intervention. A score of 5-7 is considered a moderate and a score of 4 or less a high risk of bias. For the NOS and NIH checklist a similar classification was used. Finally, based on the risk of bias assessment and the study design, included studies are rated on methodological quality based on the GRADE grading system[20] (Table 1).

INSERT TABLE 1

Data extraction

Data extraction was executed by two independent researchers (XC, JVS) with cross-referencing to reduce the risk of errors. An excel template that was developed according to the purpose of this review was used. The included items are study design, characteristics of included participants (amount (N); age; time post-stroke at randomization) and intervention (VR and tele-rehabilitation methods; intensity, frequency and type of balance training), methodological quality (according to grading system, see Table 1) and finally outcome measures as well as observed effects within and between groups.

Data analysis

Outcome measures will be grouped according to feasibility and effectiveness. The first implies the safety of the intervention, adherence to therapy, perceived enjoyment of the users and finally a cost-benefit. Effectiveness will be analysed in randomised controlled trials on balance and gait measurements.

Pooling of data is considered if at least three independent randomised controlled trials compared a similar balance outcome measure between a tele-rehabilitation group and a control group which is provided a similar intervention in the clinical setting. In addition, results need to be reported adequately. If this is not the case, reviewers will contact the author(s) to provide data for analysis.

Results

Literature search

The search process resulted in 1110 hits (September 2017) (Figure 1). After de-duplication, 677 unique studies were included for screening. Of these studies, 29 studies were included based on title and abstract. After screening on full-text, 22 studies were excluded: 19 studies based on the intervention, two studies according to design and one according to the outcome. This led to a total of seven studies which are included for interpretation. Hand searching and a finale update on 29th of December 2017 yielded no additional relevant studies.

Study description

Methodological quality

Of the seven included studies, four are RCTs[21, 22, 23, 24], two are case studies[25, 26] and one is a case control study[27] and therefore different scales were used for assessing risk of bias. The researchers agreed for 95.8% of the items. A third researcher was consulted on items without agreement. Of the RCTs, one is of good quality[22] (1++), one of fair quality[21] (1+) and two present a high risk of bias[23, 24] (1- quality). Both case studies[25, 26] and the case control study[27] are according to design (small sample size) and modest to high risk of bias ranked as 2- quality (Table 2).

INSERT TABLE 2

Participants

A total of 120 participants were recruited in the seven studies, including both stroke patients in the late subacute (3-6 months post-stroke)[23, 24, 25] and chronic (>6 months post-stroke) [21, 22, 26, 27] phase. Baseline scores on the Berg Balance Scale indicate that most studies investigated on a mild-to-moderate disabled (BBS score >31[28]) population (experimental group)[21, 23, 24, 25].

VR system

Three included studies used a commercially available gaming device to provide VR. The Wii uses hand-hold sensors and/or a force plate to interact with the VR[27]. The PlayStation 2 EyeToy[26] and Microsoft Kinect[21] use a camera for full-body capture to interact with the VR. A system similar to the Wii balance board is utilized by Cikajlo et al.[24, 25] and Krpic et al.[23] as a force plate (Balance Trainer) is used which is attached to a computer, screening the VR and therefore provide feedback based on centre-of-pressure displacement in a game-like environment. Lin et al.[22] utilized a touch screen to allow interaction with the VR (Table 3). All systems investigated in this review displayed the VR on a screen placed in front of the user. In general, the television or the computer screen of patients are used. This emphasizes the accessibility of this intervention since purchasing expensive gear is (partially) avoided, lowering the costs of the intervention.

Tele-rehabilitation system

To allow supervision and guidance from remote, different tele-rehabilitation methods have been developed and utilized in the included studies. Frequent video conferences were scheduled to communicate with the patients and observe training-sessions[22, 23, 24, 25]. Additionally, included VR-systems track training performance giving an indication of adherence to and intensity of the therapy[21, 24, 26, 27] (Table 3). A specific designed program allows to track vital signs of the patients throughout the intervention to guarantee safety while training by detecting alarming signals in regard to heart rate, oxygen saturation and blood pressure [22].

INSERT TABLE 3

Outcome on feasibility

- *Perceived enjoyment*

Participants' perceived enjoyment is of great interest for this review, as VR is presented as a method to enhance motivation and adherence leading to effective repetitive task-training even after discharge from rehabilitation facilities. Lloréns et al.[21] used two questionnaires, the system usability scale (SUS) and the intrinsic motivation inventory (IMI). Both groups received the same VR-based treatment but the intervention group trained in their own environment. In both groups, high scores were reported suggesting that participants found the intervention usable and motivating irrespective of the setting and physical presence of a therapist. Lin et al.[22] utilized the following questionnaires on the attitude of the participants towards the utilization of tele-rehabilitation: System Environment Satisfaction (SES) and the Perceived Satisfaction of System (PSS). Reported scores are high suggesting tele-rehabilitation was easy to use and motivating. To investigate the usefulness of the VR-system, Flynn et al.[26] conducted an interview with participants. They also used daily logs to assess feasibility of use (FOU). They learned that training with the device (Sony Eyetoy on Playstation 2) was feasible and perceived as enjoyable and motivating since adherence to therapy was good (Table 4). These reports are in line with an excellent adherence to therapy reported in the tele-rehabilitation group emphasizing motivational aspects of VR-based training even in the home setting, without a therapist being physically present.

- *Cost-benefit*

The factors which highly influence the costs of stroke rehabilitation are human resources and travel expenses of the patients[21]. Regarding those factors, LLorens et al.[21] found, by comparing home-based and clinic-based groups, that if parts of rehabilitation can be transferred to the homes, human resources can be used more efficiently and costs of transportation services can be lowered. A similar cost-effective use of human resources is reported by Kripic et al.[23]. However, tele-rehabilitation required specific equipment which can be cost-demanding.

Outcome on effectiveness

Case (control) studies[25, 26, 27] report general positive effects of VR-based exercise interventions in a chronic stroke population (Table 4). However, due to small sample sizes and lack of a control group, outcome on effectiveness of these studies will not be reported in detail.

The only outcome measure used in all included RCTs was the Berg Balance Scale (BBS). This scale gives an indication of balance and can be used to assess changes in time. All four RCTs[21, 22, 23, 24] found general improvements over time, but not a significant difference between the intervention group(s) and the control group. Similar, no significant differences between groups for both standing on the unaffected and affected leg were found[24]. Performance-oriented mobility assessment balance subscale were discussed by Lloréns et al.[21] and again, no superior effects are detected. Equal results are documented for outcome measures of walking functions and mobility[21, 23, 24] (Table 4). Taken these results into account, the interventions are evenly effective irrespective of the setting and whether or not a therapist is physically present.

Pooling of data was impossible for the BBS post-intervention scores since Cikajlo et al.[24] and Krpic et al.[23] were excluded since they investigated dependent samples with high heterogeneity in baseline scores between groups. As a result, appropriate data is presented in only two RCTs[21, 22] which is insufficient for a meta-analysis.

INSERT TABLE 4

Discussion

The aim of this systematic review was to investigate the evidence for feasibility and effectiveness of VR-based tele-rehabilitation approaches on balance in patients suffering from stroke. Although evidence is sparse, the results for home-based VR tele-rehabilitation seem promising. The small number of RCTs included in this literature review tend to an equal effectiveness of VR-based tele-rehabilitation in the home setting compared to similar interventions in the clinical setting. Patients' perceived enjoyment and satisfaction, as well as adherence to therapy indicate a positive attitude towards VR-based tele-rehabilitation. Together with a suggested cost-benefit, these results seem to highlight the feasibility and therapeutic value of such an approach.

In recent years, several reviews and meta-analyses aimed to investigate the therapeutic value of VR-based interventions in stroke rehabilitation on balance and mobility[13, 14, 29, 30, 31, 32, 33, 34]. To sum up, there is a general trend in literature supporting the use of VR-based interventions since feasibility is proven and superior results are found even if groups are dose-matched (regarding time scheduled for therapy)[14]. Advantageous factors determining superiority are, to our opinion, two-fold and will briefly be discussed here. A motivational environment receives increasingly attention in stroke rehabilitation research[35] since data showed that the rehabilitation period is described as a time of being inactive and alone[36, 37]. Despite a dose-response relationship suggesting an association between more therapy and improved outcome[38, 39], current rehabilitation practice apparently fails to provide an environment that encourages stroke patients to stay active and engage in exercise. Since VR-based interventions are game-like, they might enhance active engagement and therefore provide such a motivational environment which allows longer exercise sessions and greater adherence to therapy. The latter notion is important also in the chronic phase to counteract deconditioning which typically occurs due to a sedentary lifestyle[40]. This review found adherence to home-based therapy to be excellent without physically presence of a therapist and even in an older population (e.g. mean age of 55.6 years old in the study of Llorens et al.[21]) which are typically not used to such technology. In addition, specific outcome measures on the perceived enjoyment highlight the motivational aspects of VR. However, data is sparse and therefore more in-depth research on the motivational aspect of VR in stroke rehabilitation is warranted[13]. The enjoyment while interacting with the VR might not only lead to more time spent exercising but might even improve skill learning and retention. Basically, VR-based interventions are perceived by the patients as games which provide a reward when patients recover[41, 42]. Additionally, interaction with the VR is based on biofeedback (e.g. COP displacement) and this feedback might facilitate learning[41, 42]. Taken together, the two-fold advantage of VR are the motivational aspect which can lead to more time spent exercising and secondly, the correspondence to motor learning principles by providing reward and feedback which might enhance training-induced functional gains. These factors might explain the trend in literature favouring VR-based balance and gait training[13, 14, 29, 30, 31, 32, 33, 34]. Equal effectiveness documented here, which might seem to be in contradiction to this trend, are most likely related to the methodology rather than the intervention itself. A lower dose and frequency of therapy is provided compared to inpatient rehabilitation trials and small sample sizes (n=120) are included as studies in this domain are generally underpowered.

VR-based interventions allow efficient training in the home setting as effectiveness in comparison to clinic-based interventions appears to be equal. The great economic advantage of this approach is that the patient does not necessarily have to relocate from home to clinical practice to exercise. Videoconferences while exercising in the home even allow supervision of task performance by clinicians. This can lower the global costs of stroke rehabilitation by reducing transportation efforts and guarantee efficient use of human resources, as documented in a RCT included in this review[21]. Tele-rehabilitation appears to be a promising therapy modality to provide qualitatively care to a growing chronic stroke population. The promising concept on combining the benefits of tele-rehabilitation and VR-based training together with preliminary evidence presented here, justifies further research in this domain.

Limitations of the review and implications for future research

Some limitations need to be acknowledged. Firstly, as described above, high-quality data is limited in this domain of research. There were only seven studies to fit the inclusion criteria which are case studies and pilot RCTs with small sample sizes. Therefore, investigation of feasibility and effectiveness was possible in a population of in total only 120 patients. It remains unknown whether results documented here can be generalized to a broader stroke population. Secondly, considering relatively high baseline scores of participants, it remains largely unknown how more severely affected and non-ambulatory stroke patients can safely be engaged in exercises in the home setting. Further research in this specific sub-group is highly warranted considering those stroke survivors' physical inactivity and inability to participate in the community. Thirdly, there is a high heterogeneity between studies: The type of VR differed, as some researchers use sensors (force-plate or hand-held controller) and others used cameras for motion capturing. Different software applications were used and different games were utilized. In some studies participants are taught to train with the VR-systems in-clinic and transfer the treatment afterwards to the home-setting while others start immediately in the home. The groups also differ as both subacute[23, 24, 25] and chronic[21, 22, 26, 27] stroke survivors are recruited. Lastly, due to the nature of this intervention blinding of subjects and therapists is very hard leading to a higher risk of bias. To sum up, limited data, low methodological quality and high heterogeneity make it difficult to draw uniform conclusions about the utilization of VR-based tele-rehabilitation in the stroke population. However, preliminary evidence and a promising concept encourage further research to answer the limitations outlined here.

Conclusion

Tele-rehabilitation could be a promising tool to overcome burdens that restrict accessibility to rehabilitation in the future. Limited evidence points in the direction that VR-based therapy is motivating allowing longer exercise sessions and greater adherence to therapy. Therefore, combining the accessibility of tele-rehabilitation and motivational aspects of VR seem convenient. Indeed, the current review emphasizes the feasibility of this approach. The functional improvements tend to be equal compared to a similar intervention with therapist-supervision in the clinic, suggesting that for efficient rehabilitation parts of therapy could be transferred to the homes. This should not be interpreted as substituting current practice or therapeutic interventions, but to allow a more efficient use of human resources and achieve more time actively exercising. Despite this promising concept, evidence is sparse and further research is highly warranted.

Implications for Rehabilitation

- The use of tele-rehabilitation could be a promising tool to overcome burdens that restrict the access of stroke survivors to long-term rehabilitative care.

- VR-based interventions are game-like and therefore seem to provide a motivational environment which allows longer exercise sessions and greater adherence to therapy.

Declaration of interest

Finally, the author(s) declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

Tables

Table 1: assessing methodological quality adapted from the SIGN guidelines

1++	RCT’s with a very low risk of bias (high quality)
1+	RCT's with a low risk of bias (fair quality)
1-	RCT's with a high risk of bias (poor quality)
2+	well conducted observational studies with a low risk of bias (fair quality)
2-	observational studies with a high risk of bias (poor quality)

Table 2.a: Risk of bias assessment of RCT's based on the PEDro scale

	Eligibility criteria	Random allocation	Concealed allocation	Baseline comparability	Blind subjects	Blind therapists	Blind assessor	Adequate follow-up	Intention-to-treat analysis	Between-group comparisons	Point estimates and variability	Total	Risk of bias
Cikajlo 2012 [24]	Yes	No	No	No	No	No	No	Yes	Yes	Yes	Yes	4/10	High
Krpic 2013 [23]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4/10	High
Lin 2014 [22]	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9/10	Low
Lloréns 2015 [21]	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7/10	Modest

Table 2.b: Risk of bias assessment of case studies based on the NOS scale

	Clear objective	Population description	Consecutive cases	Comparability	Intervention description	Outcome measure description and usage	Adequate follow-up	Statistical methods description	Results description	Total	Risk of bias
Cikajlo 2009 [25]	Yes	Yes	/	/	Yes	No	No	Yes	Yes	5/9	Modest
Flynn 2007 [26]	Yes	Yes	/	/	Yes	Yes	Yes	No	Yes	6/9	Modest

Table 2.c: Risk of bias assessment of case control study based on the NIH checklist

	Selection	Comparability	Exposure	Total	Risk of bias
Mouawad 2011 [27]	***	/	/	3/9	High

Reference			Participants			Intervention				
Study	Aim	Design	VR group: N (adherence), age (SD), stroke interval (SD)	Additional group	Control: N (adherence), age (SD), stroke interval (SD)	VR: presentation, motion capturing	Tele-rehabilitation	Intervention (VR)	Intervention (Add group)	Intervention (Control)
Lloréns 2015 [21]	To evaluate the clinical effectiveness of a VR-based tele-rehabilitation program in the balance recovery in comparison with an in-clinic program, to compare the subjective experiences and to contrast the costs of both programs.	RCT	N=15 (100%), 55.5y (9.6), 11.1mo (2.0)		N=15 (93.75%), 55.60y (7.29), 11.14mo (0.32)	Screen-based, Microsoft Kinect (camera) motion capturing of the feet	Analysis of outcome measures and adjustment of difficulty by system	20 sessions, 3x/week, 45 min VR training consisting of 6x 6-minute in home + 2x/week conventional physical therapy in clinic		Same intervention in clinical setting
Lin 2014 [22]	To evaluate the effect of a bidirectional and multi-user tele-rehabilitation system on balance and satisfaction in patients with chronic stroke living in long-term care facilities.	RCT	N=12 (91.6%), 74.6y (2.3y), 31.8mo (11.3)		N=12 (100%), 75.6 (+-3.4), 41.7mo (12.4)	Screen-based (Maya/3D Max systems), interactive games with touch screen	Videoconference including vital signs monitoring, education and consultation section, assessment and therapy section	4 weeks, 3x/week, 50min balance training + 10min standing exercise with 3D animation videos + 10 min 3D interactive games in home		4 weeks, 3x/week, 50min of standing balance training in clinic
Krpic 2013 [23]	To compare a novel tele-rehabilitation system for virtual reality-supported balance training with balance training with only a standing frame and with conventional therapy in the hospital.	RCT	N=6 (100%), 58.8y (12.1), 3-8 mo	N=9 (100%), 61.0y (7.4), 1-10mo	N=11 (100%), 63.0(+-8.5), 2-10mo	Screen-based (Panda3D engine), balance-trainer standing frame	Videoconference, tele-diagnostics from a remote computer, tablet, or smartphone	3 weeks 5x/week 15min VR-based balance training, home-setting	4 weeks, 5x/week, 20 min balance training without VR, home-setting	4 weeks, 5x/week, conventional therapy in clinic
Cikajlo 2012 [24]	To present the development of the VR supported balance training using the dynamic standing frame.	RCT	N=6 (100%), 58.5y (12.1), 2-8mo		N=20 (91%), 61.0 (7.1) , subacute	Screen-based (VRML 2.0), balance-trainer standing frame	Videoconference during balance training	2 weeks clinical + 1 week VR-based balance training in home, 20min 5x/week		5x/week, 20 min balance training with standing frame without VR in clinic
Mouawad 2011 [27]	To investigate the efficacy of Wii-based therapy for post-stroke rehabilitation.	Case control	N=7 (100%), 65.3y (14.6), 15.3mo (12.6)		N=5 (100%), 58.8y (13.5), (healthy)	Screen-based (Nintendo Wii Sports), hand-held controller	Daily schedules, motor activity diaries, feedback care-giver	10 sessions, 5x/w of 1h supervised Wii-training + home Wii practice progressively increasing to 3h /day		10 consecutive weekdays, 1h of supervised Wii-training
Cikajlo 2009 [25]	To evaluate the effect of standing frame balance training transferred to subjects' home, on motivation and balance capabilities.	Case study	N=1 (100%), 47y, 1mo			Screen-based (VRML 2.0), balance-trainer standing frame	Videoconference during balance training	4 weeks in SmartHome Iris, 3x/week, 17-20min		
Flynn 2007 [26]	To explore the feasibility of using a VR gaming device to improve function, two years after stroke, for an individual who has exhausted all traditional rehabilitative interventions.	Case study	N=1 (100%), 76y, 17 mo			Screen-based (Play Station 2), Sony Eyetoy (camera): Play 2	Compliance was monitored via daily logs (games played, time of session)	4,5 weeks 3x/week		
Legend: RCT= randomised controlled trial. y= years. mo=months. VR=virtual reality. N=number. (%)=percentage of adherent participants.										

Table 3: Characteristics of included studies

Study	MQ	Relevant outcomes	Significance (p-value)	Evolution	Authors conclusion
Lloréns 2015 [21]	1+	BBS, POMA-B, POMA-G, IMI, SUS	BBS: TE:0.001 int:>0.05, POMA-B: TE:0.006 int:>0.05, POMA-G: TE:0.001 int:>0.05, IMI X, SUS X	BBS: TE:↑ int:=, POMA-B: TE:↑ int:=, POMA-G: TE:↑ int:=, IMI:=, SUS:=	VR-based tele-rehabilitation complementing conventional therapy could be considered when cost savings are mandatory, when the transport to the clinic is difficult, or both.
Lin 2014 [22]	1++	BBS, SES, PSS, PU, PEU, ATU	BBS: TE:<0.001 GE: 0.770 Int: 0.829. Between groups: SES: >0.05, PSS: >0.05. Within tele-group: PU:0.053, PEU:<0.05, ATU:<0.05	BBS: TE:↑ GE:= Int:=. Between groups: SES:=, PSS:=. Within tele-group: PU:=, PEU:↑ ATU:↑	The tele-rehabilitation program is feasible for improving balance and functional activity similar to conventional therapy.
Krpic 2013 [23]	1-	BBS, TUG, 10mWT	BBS:>0.05, TUG:>0.05, 10mWT:>0.05	BBS:=, TUG:=, 10mWT:=	Tele-rehabilitation allows the patient to maintain contact with medical professionals from a home environment, while also enabling the continuation of long-term rehabilitation.
Cikajlo 2012 [24]	1-	BBS, TUG, 10mWT, SUE, SAE	BBS: TE:<0.001 GE:0.068 Int:0.486, TUG: TE:<0.001 GE:0.312 Int:0.842, 10mWT: TE:0.011 GE:0.133 Int:0.393, SUE: TE:<0.001 GE:0.127 Int:0.910, SAE: TE:<0.001 GE:0.266 Int:0.904	BBS: TE:↑ GE:= Int:=, TUG: TE:↑ GE:= Int:=, 10mWT: TE:↑ GE:= Int:=, SUE: TE:↑ GE:= Int:=, SAE: TE:↑ GE:= Int:=	The tele-rehabilitation approach allows patient more independence, earlier return to home and continuation of balance training at home. Therapist was relieved from direct manual contact.
Mouawad 2011 [27]	2-	BBS	*** BBS: pre:49.2(+-3.4) post:53.2 (+-2.1)	BBS:↑	The use of Wii-based tele-rehabilitation is yet to be explored, but the simplicity and affordability of the system emphasizes the potential to provide therapy for patients isolated in rural centres.
Cikajlo 2009 [25]	2-	BBS, TUG, 10mWT, SUE, SAE	BBS:X, SUE:0.71, SAE:0.023, TUG:0.0024, 10mWT:0.0298	BBS,↑, TUG:↑, 10mWT:↑, SUE:=, SAE:↑	VR based tele-rehabilitation balance training in combination with short term full rehabilitation treatment in a clinical environment in the acute stage and later homecare can reduce cost and contribute to subject's individual independence.
Flynn 2007 [26]	2-	FMA balance, BBS, DGI, TUG, 6minWT, FOU	FMA balance: -1, BBS:3, DGI:4, TUG:3.11, 6minWT:55, * FOU:X	FMA balance:=, BBS: ↑, DGI: ↑, TUG: ↑, 6minWT: ↑, FOU: feasible and enjoyable to use,	A low-cost VR-system was easily used in the home. In the future, it may be used to improve recovery following stroke as an adjunct to standard care.

Legend: VR=virtual reality. TUG= Timed Up and Go, BBS= Berg Balance Scale. 10mWT=10m walk test. 6minWT=6-minute walk test. SUE=standing unaffected leg. SAE=Standing affected leg. TE=time effect. GE=group effect. Int=interaction effect. FOU=feasibility of use. DGI=dynamic gait index. FMA=Fugl-Meyer assessment. POMA-G=performance-oriented mobility assessment - gait subscale. POMA-B= performance-oriented mobility assessment - balance subscale. IMI=intrinsic motivation intervention. SUS=system usability scale. SES= system environment satisfaction. PSS= perceived satisfaction of system. PU= perceived usefulness. PEU= perceived ease of use. ATU= attitude toward using. * p-value not reported, difference between lowest and highest score is given. ** p-value not reported, improvement in % is given. *** only the data of 5 patients was given, no p-value was given. ↑=more improved than control group. ↓=less improved than control group, ==no significant difference. X=not mentioned.

Table 4: Outcome and results of included studies

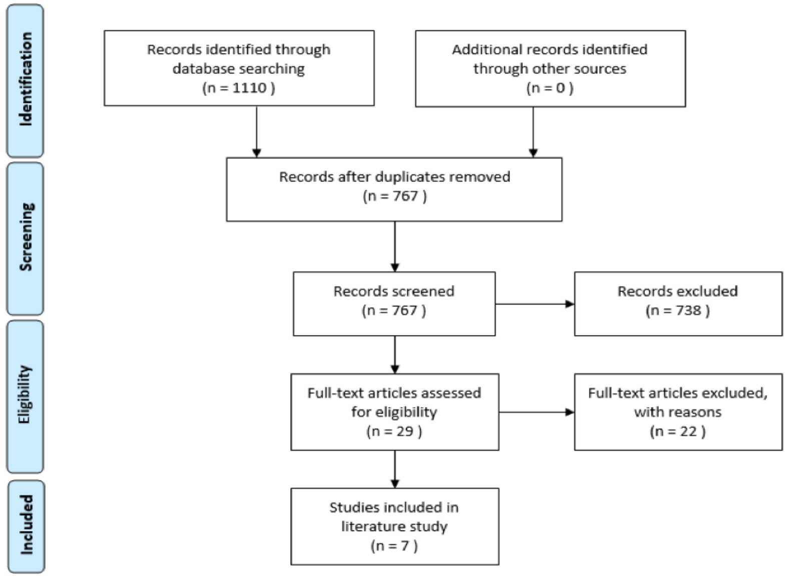

Figure 1: Flow char

Supplement material

Table: adapted search strategies

Database	Search strategy	Results
Pubmed	(Stroke OR stroke [MeSH Terms]) AND (tele-rehabilitation [MeSH Terms] OR home OR “home-based” OR tele-rehabilitation OR "virtual reality” OR (virtual AND training) OR "virtual reality exposure therapy"[MeSH Terms]) AND ("postural balance"[MeSH Terms] OR balance OR “postural control”)	267
Web of Science	(Stroke AND (tele-rehabilitation OR home OR home based OR tele-rehabilitation OR virtual reality OR (virtual AND training) OR virtual reality exposure therapy) AND (postural balance OR balance OR postural control))	517
Pedro	Stroke AND virtual reality	96
Rehab Data	Stroke AND virtual AND reality	89
Cochrane library	(Stroke AND (telerehabilitation OR home OR home based OR tele-rehabilitation OR virtual reality OR (virtual AND training) OR virtual reality exposure therapy) AND (postural balance OR balance OR postural control))	141

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