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REVIEW ARTICLE

EFFECTS OF VISUAL FEEDBACK THERAPY ON POSTURAL CONTROL IN BILATERAL STANDING AFTER STROKE: A SYSTEMATIC REVIEW

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Objective: **To establish whether bilateral standing with visual feedback therapy after stroke improves postural control compared with conventional therapy and to evaluate the generalization of the effects of visual feedback therapy on gait and gait-related activities.**
Design: **A systematic review.**
Methods: **A computer-aided literature search was performed. Randomized controlled trials and controlled clinical trials, comparing visual feedback therapy with conventional balance treatments were included up to April 2005. The methodological quality of each study was assessed with the Physiotherapy Evidence Database scale. Depending on existing heterogeneity, studies with a common variable of outcome were pooled by calculating the summary effect-sizes using fixed or random effects models.**
Results: **Eight out of 78 studies, presenting 214 subjects, were included for qualitative and quantitative analysis. The methodological quality ranged from 3 to 6 points. The meta-analysis demonstrated non-significant summary effect-sizes in favour of visual feedback therapy for weight distribution and postural sway, as well as balance and gait performance, and gait speed.**
Conclusion: **The additional value of visual feedback therapy in bilateral standing compared with conventional therapy shows no statistically significant effects on symmetry of weight distribution between paretic and non-paretic leg, postural sway in bilateral standing, gait and gait-related activities. Visual feedback therapy should not be favoured over conventional therapy. The question remains as to exactly how asymmetry in weight distribution while standing is related to balance control in patients with stroke.**

Key words: cerebrovascular disorders, visual feedback, force plate, postural control, rehabilitation, meta-analysis.

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INTRODUCTION

The rate in which stroke occurs in developed countries is approximately 2400 per 1 million persons per year (1). Stroke is one of the leading causes of impairment and disability in the Western world (2). Many patients with stroke suffer from significant motor and cognitive impairments, such as visual spatial impairments, aphasia, hemi-neglect, dyspraxia, gait disorders and poor sitting and standing balance control (3, 4). In particular, recovery of postural control is found to be a prerequisite for regaining independence in activities of daily living (ADL) (5).

Unfortunately, there is no generally accepted definition of the term "postural control"; however, the definition of Pollock and colleagues (6) is frequently used. They described postural control as "the act of maintaining, achieving or restoring a state of balance during any posture or activity". In hemiplegic patients postural control is characterized by an increased postural sway (7, 8) and asymmetrical weight distribution with a shift in the average position of the body's centre of pressure towards the unaffected side (9, 10). Current research concerning balance deficits in hemiplegic patients focuses on differential components such as postural sway and symmetry of weight distribution. The use of force plate feedback in stroke rehabilitation has been examined in a number of these studies. This type of therapy provides visual or auditory feedback of patient's postural sway or weight distribution between the paretic and non-paretic lower limb (11, 12). The interest in force plate feedback as a rehabilitation instrument was positively influenced by the development of the Balance Master™ (NeuroCom International). This computerized force plate provides continuous visual feedback on the position of the centre of gravity (COG), giving a new tool for training: the visual feedback therapy (VFT). Despite the number of publications dedicated to feedback therapy, only one recent review has systematically evaluated the effectiveness of this therapy on promoting the recovery of postural control after stroke (13). Barclay-Goddard et al. (13) concluded after systematic

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reviewing 7 randomized controlled trials (RCT), that force plate feedback (visual or auditory) improved stance symmetry after stroke, but they could not establish effects on postural sway or measures related to gait and independency in ADLs.

The purpose of the present systematic review was to examine the effects of the additional VFT on postural control in bilateral standing in subjects suffering from stroke. The primary aim of this review was to establish whether VFT reduces postural sway and improves symmetry of weight distribution in bilateral standing after stroke compared with conventional treatment. In addition, the effects of VFT on parameters of gait and gait-related activities including ADL were evaluated.

METHODS

Search strategy for study identification

A computer-aided literature search was performed in the following electronic databases; PubMed (MEDLINE), Cochrane Central register of Controlled Trials, CINAHL, Physiotherapy Evidence Database (PEDro) and DOC-online. Only articles published in the period up to April 2005 and written in English, German or Dutch were included. All references presented in relevant studies were also examined. The following MeSH and keywords were used: cerebrovascular accident, cerebrovascular disorders, hemiplegia, paresis or stroke (patient type), rehabilitation, posture, symmetry, balance, postural control, musculoskeletal equilibrium or weight-bearing (intervention type), force plates, force platforms or feedback (device type) and randomized controlled trial, controlled clinical trial, comparative study or trial (publication type). The complete study identification was performed by 2 independent reviewers (RPSvP, MK). The databases were searched using a study identification strategy that was formulated in PubMed and adapted to the other databases. The full search strategy is available on request from the first author.

The abstracts of the publications, retrieved from the computer-aided literature search, were selected on basis of the following 3 inclusion criteria:

- The studies involved adult subjects suffering from stroke. The participants were diagnosed as patients with stroke following the definition of the World Health Organization. Stroke is defined as "a focal (at times global) neurological impairment of sudden onset, and lasting more than 24 hours (or leading to death) and of presumed vascular origin" (14).
- Effects of VFT on postural control in bilateral standing were evaluated. The feedback had to provide visual representations of the individual's centre of gravity or weight distribution between the paretic and non-paretic leg. In the present review feedback is defined as a "process by which a person uses biofeedback information to gain voluntary control over processes or functions that are primarily under autonomic control" (15).
- The studies were RCT or controlled clinical trials (CCT) (16).

Methodological quality assessment

The methodological quality of the selected RCTs and CCTs was rated using the PEDro scale (17, 18) by 2 independent reviewers (RPSvP, MK). Reviewers were not blinded to author(s), institution(s) or journal. The PEDro-scale contains 11 items. The first item assesses external validity and the other 10 items assess the internal and statistical validity of the studies (17, 18). These 10 items were used to calculate the PEDro-score. All items were scored binary (i.e. yes = 1/no = 0), which could result in a maximum score of 10 points. Agreement regarding each item was evaluated by calculating a Kappa statistic. Disagreements regarding items were solved by discussion between the reviewers. If disagreement persisted, a third reviewer (GK) made the final decision.

Quantitative analysis

Analysis of the results was performed separately for each study. When the interventions, patient characteristics and outcome measures were comparable, statistical pooling was performed. The data were re-analysed by pooling the individual effect-sizes (g_i) using Hedges' g model (19, 20). In this model the difference between mean changes in the experimental group and in the control group during the therapy period were calculated and divided by the average population standard deviation (SD_i).

Subsequently, unbiased effect sizes (g^u) were calculated for each study after adjusting for the number of degrees of freedom. The impact of sample size was addressed by calculating a weighting factor (w_i) for each study, and assigning larger effect-weights to studies with larger samples. Subsequently, g^u's of individual studies were averaged, resulting in a weighted summary effect size (SES), whereas the weights of each study were combined to estimate the variance of the SES (21). The fixed effects model was used to decide whether a SES was statistically significant (SES [fixed]). If significant between-study variation existed a random effects model was applied (SES [random]) (22). *Post hoc* sensitivity analysis for study design was performed if significant heterogeneity was found between individual effect-sizes. For all outcome variables, the critical value for rejecting H_0 (i.e. there is no evidence for VFT) was set two-tailed at 0.05.

RESULTS

Study identification

After screening 78 identified studies, 9 were found to be relevant for further analysis (8, 11, 12, 23–28). The study of Engardt et al. (25) was excluded, because the patients in this study received postural control therapy with auditory instead of visual feedback. A total of 8 studies, involving 214 patients, met all the inclusion criteria (8, 11, 12, 23, 24, 26–28). The patients included in the study of Grant et al. ($n = 16$) (26), however, showed to be a subset of the study of Walker and colleagues (12). Therefore the study of Grant was only used for outcomes not investigated by the study of Walker and colleagues (12). Six studies ($n = 128$) were classified as RCTs (8, 11, 12, 23, 26, 27) and 2 as CCTs ($n = 86$) (24, 28). Table I shows the main characteristics of the 8 eligible studies included in the systematic review. All studies were performed within the first 6 months post-stroke, ranging from 5 weeks (8, 26) to 20 weeks (7) after stroke onset.

Methodological quality assessment

The methodological quality of the 8 included studies is presented in Table I (8, 11, 12, 23, 24, 26–28). Therefore 80 quality items (10 per study) were scored. Initially, the 2 reviewers disagreed on 5 of the 80 (6.3%) quality items. This resulted in an average Cohen's Kappa score for all items of 0.88. The median PEDro-score was 4, ranging from 3 to 6 points.

Eight studies did not use a randomization procedure with concealed allocation and did not describe an intention-to-treat analysis (8, 11, 12, 23, 24, 26–28). In 1 study the observers were blinded to treatment allocation (27).

Quantitative analysis

Pooling of outcomes was possible for (i) weight distribution and postural sway while bilateral standing; (ii) Berg Balance

Table I. *Characteristics of the included studies*

Reference (year)	Objective study	Design	*n* (E/C)	Mean age (E/C)	Time (days) since stroke (E/C)	Equipment	Training period (weeks)	Outcome (bilateral standing)[1]	Outcome (gait & gait-related activities)[1]	Conclusions (author)	Methodological quality**
Shumway-Cook et al. (1988)	To investigate the effect of additional VFT compared with CT in re-establishing stance stability in post-acute stroke patients.	RCT	16 (8/8)	66/64	36/37	Standing Feedback Trainer	2	Total Sway area (EO), Lateral Sway (EO)	–	VFT is more effective than CT in reducing lateral sway and increasing load on the affected leg, however, no significant post-treatment effects were found.	External validity#: yes 4 points** Failure at the questions: 3, 4, 5, 6, 7, 9
Winstein et al. (1989)	To investigate the effect of additional VFT compared with CT for balance retraining in post-acute stroke patients with a standing feed-back trainer.	CCT	42 (21/21)	52/54	54/44	Standing Feedback Trainer, Stride analyser system	3-4	Sway (EO), Weight Distribution	Gait speed	Significant improvement of static standing symmetry was found in VFT-group. No additional effects of VFT on gait speed, cadence, stride length and cycle time were observed.	External validity#: yes 3 points** Failure at the questions: 2, 3, 5, 6, 7, 8, 9
Sackley et al. (1997)	To investigate the effectiveness of additional VFT vs placebo VFT in improving stance symmetry and f unctional ability in post-acute stroke patients.	RCT	26 (13/13)	61/68	141/132	Nottingham Balance Platform	4	Sway (EO), Weight Distribution	Nottingham 10 Points ADL Scale, Rivermead Motor Function Assessment	Significant better performance VFT on stance symmetry and sway and motor and ADL function. Between group differences disappeared at 3 months post-stroke.	External validity#: yes 6 points** Failure at the questions: 3, 5, 6, 9
Walker et al. (2000)	To investigate the effect of additional VFT compared with balance training on CoG position in post-acute stroke patients.	RCT	32## (16/16)	65/62	41/35	Balance Master™	3-8	Sway (EO) Sway (EC)	BBS, TUG, Gait speed	No between-group differences in any of the outcome measures were found.	External validity#: yes 4 points** Failure at the questions: 3, 5, 6, 7, 8, 9
Grant et al. (1997)	To investigate the beneficial effect of VFT compared with CT for balance retraining in post-acute stroke patients.	RCT	16 (8/8)	65/65	33*	Balance Master™	3-8	Sway (EO), Sway (EC), Weight Distribution	BBS, TUG, Gait speed	No between group differences on any outcome measure were found, although the CT group tended to perform better on tasks involving gait.	External validity#: yes 5 points** Failure at the questions: 3, 5, 6, 7, 9
Geiger et al. (2001)	To investigate the effects of additional VFT compared with CT on balance and mobility in post-acute stroke patients.	RCT	13 (7/6)	62/59	100/134	Balance Master™	4	–	BBS, TUG	No additional effects of VFT was found compared with the CT group.	External validity#: yes 5 points** Failure at the questions: 3, 5, 6, 7, 9
Chen et al. (2002)	To investigate the delayed effects of additional VFT compared with CT on balance retraining in post-acute hemiplegic patients.	RCT	41 (23/18)	59/55	90/113	Balance Master™	2	Sway (EO), Sway (EC), Static Stability, Dynamic Stability	Brunnstrom stages; FIM	No significant between-group differences were found with respect to static balance and locomotion and mobility scoring of FIM. Significant improvements were observed for dynamic balance function and outcome of ADL in favour of VFT.	External validity#: yes 5 points** Failure at the questions: 3, 5, 6, 7, 9

Table I (*Continued*)

Reference (year)	Objective study	Design	n (E/C)	Mean age (E/C)	Time (days) since stroke (E/C)	Equipment	Training period (weeks)	Outcome (bilateral standing)[1]	Outcome (gait & gait-related activities)[1]	Conclusions (author)	Methodological quality**
Cheng et al. (2004)	To investigate the effects of additional VFT compared with CT on the occurrence of falls in post-acute hemiplegic patients.	CCT	52 (28/24)	61/61	96/99	Balance Master™	3	Static Stability, Dynamic Stability	Fall occurrence	No between-group difference for any static stability outcome was found. The post-training test showed significantly better dynamic balance performance in favour of VFT. The occurrence of falls decreased, although not statistical significant in favour of the VFT group was not significant.	External validity[#]: yes 4 points** Failure at the questions: 2, 3, 5, 6, 7, 9

[1]Only outcomes relevant for this systematic analysis are presented.
*Average time since stroke of both groups.
**Quality assessment of RCTs is measured by counting the number of checklist criteria (2-11) of the PEDro-scale, that are satisfied in the trial report (sumscore 0-10) of the items 2-11).
[#]The first item of the PEDro-scale has a yes/no-score. Yes means that the external validity is satisfied.
[##]The VFT group is compared with the conventional group (the data of the 3rd group-control group-are not used in this meta-analysis).
BBS = Berg Balance Scale; C = Control Group; CCT = Controlled Clinical Trial; CoG = Center-of-Gravity; CT = conventional balance therapy; E = Experimental Group; EC = eyes closed; EO = eyes open; FIM = Functional Independence Measure; n = number of patients; PEDro = Physiotherapy Evidence Database; RCT = Randomized Controlled Trial; TUG = Timed Up & Go test; VFT = visual feedback therapy.

Scale (BBS) (29, 30); (iii) Timed Up & Go test (TUG) (31) and (iv) gait speed.

Weight distribution while bilateral standing

For the purpose of the present meta-analysis all weight distribution data were put in comparable datasets. A homogeneous non-significant SES was found for 3 studies (n = 75), 2 RCTs (26, 27) and 1 CCT (28) evaluating weight distribution with VFT in bilateral standing compared with conventional treatment (SES [fixed] 0.40; CI −0.06 to 0.86) (26–28) (Fig. 1). Winstein et al. (28) presented the weight distribution in percentage body weight on the paretic side. Grant et al. (26) and Sackley et al. (27) depicted the weight distribution data as a ratio of the paretic vs the non-paretic limb. A *post hoc* sensitivity analysis for study design was performed. Subsequently, when the CCT of Winstein et al. (28) was excluded from the analysis the *post hoc* analysis resulted in a non-significant SES between VFT in bilateral standing and conventional therapy (SES [fixed] 0.51; CI −0.11 to 1.14) (26, 27).

Postural sway in bilateral standing

Postural sway was measured in 2 conditions: with eyes open and with eyes closed. Five studies (n = 148), 4 RCTs (8, 12, 23, 27) and 1 CCT (28), investigated the effects of VFT on postural sway in bilateral standing with eyes open. Two of these studies (12, 23) presented the postural sway (eyes open) in percentage (%) of the theoretic limits of stability and 2 studies (27, 28) presented this outcome in displacement values. Despite the differences regarding postural sway measurement, all data were included in the present meta-analysis. After intervention a non-significant heterogeneous SES was found for postural sway (eyes open) (SES [random] 0.20; CI −0.12–0.53) (8, 12, 23, 27, 28) (Fig. 1). The data in the RCT of Shumway-Cook and colleagues were presented in interquartile ranges and standard error measurements (SEM) (8). The means of the pre- and post-treatment data were analysed and SEM was converted to standard deviations (SD) (16). Excluding the CCT of Winstein et al. (28) a *post hoc* sensitivity analysis for study design resulted in a non-significant SES between VFT and conventional therapy (SES [fixed] 0.26; CI −0.11–0.63) (8, 12, 23, 27).

Two RCTs (n = 73) measured the effects of VFT on postural sway with eyes closed in bilateral standing (12, 23). In both studies the postural sway data were presented in percentage limits of stability. The meta-analysis resulted in a non-significant homogeneous SES for postural sway (eyes closed) in bilateral standing comparing VFT and conventional therapy (SES [fixed] 0.28; CI −0.18–0.75) (12, 23) (Fig. 1).

Berg Balance Scale

Two RCTs (n = 45) evaluated the effects of VFT while bilateral standing on balance, measured with the BBS (11, 12). A non-significant homogeneous SES was found for BBS (SES [fixed] −0.20; CI −0.79–0.39) (11, 12) (Fig. 2).

Timed Up & Go test

The TUG is evaluated in 2 RCTs ($n = 44$) (11, 12). The effects of VFT in bilateral standing on the outcome measure TUG are presented in Fig. 2. A non-significant homogeneous SES was found for TUG, when comparing VFT with conventional therapy (SES [fixed] −0.14; CI −0.73–0.45) (11, 12).

Gait speed

Two studies ($n = 72$), 1 RCT (12) and 1 CCT (28), evaluated the effects of VFT while bilateral standing on gait speed. A non-significant heterogeneous SES was found for gait speed when comparing VFT with conventional therapy (SES [random] 0.08; CI −0.97–1.14) (12, 28) (Fig. 2).

The balance and gait performance tests (BBS, TUG and gait speed) tended to favour the conventional treatment instead of the VFT, but without statistical significance.

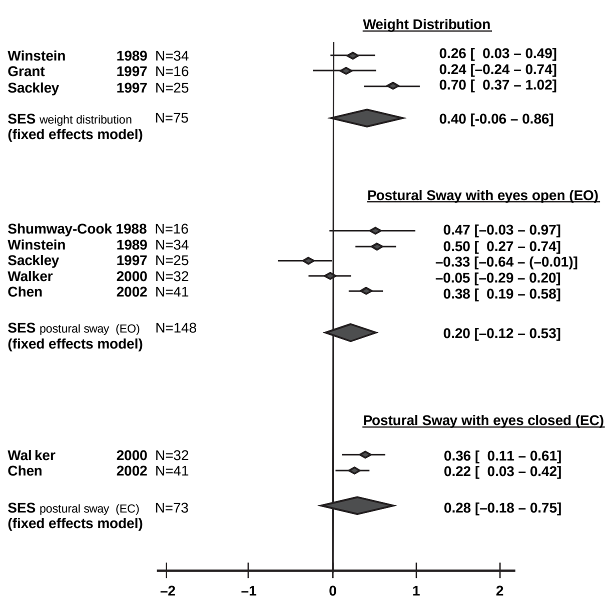

Fig. 1. Meta-analysis of visual feedback therapy (VFT) trials measuring outcomes of weight distribution and postural sway performance while bilateral standing. Meta-analysis of weight distribution between paretic and non-paretic lower limb, postural sway with eyes open (EO) and postural sway with eyes closed (EC) in VFT vs conventional therapy. Effect-sizes are based on Hedges g (and 95% confidence intervals (CI)). The middle of each bar represents the mean effect-size, whereas the length of the bar reflects the 95% CI. Bars to the right of the vertical line denote a positive effect for the VFT and vice versa. When the bar of an individual study crosses the vertical line at zero, no definite conclusions can be drawn in favour of the VF or conventional group. The summary effect-sizes (SES) value represents the summarized effect-size of all included studies.

DISCUSSION

The present systematic review aims to estimate the effects of the additional value of VFT while bilateral standing on postural control, gait performance and gait-related activities after stroke. This review shows, however, no significant effects in favour of VFT for (left-right) symmetry of weight distribution in bilateral standing, postural sway, balance control measured with BBS, transfers and walking ability measured with TUG or gait speed. Despite differences between inclusion criteria and number of included studies, the findings presented in this systematic review correspond to a large extent with those of Barclay-Goddard et al. (13) who reviewed studies that also included non-stroke victims.

Improving symmetry of weight distribution while bilateral standing, is one of the main treatment goals in the rehabilitation of patients with stroke, acknowledging that the degree of asymmetric weight distribution during quiet standing is negatively associated with motor function and independence (7). Furthermore, the transfer of weight distribution is seen as an indicator for walking performance (9, 32). It has been documented that patients with stroke shift 60–90% of the body weight to the non-paretic limb (27, 33, 34). However, the question is how this asymmetry in weight distribution while standing is related to balance control and with that to the safety not to fall. For example, Kirker et al. (35) found that patients with stroke are more stable, while standing when they keep their postural control, as soon as the centre of pressure is successfully shifted above the unaffected limb (35). This finding suggests that the asymmetrical stance of people with hemiparesis may be a compensatory strategy to overcome muscle weakness (36, 37), delayed muscle activation, (35, 38) synergistic-dependent activation patterns of muscles (39) and existing perceptual deficits (40–42). This assumption is also supported by Sackley (7), who noted that asymmetrical weight transfer does not necessarily imply that the subjects are more unstable and less able to control their balance in order to prevent falling. In other words, asymmetry does not necessarily imply a decreased postural control and higher risks for falling (43, 44). Unfortunately, almost none of the studies, except that of Cheng et al., did measure the impact of VFT on the incidence of falling or near falling after stroke (24).

The lack of evidence on postural control may also reflect the absence of valid outcome measures that represents more appropriate the strategy to obtain postural control while bilateral standing on 2 force plates. For example, De Haart et al. (45) stated that the speed (i.e. number of weight shifts) and imprecision (normalized average lateral displacement) by asking patients well-controlled weight shifts in the frontal plane, could provide additional information about their improvement in balance control after stroke compared with the traditional measures of outcome. In addition, it might be hypothesized that in stroke patients different strategies are used for maintaining upright position during quiet bilateral standing. For example, stabilogram analysis revealed that

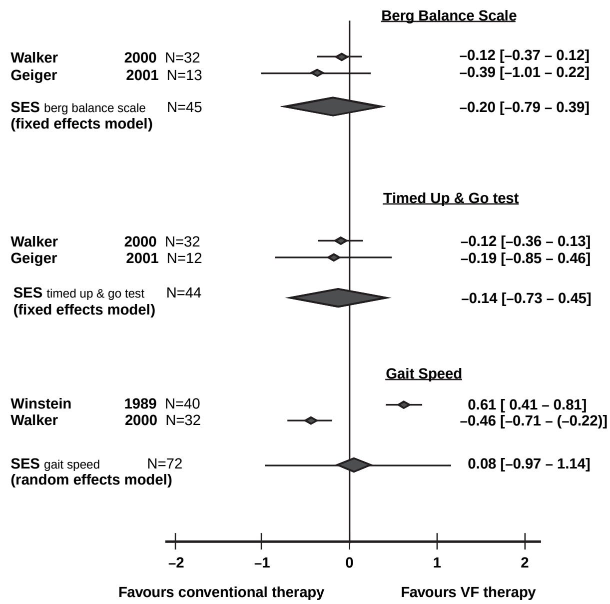

Fig. 2. Meta-analysis of visual feedback therapy (VFT) trials measuring outcomes of gait and gait-related activities. Meta-analysis of the Berg Balance Scale, the Timed Up & Go test and gait speed in VFT vs conventional therapy. Effect-sizes are based on Hedges g (and 95% confidence intervals (CI)). The middle of each bar represents the mean effect-size, whereas the length of the bar reflects the 95% CI. Bars to the right of the vertical line denote a positive effect for the VFT and vice versa. When the bar of an individual study crosses the vertical line at zero, no definite conclusions can be drawn in favour of the VF or conventional group. The summary effect-sizes (SES) value represents the summarized effect-size of all included studies.

delaying time intervals of open-loop control mechanisms as well as inappropriate timing of descending commands to postural muscles, may be important factors that contribute to inappropriate displacements of the centre of pressure beyond the limits of safety (46, 47). A further understanding of these changes, as well as the adaptive mechanisms underlying the functional (re)organization of postural control is needed to conceptualize the effects of hemiplegia on postural instability in patients with stroke. Subsequently, new treatment programs need to be developed aiming to improve postural control in stroke instead of restoring symmetry alone.

The present review also suggests that VFT failed to generalize to a better balance control while performing gait and gait-related activities. These results are of great clinical value, indicating that training of postural control should preferably be applied while performing the gait-related tasks itself. It should be noted, however, that the BBS is sensitive to ceilings effects (48) and may have prevented the detection of significant effects, for example in the study of Walker et al. (12). Future studies are needed to investigate the relationship of patients preferred asymmetrical standing position to performance of gait and to establish how recovery of (left-right) symmetry in standing balance is related to improvements in gait and gait-related activities.

Unfortunately, in the present review not all outcomes could be pooled. For example, the ADL outcomes of Sackley & Lincoln (27) and Chen et al. (23) were too diverse to be pooled. The studies reported significant effects on the Nottingham 10 points ADL scale (27) and FIM™ (23) that favoured VFT. One should notice that these positive effects are in contrast to the findings of the present meta-analysis. However, only limited evidence could be attributed to the individual results of these studies. Additionally, the data of the Balance Master™ outcome "dynamic stability" were not defined in the individual studies (23, 24). As a consequence, it was unclear how to interpret these outcomes in terms of improvement in postural control.

Limitations of this systematic review

The present review has a number of shortcomings. We may have missed relevant studies not published in scientific journals or published in other languages than English, German or Dutch. These shortcomings emphasize the need for more high-quality and larger RCTs in stroke rehabilitation studies in the future.

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