Review Article

Effects of Virtual Reality Compared to Conventional Therapy on Balance Poststroke: A Systematic Review and Meta-Analysis

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Objective: The objective of this study was to systematically review the effect of virtual reality on balance as compared to conventional therapy alone poststroke. *Methods:* The databases of PubMed, Cochrane, and Ovid were searched using select keywords. The randomized controlled trials published between January 2000 and August 2017 in English language were included if they assessed the effect of virtual reality on balance ability compared to conventional therapy alone in adults' poststroke. The Physiotherapy Evidence Database scale was used to assess the methodological quality. *Results:* Fourteen papers were included in this review. The experimental groups largely (n = 13) used virtual reality in combination with conventional therapy. Among the high quality studies, significant between-group improvement favoring virtual reality in combination with conventional therapy was found on Berg Balance Scale (n = 7) and Timed Up and Go Scale (n = 7) when compared to conventional therapy alone. The studies were limited by low powered, small sample sizes ranging from 14 to 40, and lack of blinding, concealed allocation, and reporting of missing data. Thirteen homogenous (n = 348, $I^2 = 37.6\%$, $P = .083$) studies were included in the meta-analysis using Berg Balance Scale. Significant improvement was observed in the experimental group compared to control group with a medium effect size of .64, confidence interval of .36-.92. *Conclusions:* The findings of this review indicate that virtual reality when combined with conventional therapy is moderately more effective in improving balance than conventional therapy alone in individuals' poststroke.

Key Words: Virtual reality—stroke—hemiplegia—balance—systematic review—meta-analysis

Introduction

Stroke survivors often have deficits in motor control which contribute to reduced balance,[1,2] postural control and mobility,[3] and proprioception.[4] Reduced static and dynamic balance are major risk factors for falls[5,6] and limit the ability to perform activities of daily living.[7] Several interventions for balance and trunk control have been investigated, such as weight-shifting on an unstable surface,[8] balance control training,[9] and gait training with auditory stimulation,[10] among others.

Given that stroke prevalence is rising each year, there is an urgent need to identify interventions that are both cost-effective and safe. Virtual reality (VR) presents a unique opportunity for the field of rehabilitation in designing carefully monitored interventions that can

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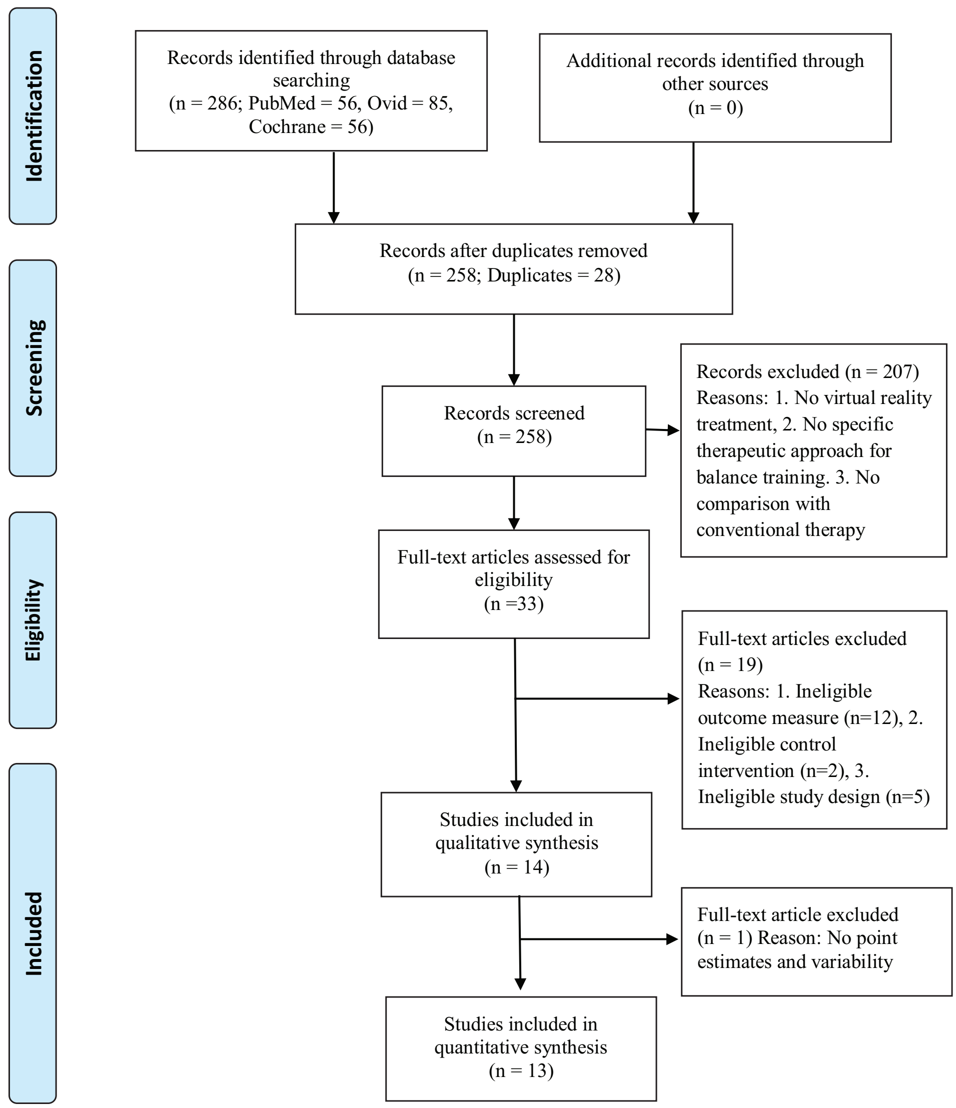

Figure 1. *PRISMA study selection flow chart. PRISMA, Preferred Reporting for Items for Systematic Reviews and Meta-Analyses. (Color version of figure is available online.)*

reach a large group of individuals. VR has been applied in stroke rehabilitation to simulate real-world conditions.[11] VR is a computer-based technology that allows users to interact with a multisensory simulated environment and receive real-time feedback on performance,[12] and allows exposure to a higher level of functional tasks.[13] Multiple recent systematic reviews about the effect of VR training supported the use of VR in lower extremity stroke rehabilitation to improve balance and gait ability.[14-18] In contrast to the studies supporting VR training, 2 recently published reviews using a commercial VR system concluded that there was insufficient evidence to ensure the effectiveness of VR training on balance ability.[19,20]

Given that there has been a rapid development of VR programs, it is essential to review the evidence of VR on balance control in stroke survivors to enable clinicians to have an up-to-date understanding of the effect of these clinical applications on balance. The aim of this review is to systematically evaluate the evidence of the effectiveness of VR compared to conventional therapy alone on improving balance abilities in people with stroke.

Methods

The Preferred Reporting for Items for Systematic Reviews and Meta-Analyses guidelines were followed for this review.[21] Databases of PubMed, Cochrane libraries, Ovid were searched for scientific articles of original research published between January 2000 and August 2017. The following key terms were used: VR AND (stroke OR hemiplegia) AND balance. The key terms were organized according to the search engine features of the database. Retrieved articles were assessed according to the following eligibility criteria. Inclusion criteria were: (1) randomized clinical trials; (2) compared VR and conventional therapy alone; (3) aimed to improve balance control; (4) individuals poststroke; and (5)

Table 1. *Physiotherapy Evidence Database criteria and scores for the included studies*

Author year (citation)	Barala et al. (2013)[9]	Cho et al. (2012)[31]	Cho and Lee (2013)[37]	Cho and Lee (2014)[34]	Huh et al. (2015)[10]	In et al. (2016)[33]	Kim et al. (2009)[32]	Lee et al. (2012)[36]	Lee et al. (2015)[29]	Llorens et al. (2015)[30]	Park et al. (2017)[28]	Rajaratnam et al. (2013)[26]	Song et al. (2014)[27]	Yatar and Yildirim (2015)[35]
Random allocation	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Concealed allocation	1	1	1	1	1	1	1	1	1	1	1	1	0	0
Baseline comparability	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Subject blinded	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Therapist blinded	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Assessor blinded	1	0	1	1	0	1	1	1	1	0	1	1	0	0
Data for at least 1 outcome from >85% of subject	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No missing data or, intention-to-treat	1	1	1	1	1	1	0	1	0	1	1	1	0	1
Between-group analysis	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Point estimates and variability	1	1	1	1	1	1	1	1	1	1	1	0	1	1
Total score (out of 10)	8	7	8	8	7	8	9	8	7	7	8	7	5	6

Note: The first PEDro criterion for eligibility reporting was satisfied in all studies and is not included here since it does not contribute toward the calculation of the total score. Interpretation of total score: high quality = 6-10, low quality = 0-5.

English language. All stages of stroke including acute, subacute, and chronic were included. The identified articles were screened for eligibility within the titles and abstracts, duplicates were removed, and full text reviewed by 2 raters as shown in Preferred Reporting for Items for Systematic Reviews and Meta-Analyses flow diagram in Figure 1. The included articles were assessed for methodological quality with Physiotherapy Evidence Database (PEDro) scale.[22] This scale consists of 11 items that can contribute 1 point to the total score if they are satisfied, except for item 1 (eligibility criteria), which is scored "yes" or "no." The PEDro scale is reported to have sufficient reliability to determine the quality of randomized controlled trials (RCTs). Articles with a score of 6 or higher are considered as high quality, and those with scores of less than 6 are defined as lower quality.[23] In case of disagreement in the quality assessment of the 2 reviewers (AVS and RM), consensus was reached by discussion or consulting a third person (MM). The PEDro item-by-item score is reported in Table 1. Data extracted from the final set of studies included participant characteristics, VR device or system, dosing, balance related outcome measures and their results.

Statistical Analysis

The effect size estimates were computed using Cohen's D-value. The interpretation of D-value was as follows: negligible $<.2$; small $= .2$; medium $= .5$; and large $= .7$.[24] All studies included the Berg balance scale (BBS) and this enabled meta-analysis for balance outcome. The mean differences with 95% confidence interval were calculated when the pooled studies used the BBS. The Timed Up and Go (TUG) outcome measure used in multiple studies does not primarily assess balance and includes mobility components within its construct. Thus, meta-analysis was not performed on the TUG variable. Heterogeneity was assessed by means of the value of the I^2 statistic. Generally, a value greater than 50% would indicate substantial heterogeneity.[25] All analyses were performed with the statistical software STATA version 11 (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP).

Results

This review retrieved 268 articles that were subject to a systematic article selection process shown in Figure 1. The final 14 articles that met the inclusion criteria were identified after full-text review and included in the qualitative synthesis. The quantitative synthesis included 13 articles, since 1 study did not provide point estimates and variability.[26] We were unsuccessful at contacting the corresponding author to obtain the quantitative data after multiple attempts. The BBS outcome measure was used in all studies and selected for meta-analysis. The I^2 statistic was not significant indicating homogeneity among the included studies ($I^2 = 36.7\%$, $P = .08$). There were 3 studies with participants

Table 2. *Characteristics of included studies*

Study author year [reference]	Participant characteristics	Time since stroke onset	Device/system	Training protocol	Outcome measure	Result*
Barcala et al. (2013)[9]	n = 20; exp: 10 (5M/5F); cont: 10 (4M/6F); mean age 64.35 y	Chronic: >6 mo	Wii Fit Balance board	Exp: CT 1 hour + VR, 30 min/d, 2 times/wk, 5 wk	BBS	*Within-group*: Both groups had sig. improvements on BBS & TUG ($P < .05$)
				Cont: CT 1 h 30 min/d, 2 times/wk, 5 wk	TUG	*Between-group*: No sig differences ($P > .05$) BBS: D-value (.05); TUG: D-value (.14)
Cho et al. (2012)[31]	n = 22; exp: 11 (8/3); cont: 11 (6/5); mean age 64.19 y	Chronic: >6 m	Wii fit Balance board	Exp: CT1 h +VR, 30 min/d, 3 times/wk, 6 wk	BBS	*Within-group*: Both groups had sig. improvements on BBS & TUG ($P < .001$)
				Cont: CT1 h/d, 3 times/wk, 6 wk	TUG	*Between-group*: Greater improvements were reported in exp. group compared to cont. group ($P < .01$); BBS: D-value (1.19); TUG: D-value (.81)
Cho and Lee (2013)[37]	n = 14; exp: 7(3/4); cont: 7(4/3); mean age 64.85 y	Chronic: >6 mo	Virtual walking program with real-world video recording	Exp: CT + VR 30 min/d 3 times/wk, 6 wk	BBS	*Within-group*: Both groups had sig. improvements on BBS & TUG ($P < .05$)
				Cont: CT + treadmill training 30 min/d, 3 times/wk, 6 wk	TUG	*Between-group*: Greater improvements were reported in exp. group compared to cont. group (($P < .05$); BBS: D-value (2.29); TUG: D-value (1.31)
Cho and Lee (2014)[34]	n = 30; exp: 15 (7M/8F); cont: 15 (8M/7F); mean age 64.69 y	Chronic: >6 mo	Treadmill based real-world video recording	Exp: CT 30 min + VR, 30 min/d, 3 times/wk, 6 wk	BBS	*Within-group:* Both groups had sig. improvements on BBS & TUG ($P < .05$)
				Cont: CT 30 min + treadmill, 30 min/d, 3 times/wk, 6 wk	TUG	*Between-group*: Greater improvements were reported in exp. group compared to cont. group ($P < .05$); BBS: D-value (1.8); TUG: D-value (1.26)

Table 2 (*Continued*)

Study author year [reference]	Participant characteristics	Time since stroke onset	Device/system	Training protocol	Outcome measure	Result*
Huh et al. (2015)[10]	n = 40; exp: 23 (16M/7F); cont: 17 (10M/7F); mean age 64.68 y	Subacute: >3 mo	BalPro	Exp: CT 30 min + VR, 30 min/d, 5 d/wk, 2 wk	BBS	*Within-group:* Both groups had sig. improvements on BBS & TUG ($P < .05$)
				Cont: CT 1 h/d, 5 d/wk, 5 wk	TUG	*Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) in BBS; BBS: D-value (3.36); TUG: D-value (1.24)
In et al. (2016)[33]	n = 25; exp: 13 (7F/6F); cont: 12 (5M/7F); mean age 55.86 y	Chronic: >6 mo	Virtual Reality Reflection Therapy	Exp: CT30 min + VR 30 min/d, 5 times/wk, 4 wk	BBS	*Within-group:* Exp. group had sig. improvements on BBS, FRT, & TUG ($P < .05$). Cont. group had sig. improvements on BBS ($P < .05$)
				Cont: CT 30 min/d, 5 times/ wk, 4 wk	FRT	*Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) in BBS, FRT, & TUG. BBS: D-value (2.29); TUG: D-value (2.71); FRT: D-value (4.33)
					TUG	
Kim et al. (2009)[32]	n = 24; exp: 12 (6M/6F); cont: 12 (7M/5F); mean age 51.96 y	Chronic: >1 y	IREX VR	Exp: CT 40 min + VR 30 min/d, 4 d/wk, 4 wk	BBS	*Within-group:* No analysis
				Cont: CT 40 min/d, 4 days/wk, 4 wk		*Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) in BBS; BBS: D-value (5.17)

(*Continued*)

Table 2 (*Continued*)

Study author year [reference]	Participant characteristics	Time since stroke onset	Device/system	Training protocol	Outcome measure	Result*
Lee et al.)2012)[36]	n = 40; exp: 20 (13M/7F); cont: 20 (12/8); mean age 53.18 y	Chronic: >6 mo	BCT VR	Exp: CT 1 h + VR 20 min/d, 5 times/wk, 4 wk Cont: CT 1 h/d, 5 times/wk, 4 wk	BBS TUG	*2 wk* *Within-group:* Exp. group had sig. improvements on BBS & TUG ($P < .05$) Cont. group had sig. improvements on BBS ($P < .05$) *4 wk* *Within-group:* Exp. group had sig. improvements on BBS & TUG ($P < .05$) *2 & 4 wk* *Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) in BBS & TUG. BBS; D-value (4.2); TUG: D-value (2.7)
Lee et al. (2015)[29]	n = 20; exp:10 (6M/4F); cont: 10 (5M/5F); mean age 54.95 y	Chronic: >6 mo	Bio Rescue	Exp: VR 45 min/d, 3 times/wk, 6 wk Cont: CT 45 min/d, 3 times/wk, 6 wk	BBS TUG	*Within-group:* Exp. group had sig. improvements on BBS & TUG ($P < .05$) *Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) in BBS & TUG; BBS: D-value (5.5); TUG: D-value (3.8)
Llorens et al. (2015)[30]	n = 20; exp: 10 (5M/5F); cont: 10 (4M/6F); 56.5 mean age y	Chronic: >6 mo	BioTrak VR based stepping exercise	Exp: CT 30 MIN + VR 30 min/d, 5 d/wk, 4 wk Cont: CT, 1 h/d, 5 d/wk, 4 wk	BBA BBS Tinetti Balance	*Within-group:* Both groups had sig. improvements on BBS ($P < .05$) *Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) on BBS; BBS: D-value (2.00); BBA −no scores reported.

Table 2 (*Continued*)

Study author year [reference]	Participant characteristics	Time since stroke onset	Device/system	Training protocol	Outcome measure	Result*
Park et al. (2017)[28]	n = 20; exp:10 (5M/5F); cont:10 (5M/5F); mean age 63.65 y	Chronic: >6 mo	X-Box Kinect	Exp: CT 30 min + VR 30 min/d, 6 wk	BBS	*Within-group:* Both groups had sig. improvements on BBS & TUG ($P < .05$)
				Cont: CT 30 min/d, 6 wk	TUG	*Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) in BBS & TUG; BBS: D-value (6.8); TUG: D-value (4.01);
Rajaratnam et al. (2013)[26]	n = 19; exp: 10 (4M/6F); cont: 9 (3M/6F); mean age 62 y	Recent: >15 d	VRBT Wii fit Balance board	Exp: CT 40 MIN + VR 20 min/d, 15 sessions	BBS	*Within-group:* Exp. group had sig. improvements on FRT & TUG ($P < .05$); Cont. group had significant improvements on TUG ($P < .05$)
				Cont: CT 60 min/d, 15 sessions	FRT	*Between-group:* Greater improvements were reported in exp. group compared to cont. group ($P < .05$) in FRT: D-value (has not recorded).
					TUG	
Song et al.)2014)[27]	n = 20; exp: 10 (4M/6F); cont: 10 (5M/5F); Tetrax group: 10 (7M/3F); mean age 63.40 y	Recent: >30 d	IREX	Exp: CT 25 min/d + VR 25 min/d, 3 times/wk, 3 wk	BBS	*Within-group:* All 3 groups had sig. improvements in BBS ($P < .05$)
				Cont: CT 25 min/d, 5 times/wk, 3 wk		*Between-group:* No sig differences ($P < .05$) in BBS: D-value (1.3)
		Chronic: >6 mo	Wii Fit Balance board		BBS	

(*Continued*)

Table 2 (*Continued*)

Study author year [reference]	Participant characteristics	Time since stroke onset	Device/system	Training protocol	Outcome measure	Result*
Yatar and Yildirim) 2015)[35]	n = 30; exp: 15 (6M/9F); cont: 15 (7M/8F); mean age 59.70 y			Exp: CT 30 min + VR 30 min/d, 3 times/wk, 6 wk		*Within-group:* Both groups had sig. improvements on BBS & TUG ($P < .05$)
				Cont: CT 1 h/d, 3 times/wk, 6 wk	TUG	*Between-group:* No sig differences ($P < .05$); BBS: D-value (.13); TUG: D-value (1.62; Balance Board > Wii Fit)

BBA, Brunel Balance Assessment; BBS, Berg Balance Scale; BCT, balance control trainer; CT, conventional therapy; Exp, experimental; Cont., control; FRT, Functional Reach Test; IREX, Interactive Rehabilitation Exercise Software; M, male; F, female; MMAS, Modified Motor Assessment Scale; TUG, Timed up and Go test; VR, virtual reality; VRBT, virtual reality balance training.

*D-values are added only for between-group differences consistent with our research question.

in the subacute stage.[10,26,27] The sample sizes of included studies ranged from 14 to 40. The detailed characteristics of the included studies are shown in Table 2.

Methodological Quality

The PEDro scores for the included studies are reported in Table 1. The differences between raters occurred for less than 10% of the item ratings and were resolved by discussion. The studies were overall of high quality with a mean of 7.42 (SD .98) and scores ranging from 5 to 9 out of 10. There was only 1 low quality study with a score of 5 out of 10.[27] The PEDro criteria satisfied by all the studies were on reporting of eligibility criteria, reporting of at least 1 outcome from 85% of the subjects, and reporting of between-group analysis. The criteria lacking in most studies were reporting of blinding of subjects (93% of studies) and therapists (93% of studies). The other deficient criteria were blinding of assessors (36% of studies), reporting of missing data (21%), and concealment of allocation (14% of studies). The point and variability estimates were missing in 1 study.[26]

Population

Five studies had a sample size of 20,[9,27-30] 7 studies had a sample size greater than 20[10,31-36], and 2 studies had less than 20 participants.[26,37] All studies included relatively equal number of male and female participants except 1 study[36] that included 25 male and 15 female participants. The mean age of participants was 60.29 years (SD 4.79 years) and ranged from 52 to 65 years. The mean time poststroke onset ranged from 15 days to 1 year. All studies included people with chronic stroke past 6 months except 2 studies that included subacute stroke[26,27] and 1 study that included subacute and chronic stroke.[10] Table 2 shows the characteristics of the participants.

Intervention

The VR interventions varied greatly among the included studies. All experimental VR interventions were combined with conventional therapy except for 1 study[29] which had an only VR study arm. All studies included VR training with nonimmersive systems that included a monitor, speakers, and a static or dynamic balance training surface or floor space. Two studies utilized the Interactive Rehabilitation Exercise Software (IREX) VR system and additionally included cyber gloves, virtual objects, and scenes.[27,32] Two studies utilized treadmill training with a prerecorded real-word video for a combined VR training for dynamic balance.[34,37] The participants using the treadmill could grab the rail as needed for safety. Three studies utilized a sensor-based tilting surface with games for balance training with BalPro, BalTrak, and Bio-Rescue systems.[10,29,30] The BalPro system utilized safety bar and harness to prevent falls.[10] The VR Reflection Therapy was played in seated with mirroring of the unaffected limb movements for training affected lower limb using VR.[33] The other 7 studies utilized commercial gaming systems of Nintendo Wii-fit with balance board[9,10,31,35,36] or Microsoft X-box Kinect,[28] or both.[26] The study involving X-box Kinect[28] used a harness suspended from the ceiling for safety. There were no adverse events among the participants as reported in 2 studies[10,36] and other studies lacked reporting of adverse events. The types of games played by the participants were not described adequately and the competitive or team-based nature of the games and their effects is not known.

The control group was mainly comprised of conventional therapy using neurorehabilitation-based techniques of traditional rehabilitation. The conventional training involved range of motion, stretching, strengthening, therapeutic exercises,[37] functional electrical stimulation,[37] gait and balance training,[28] neurodevelopmental treatment,[35] and functional activities.[9] Two studies provided treadmill training without VR in the control group training[34,37]. One study compared 3 groups; VR with IREX VR, conventional therapy, and Tetrax system with force plate used to for training the participant in moving the center of pressure with visual feedback.[27] The control group intervention was not adequately described in most studies.

The dosage of the intervention was varied among the included studies. The session duration of the VR training was fairly consistent and was on average 30 minutes per session (10 studies) and ranged from 20 to 45 minutes. The VR training in the experimental group was either delivered alone for a longer duration (45 minutes)[29] or combined with conventional therapy to match the duration of the control group,[9,10,26,30,34,35,37] or was in excess of the time spent by the control group.[27,28,31-33,36] The total number of sessions ranged from 10 to 20 in total for experimental and control groups. The frequency of the sessions ranged from 2 to 5 days per week for both groups. The total duration of the training had greater variability and ranged from 2 weeks to 6 weeks. The rationale for the total training duration of 2,[10,26,35] 3,[27] 4,[30,32,33,36] 5,[9] and 6[28,29,31,34,37] week protocols was not clearly described.

Outcome Measures

All studies recorded more than 1 outcome measure at baseline and after intervention except 1 study[27] that only used BBS. All studies used BBS, 12 studies used TUG, 3 studies used Functional Reach Test (FRT), 1 study used Tinetti Balance Assessment, and 1 study used Brunel Balance Assessment (BBA). For between-group comparisons on BBS, 10 studies reported statistically significant differences[10,28-34,36,37] and 4 studies reported no change.[9,26,27,35] For between-group comparisons on TUG, 7 studies reported statistically significant differences[28,29,31,33,34,36,37] and 5 studies reported no change.[9,10,26,27,35] For between-group differences on FRT, 2 studies reported statistically significant difference,[26,33] and 1 study reported no change.[36] For between-group differences on BBA, there were no reported scores, however the categories with number of participants improved in each category showed significant differences on chi-square test.[30] For between-group difference on Tinetti Balance Assessment, there were no reported changes.[30] The within-group comparisons for BBS, were statistically significant for both groups in 10 studies,[9,10,28,30,31,33-37] for experimental group only in 2 studies[26,29] and not reported in 1 study.[32] The within-group comparisons for TUG were statistically significant for both groups in 9 studies[9,10,26-28,31,34,35,37] and for experimental group only in 3 studies.[29,33,36] The within-group comparisons for FRT were statistically significant for experimental group only in 3 studies.[33,36] The within-group comparisons for BBA were not reported[30] and for Tinetti Balance Assessment they were not significant.[36]

Meta-Analysis

The BBS included in all studies was used for meta-analysis of 13 studies.[9,10,27-37] These studies reported data on 328 participants, 166 of whom received VR. The I^2 statistic of 36.7% represents low heterogeneity. The experimental group significantly improved balance, with a standardized mean difference of .64 points on the 0 to 56-point BBS (95% confidence interval .36-.92), as presented in Figure 2.

Discussion

The findings from this systematic review and meta-analysis provide evidence for moderate beneficial effect of VR training combined with conventional therapy over conventional therapy alone in individuals poststroke. BBS was the most frequently used outcome measure for static and dynamic balance and enabled meta-analysis for this review with its primary focus on balance. TUG was the next most commonly used measure in the included studies. BBS also covered the construct of balance more fully than TUG, which involves balance and mobility. The positive findings in favor of VR have been reported in previous reviews on the effect of VR on the lower extremity in patients with stroke.[14-18] Since none of them have focused on comparison of balance ability between VR combined with conventional and conventional alone, it is important to note the differences in pooled effect sizes. The overall pooled effect size for BBS in this study was a moderate value of .64. A prior meta-analysis reported the pooled effect size for BBS to be much higher with a value of 1.46.[18] A possible explanation for this difference is the narrow inclusion criteria in our study. In a recent study, Corbetta et al[17] reported that the studies focused on balance had much higher heterogeneity and are difficult to be pooled for a meta-analysis. This study contributes new knowledge in this area by selecting a more homogenous sample for meta-analysis and providing a more accurate moderate estimate of effect size (.64) as compared to prior high estimates (1.46).[18]

The VR interventions included in this review self-identified themselves as using VR. The lack of definition of VR is noted across the literature. The conceptualization of what constitutes VR varied greatly among the included studies reducing the validity of the comparisons between them. However, repetition and high intensity of targeted training is prevalent among all the VR interventions. The 3 main types of VR interventions were games with balance board or a tilting platform with handle bars, treadmill training with real-world video, and commercial video games. The outcomes with custom-designed systems (8 out of 9 studies with greater benefit to the VR group) that utilize specialized platforms are comparable to the commercial gaming systems (3 out of 5 studies with greater benefit to the VR group) and could be seen as marginally better than commercial games. The details of the conventional therapy were not described adequately in most of the studies. Future studies should explain the VR component by describing the system, the games or non-game environments, feedback and/or assistance provided to the subject, and the adverse effects experienced within the VR environment. The dosage per session although consistent (30 minutes) across studies, there was great variability in the number of weeks the protocols were implemented. There were no differences in outcomes based on the dosage of interventions. For future studies, study design should involve periodic assessments to identify the optimal dosage that would result in the meaningful changes in function using the minimal clinically important difference estimates.

Study Design Considerations

The studies included in this systematic review overwhelmingly lacked adequate sample sizes, power calculations, and blinding. Even when blinding was reported (Kim 2009), there was a lack of clear explanation of how this was implemented procedurally. Future studies should reduce bias by performing sample size calculations, and blinding assessors, subjects and therapists delivering the intervention. To further reduce bias, blinding check after the completion of the study should be performed to verify if the blinding was truly preserved. There were also a few studies that lacked reporting of missing data, intent to treat analysis, and concealing allocation. Although these deficiencies were not as common, they are important components of RCT and should be included within the study design.

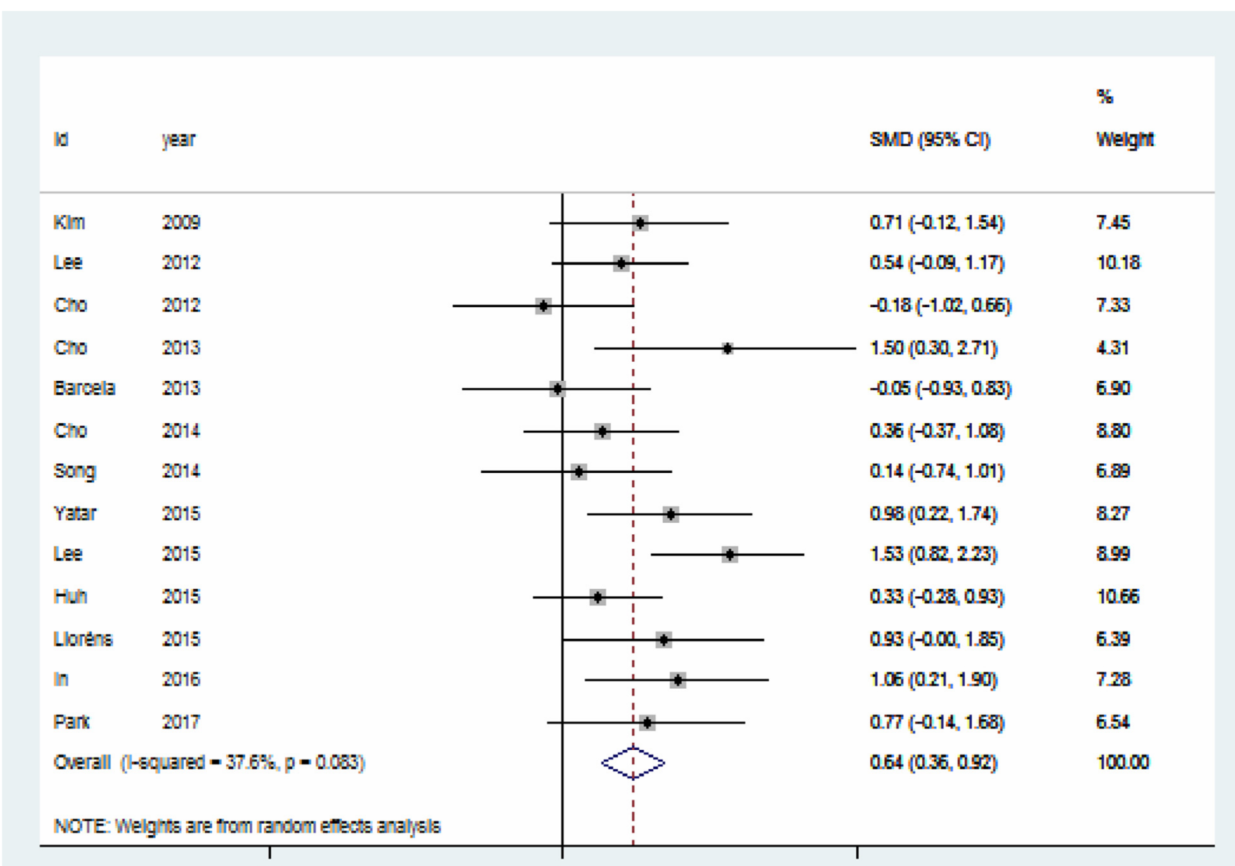

Figure 2. *Forest plot of the pooled results of the effect of VR training on Berg Balance Scale in which VR was additional to conventional therapy. VR, virtual reality, SMD; summary mean difference, CI, confidence interval. (Color version of figure is available online.)*

Limitations

Limitations of this systematic review include lack of a comprehensive listing of keywords that may have resulted in missed articles, particularly due to the lack of access to a systematic review librarian. However, the inclusion of 4 databases and manual searching provided adequate coverage of rehabilitation journals to add rigor to the methodology. Another limitation is the use of risk of bias measurement with the PEDro scale that has only 10 criteria for assessing study quality. Although PEDro is a standard reporting tool in the physical therapy literature, it may not have captured the full spectrum of quality indicators for a randomized controlled trial. The exclusion of instrumented outcomes such as force platform indicators, kinematics, and mobility-related outcomes within this review is also a limitation of this review.

Conclusion

This study reviews the comparative effectiveness of VR combined with conventional therapy compared to conventional therapy alone on balance poststroke. The findings of this review indicate that VR when combined with conventional therapy is moderately more effective in improving balance than conventional therapy alone in individuals' poststroke. The VR systems that showed significant between-group differences on BBS were: IREX VR,[32] Balance Control Trainer VR, Bio Rescue,[29] BioTrack VR[30] based stepping and balance training,[36] Wii Fit Balance Board,[31] X-box Kinect,[28] VR reflection therapy,[33] BalPro,[10] and treadmill based real-word video recording viewing.[34,37] Future research is needed with better descriptions of VR and games, larger sample sizes, blinding to reduce risk of bias, examining the optimal dosage needed for a meaningful change, and follow-up data to measure long-term effects.

Disclosure of Interest

The authors report no conflicts of interest and this study has no source of funding.

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