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Force platform feedback for standing balance training after stroke (Review)

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[Intervention Review]

Force platform feedback for standing balance training after stroke

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ABSTRACT

Background

Standing balance deficits are common in individuals after stroke. One way to address these deficits is to provide the individual with feedback from a force platform while balance activities are performed. The feedback can take visual and/or auditory form.

Objectives

To determine if visual or auditory force platform feedback improves the clinical and force platform standing balance outcomes in clients with stroke.

Search methods

We searched the Cochrane Stroke Group trials register (last searched December 2003), and the following electronic bibliographic databases: the Cochrane Central Register of Controlled Trials (*The Cochrane Library* Issue 3, 2003), MEDLINE (1966 to May 2003), EMBASE (1974 to May 2003), CINAHL (1982 to May 2003), PEDro (May 2003), CIRRIE (May 2003) and REHABDATA (May 2003). Reference lists of articles were reviewed and manufacturers of equipment were contacted.

Selection criteria

Randomized controlled trials comparing force platform with visual feedback and/or auditory feedback to other balance treatments.

Data collection and analysis

Two reviewers independently assessed trials for inclusion, methodological quality, and data extraction. Trials were combined for meta-analysis according to outcome and type of feedback.

Main results

We included seven trials (246 participants). Force platform feedback did not improve clinical measures of balance when moving or walking (Berg Balance Scale and Timed Up and Go). Significant improvements in laboratory force platform indicators of stance symmetry were found for regimens using visual feedback (standardised mean difference (SMD) -0.68, 95% confidence interval (CI) -

1.31 to -0.04, p = 0.04) and the concurrent visual and auditory feedback (weighted mean difference (WMD) -4.02, 95% CI -5.99 to -2.04, p = 0.00007). There were no significant effects on laboratory postural sway indicators, clinical outcomes or measures of function at follow-up assessment.

Authors' conclusions

Force platform feedback (visual or auditory) improved stance symmetry but not sway in standing, clinical balance outcomes or measures of independence.

PLAIN LANGUAGE SUMMARY

Force platform feedback for standing balance training after stroke

Feedback from a force platform improves standing balance but the impact on independence is unclear. People who have had a stroke often experience problems with standing balance. Impaired standing balance is often treated with balance exercises suggested by a physiotherapist. Exercises are sometimes given with feedback from a force platform to indicate the person's standing position. The results of seven clinical trials indicated that providing feedback from a force platform resulted in patients standing more evenly but did not improve balance during active functional activities, nor did it improve overall independence.

BACKGROUND

Stroke is defined as " ... a sudden loss of brain function ... caused by the interruption of the flow of blood to the brain or the rupture of blood vessels in the brain" (Heart & Stroke 2003). In Canada, there are approximately 300,000 stroke survivors, with an incidence of 40,000 to 50,000 new cases per year (Heart & Stroke 2003). Stroke is a major cause of disability: 25% of stroke survivors live with minor disability, 40% with moderate to severe disability, and 10% require long-term care (Heart & Stroke 2003). Poor balance when walking is a common cause of disability after stroke.

It has been suggested that an individual has functional standing balance if three competencies are demonstrated (Berg 1989a). Firstly, the individual must be able to maintain the standing position in static circumstances. Secondly, the individual must be able to maintain standing while experiencing internally produced perturbations associated with movements of their extremities. Finally, the individual must be able to maintain standing while experiencing externally produced perturbations.

Force platform technology provides a method for quantifying an individual's ability to meet these competencies. For example, calculation of the position of the centre of pressure provides an indicator of the individual's ability to meet the first competency.

Asymmetric weight bearing in a standing position, with a decrease in weight borne through the hemiplegic lower limb, is a common finding in stroke survivors (Dickstein 1984; Sackley 1990; Sackley 1992; Winstein 1991). This asymmetry has been shown to have a negative relationship with both motor function and independence in performance of activities of daily living (ADL) (Sackley 1990). However, the strength of these correlations indicates that factors other than stance symmetry are also necessary for independent performance of ADLs. Nevertheless, these correlations support the practice of addressing symmetry of weight bearing during stroke rehabilitation (Sackley 1990). It has also been noted that improving standing balance symmetry does not necessarily lead to a decrease in the asymmetrical lower limb patterns in hemiplegic gait (Winstein 1989).

Physiotherapists frequently prescribe exercises to stroke survivors which are designed to promote weight bearing through the hemiplegic lower extremity (Barclay-Goddard 2003; Carr 1994; Nilsson 1992; Ogiwara 1997). Coincident with these exercises, clinicians provide feedback to ensure that the exercise is performed to maximize its effect. This is based on motor learning theory which can be described as "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for producing skilled action" (Shumway-Cook 2001). The motor learning literature describes one form of feedback as 'knowledge of results'. This form of feedback is defined as the "augmented extrinsic information about task success provided to the performer" (Winstein 1991). Visual feedback from a computer screen and auditory feedback from an alarm are two ways of providing knowledge of results regarding performance on a force platform device (Walker 2000; Wong 1997). The feedback may be provided on a constant basis throughout the treatment or in-

termittently. Constant feedback is controversial as it may have a positive effect on performance but a negative effect on longer-term learning (Ezekiel 2001; Winstein 1991). Some of this equipment can be expensive and not widely available. Furthermore, it is controversial whether improvements in stance symmetry result in positive effects on meaningful functional activities such as walking ability.

OBJECTIVES

To determine if visual or auditory force platform feedback improves the clinical and force platform standing balance outcomes in clients with stroke.

METHODS

Criteria for considering studies for this review

Types of studies

Parallel group randomized controlled trials were included. Crossover trials were not included.

Types of participants

Participants were stroke survivors found to have either abnormal weight bearing in the standing position, or standing balance impairment during or after initial rehabilitation.

Types of interventions

The included trials evaluated standing balance training augmented by visual or auditory feedback related to the behaviour of the centre of pressure (sway) and/or position of the centre of pressure (stance symmetry). We considered trials that compared: force platform balance training with visual or auditory feedback and 'conventional' treatment; force platform balance training with visual or auditory feedback and another balance treatment; or force platform balance training with visual or auditory feedback and placebo balance treatment.

Types of outcome measures

The primary outcomes were standardized clinical methods of assessing standing balance and timed walking. Measures included, but were not limited to, the Berg Balance Scale (BBS) (Berg 1989a, Berg 1989b; Berg 1992) and the Timed Up and Go (TUG) (Podsiadlo 1991). The BBS is a clinical functional measurement of balance impairment; the TUG gives the time needed to stand up from a chair, walk three metres, turn around, walk back to the chair and sit down. Both measures give continuous data.
The main secondary outcomes were laboratory measures of standing balance using force platform indicators. Firstly, indicators of centre of pressure position were used to describe stance symmetry. Secondly, indicators of the centre of pressure behaviour over time described sway. Measures of functional activity such as the Functional Independence Measure (Hamilton 1994) were also included as secondary outcomes.

Search methods for identification of studies

See: 'Specialized register' section in Cochrane Stroke Group
Relevant trials were identified in the Cochrane Stroke Group trials register (last searched 1 December 2003). In addition, we searched the following electronic bibliographic databases: the Cochrane Central Register of Controlled Trials (*The Cochrane Library* Issue 3, 2003), MEDLINE (1966 to May 2003), EMBASE (1974 to May 2003) and CINAHL (1982 to May 2003) (Appendix 1). The Physiotherapy Evidence Database (PEDro) (http://www.pedro.fhs.usyd.edu.au/index.htm), and the specialist rehabilitation research databases CIRRIE (http://cirrie.buffalo.edu/) and REHABDATA (www.naric.com) were also searched (May 2003). Reference lists of articles were reviewed. Manufacturers of the equipment used (Neurocom International and SMS Healthcare) were contacted in an effort to identify further published or unpublished trials.

Data collection and analysis

The titles and abstracts of the results of the literature searches were screened by two independent reviewers (RBG and TS). Both reviewers were physiotherapists with experience in stroke rehabilitation. The reviewers determined whether the articles appeared to meet the inclusion criteria. The reviewers discussed any differences in findings in order to come to a consensus. The articles which appeared to meet the inclusion criteria were retrieved and the full text was reviewed in further detail by RBG and TS. English translations were obtained for trials which appeared appropriate but which were reported in languages other than English.

The methodological quality of each included trial was assessed by both RBG and TS. Differences were discussed to achieve consensus. The Jadad scoring system (Jadad 1996) was used to assess the randomization, double blinding, and withdrawals and dropouts; scores range from 0 to 5. The following information was also gathered: the method used to generate random sequence, concealment of allocation (described as adequate, unclear, inadequate, or not used), method of concealment of allocation (if used), who was blinded and whether it was successful, use of intention to treat

analysis, and the number lost to follow up. Death was treated as a loss to follow up.

The two reviewers discussed any disagreement in the evaluation of methodological quality and requested the assistance of a third reviewer (ST) in one case where a consensus could not be reached. In this case, it was clarified that if a study did not describe withdrawals or dropouts and it was not stated if there were any, the point on the Jadad scale (Jadad 1996) would not be granted. Two trialists clarified information in written format. Details of the included and excluded trials are shown in the 'Characteristics of included studies' and 'Characteristics of excluded studies' tables respectively.

Data extraction was completed by both RBG and TS. Extracted data were compared and any discrepancy resolved through negotiation. RevMan 4.1 was used for all data analysis. Analysis was performed if there were at least two trials for each type of feedback and for each outcome at the end of treatment and at follow up.

All outcomes were continuous data. The weighted mean difference and 95% confidence interval was calculated for each outcome. The standardised mean difference and 95% confidence interval was used for different outcomes measuring the same concepts. Both fixed-effect and random-effects analyses were completed.

The trials were analysed for statistical heterogeneity; a p value greater than 0.1 was considered acceptable.

RESULTS

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.

The search of all sources revealed 1118 titles and/or abstracts. Twenty-four trials appeared to fit the inclusion criteria, including two that were non-English (Jobst 1989; Lin 1998). Closer inspection of these 24 left us with 10 which fitted the criteria (Chen 2002; Chernikova 1999; Geiger 2001; Lee 1996; Lin 1998; McRae 1992; Sackley 1997; Shumway-Cook 1988; Walker 2000; Wong 1997). Two of the studies were only available as abstracts. Various attempts were made to locate and contact the authors of the two abstracts but without success, therefore, they were excluded as there were no available data (Chernikova 1999; McRae 1992). Another trial was excluded because data were not in a form that could be used for analysis (Lin 1998). Seven studies remained for this review (Chen 2002; Geiger 2001; Lee 1996; Sackley 1997; Shumway-Cook 1988; Walker 2000; Wong 1997). All studies were parallel group randomized controlled trials. See the 'Characteristics of included studies' table for information on age, gender, and time after stroke of the participants.

The seven studies used force platforms with dual forceplates and a continuous visual feedback display. Trials presented feedback in various ways. Stance symmetry was represented with bar graphs (Sackley 1997) or numerical displays, bar graphs and mirrors along with concurrent auditory feedback (Lee 1996; Wong 1997). Feedback regarding sway was provided visually by a representation of centre of gravity position and movement (Chen 2002; Geiger 2001; Shumway-Cook 1988; Walker 2000). No trials provided auditory feedback alone.

There were a total of 246 subjects in the seven included studies. All studies compared force platform feedback to some type of conventional treatment. Five studies included some type of conventional or functional treatment as well as the force platform feedback in the experimental groups (Chen 2002; Geiger 2001; Sackley 1997; Shumway-Cook 1988; Walker 2000). Due to the variety of outcomes used in the studies, not all seven studies could be combined. The following analyses were possible as there were at least two studies with the same outcome. Immediately post-treatment, the clinical methods of assessing standing balance and timed walking (Berg Balance Scale and the Timed Up and Go) and laboratory methods of assessing standing balance (stance symmetry and sway) were analyzed. An analysis of follow-up assessments was possible for sway indicators, gross motor function/walking, and ADL. The functional measures describing ADL were the self care and sphincter control subscales of the Functional Independence Measure (Hamilton 1994) and the 10 point Nottingham ADL scale (Ebrahim 1985); these were combined using the standardized mean difference. The locomotion/mobility subscale of the Functional Independence Measure and the gross motor subscale of the Rivermead Motor Assessment (Lincoln 1979), which includes ambulation and mobility items, were also combined using the standardized mean difference. For all functional measures higher scores represented increased independence. At follow up, sway was analysed using the standardized mean difference due to the different orders of magnitude of the measures. Data were further analysed by type of feedback: visual feedback alone, concurrent visual and auditory feedback, and all forms of feedback combined.

The length of treatment varied from two to eight weeks. Lee 1996 and Wong 1997 both collected data at one, two, three, and four weeks after initial treatment. The two-week data are used in the meta-analysis as they include all study subjects in both trials. The numbers of subjects in the trials declined in weeks three and four due to patients being discharged home. Two studies had follow-up data (Sackley 1997; Walker 2000). The second assessment time in Chen 2002 was at six months post-intervention. Due to the length of time from the initial pre-treatment assessment to the second assessment, the data were combined with the follow-up data from Sackley 1997 and Walker 2000 where possible.

In the Shumway-Cook 1988 trial, means and standard deviations were not presented. Data were presented in a box-plot format with median, quartile and range scores. The data were presented as

combined pre-treatment data and as the difference between pre- and post-treatment for each group (experimental and conventional treatment). In consultation with a biostatistician, the mean for pre-treatment and for treatment difference was estimated assuming that 68.2% of the results fell in one standard deviation, considering the median value and the skew of the data. The difference between the pre-treatment and treatment difference was then calculated to give the estimated mean score for post-treatment of each group. The standard deviation of the pre-treatment time for each outcome was used for both the treatment and control groups.

For follow-up data, Chen 2002 displayed change scores with bar graphs for self care/activities of daily living and mobility/ambulation outcomes. The mean change score determined by the bar graph was added to the initial mean score to determine the score at six months. The standard deviation of the initial score was used. The Chen 2002 and Walker 2000 trials measured sway both with eyes open and eyes closed. Only the eyes open outcome was used to represent centre of pressure motion (sway), consistent with the other trials.

Risk of bias in included studies

The Jadad (Jadad 1996) quality scores are shown in the 'Characteristics of included studies' table. None of the studies were described as double blinded, two described the randomization process (Geiger 2001; Sackley 1997), and two did not mention withdrawals or dropouts (Chen 2002; Geiger 2001). Concealment of allocation and intention to treat analysis was not stated in any of the studies.

Selection bias was possible in all studies since the method of allocation concealment was not described. Ascertainment bias was also possible as only Sackley 1997 used blinded assessors. Bias may be present due to the inappropriate handling of withdrawals and dropouts in some studies.

Possible confounders in Lee 1996 and Wong 1997 were the additional use of auditory feedback, and the inclusion of small numbers of hemiplegic traumatic brain injured clients. The time since stroke onset may also be a confounder in the studies. For example, the range of time since onset in Geiger 2001 was 15 to 538 days, while in Sackley 1997 it was four to 63 days.

Effects of interventions

The statistical heterogeneity was acceptable ($p > 0.1$) in all chi squared tests. Funnel plots and subgroup analyses could not be completed due to the small number of included studies. Both fixed and random-effects models were used. The results were identical between the two methods except for the Timed Up and Go and the sway indicators at follow up, which showed a slight difference in weighted mean difference. Neither Timed Up and Go nor the sway indicators at follow up showed statistical significance with either method. The fixed-effect model statistics are presented below.

The clinical outcomes of standing balance and timed walking tended to favour the control, but without statistical significance: Berg Balance Scale weighted mean difference (WMD) -1.98 (95% confidence interval (CI) -5.55 to 1.59, p = 0.3) for two studies with 43 participants; Timed Up and Go WMD 7.31 (95% CI -1.33 to 15.94, p = 0.10) for two studies with 42 participants.

For the laboratory outcomes measuring standing balance, force platform indicators of stance symmetry were represented in four studies. For each analysis, force platform feedback showed a statistically significant positive effect. Analysing visual feedback alone, two studies with a total of 41 participants resulted in a standardized mean difference (SMD) -0.68 (95% CI -1.31 to -0.04, p = 0.04). The two concurrent auditory and visual feedback studies included 120 participants and resulted in a WMD of -4.02 (95% CI -5.99 to -2.04, p = 0.00007). When both types of feedback were combined (visual alone plus concurrent auditory and visual), there were 161 participants in the four studies resulting in a SMD of -0.71 (95% CI -1.03 to -0.39, p = 0.00002). Indicators of sway were not statistically significant with a SMD of -0.10 (95% CI -0.57 to 0.36, p = 0.7) for three studies with 71 participants receiving visual feedback only.

In the follow-up period of one month or more post intervention, all feedback was in the visual form. There was no difference between groups for indicators of sway for 71 participants in two studies (SMD -0.34, 95% CI -0.81 to 0.13, p = 0.16). There was no significant difference for the functional outcomes at follow up either. Gross motor function/walking was used as an outcome in two studies with 65 participants and had a SMD of 0.16 (95% CI -0.33 to 0.65, p = 0.5). Independence in ADL was an outcome for the same two studies with a SMD of 0.23 (95% CI -0.26 to 0.73, p = 0.4).

Lesion location was not described and, therefore, this subgroup analysis was not performed. Similarly, subgroup analysis on the basis of time after stroke was not possible because of non-specific inclusion criteria and/or inconsistent description. Evaluations of economic, quality of life and handicap measures were not included in any of the studies.

DISCUSSION

We observed that the differences in the Berg Balance Scale between treatment and control groups were approximately two points with a confidence interval of -5.5 to 1.5. A change of six or more on the Berg Balance Scale was required to be 90% confident that there is a true change (Stevenson 2001). Therefore, we could not identify a clinically significant effect in the clinical balance outcome as represented by the Berg Balance Score.

Also of note were the differences in scores of the baseline Timed Up and Go scores in Walker 2000. The control group was, on average, 8.4 seconds faster than the treatment group at baseline testing. The difference in pre-treatment scores may partially explain the differences in post-treatment scores. Chen 2002 also described a significant difference between treatment and control groups in the Functional Independence Measure self care and sphincter control items at baseline, with the treatment group having lower scores. At follow up, the treatment group had a larger positive change score than the control group, but possibly due to the different pre-treatment scores, the follow-up scores were not significantly different.

One laboratory method of measuring standing balance was the force platform indicators of stance symmetry. Stance symmetry was significantly better in the treatment groups than the control groups, regardless of the form of feedback. Part of the treatment protocol in each trial included an attempt to make lower limb weight bearing more symmetrical. The assessment of outcome for the stance symmetry directly reflected part of the training protocol for the treatment group. Those participants whose regimen included this aspect of balance training improved their stance symmetry indicators on reassessment. This is consistent with task specificity of training identified by Shumway-Cook 2001 as a key concept in Motor Learning Theory. The task specific nature of training suggests that the transfer of learning from one environment to another is maximized when the practice environment is similar to the goal environment as in the circumstances where stance symmetry was both assessed and trained on a force platform.

The reliability of force platform measures is a consideration in any study involving repeated measurement using force platform outcomes. Liston 1996 described acceptable reliability coefficients for Balance Master™ indicators of sway. The reliability of the other force platforms used in the trials was not stated.

Three studies have looked at correlations between the Berg Balance Scale and force platform outcomes (Liston 1996; Niam 1999; Stevenson 1996). The studies all used different force platforms, making them difficult to compare. Liston 1996 and Niam 1999 showed moderate negative correlations between the Berg Balance Scale and force platform indicators of balance, while Stevenson 1996 showed high negative correlations between the Berg Balance Scale and static tests. The negative correlations suggest that high Berg Balance Scale scores correlate with low force platform indicators of sway, both of which reflect 'better' balance. As discussed previously, training of stance symmetry using force platform feedback may not translate into improvement in clinical measures that assess standing balance.

There are some limitations to this review. The numbers in each study were small, as were the number of studies, and not all studies could be combined together due to differences in outcomes. Some studies were poorly described, leading to low quality scores. One study could not be included due to limitations in the way that the data were presented. The use of the term 'conventional' treatment is confusing and the definitions varied from study to study. Poor description of physical rehabilitation is common (Ballinger 1999). Of note, rehabilitation therapy is individualized for each client making specific description of interventions challenging. These limitations certainly suggest that more research is needed.

Implications for theory

Results appear to be consistent with task specificity, a concept of Motor Learning Theory (Shumway-Cook 2001). Assessment and training of the task of stance symmetry on a force platform resulted in positive improvements in stance symmetry. We speculate that the task specific nature of balance training may also explain why the balance training regimens with visual and/or auditory feedback from a force platform failed to promote improvements in clinical methods of assessing standing balance as well as performance of functional activities.

Another Motor Learning Theory concept that may apply to the findings is the schedule of feedback provision. All trials provided constant feedback which has been shown to improve immediate performance but degrade learning (Ezekiel 2001; Shumway-Cook 2001; Winstein 1991). The concept of blocked practice was used in the training as well. Blocked practice is considered to be less helpful to learning than random practice (Shumway-Cook 2001). We surmize that the negative clinical outcome results may also relate to these concepts.

AUTHORS' CONCLUSIONS

Implications for practice

We found no clear evidence that the use of force platform feedback improves clinical standing balance outcomes. However, we did find a positive effect of force platform feedback training to train stance symmetry, but not sway, in standing. The use of both force platform and clinical balance outcomes in assessment may provide a more complete picture of balance after stroke.

Implications for research

Our results are based on a small number of trials recruiting a small number of patients. Further larger trials are needed. Further study is also required to investigate the association between laboratory force platform measures of improvement and clinical improvement in balance, gait and functional outcomes. Further study of the application of Motor Learning principles to physiotherapy practice is also warranted.

Better reporting of randomized controlled trials in the rehabilitation literature would make interpreting and reviewing such trials much easier. The use of the CONSORT (Consolidation of Standards for Reporting Trials) guidelines (CONSORT 2004) would be beneficial in this respect. Increased use of a description of stroke severity related to outcomes would help to determine if changes that occur are related to stroke severity.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Chen 2002

Methods	RCT SMART Balance Master (dual force platform)
Participants	Ambulatory stroke patients, mean age 58.7 years, 3 months post stroke, severity measured with the Brunnstrom scale n = 23 expt, 30% male n = 18 control, 33% male
Interventions	Visual feedback on force platform and conventional physical and occupational therapy versus conventional therapy (muscle strengthening, therapeutic exercise and ADL training), 20 minutes per day, 5 times per week 2-week study
Outcomes	Force platform: centre of pressure behaviour, centre of gravity alignment (% limits of stability) (eyes open and eyes closed) Clinical: FIM subscale scores for self care with sphincter control and mobility with locomotion
Notes	Jadad = 1 Visual feedback = centre of pressure in dynamic training with 'verbal or tactile cues' in static training No auditory feedback Withdrawals not described

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Geiger 2001

Methods	RCT Balance Master (dual force platform)
Participants	Stroke outpatients with balance problems (stand unsupported with/without assistive device for 2 minutes), mean age 60.4 years, severity not measured, mean time since stroke 115 days n = 7 expt, 71% male n = 6 control, 66% male
Interventions	Visual feedback on force platform and conventional versus conventional expt = 2 to 3 time per week, 35 minutes of 'conventional treatment' and 15 minutes Balance Master 4-week study

Geiger 2001 (*Continued)*

Outcomes	Clinical: Berg Balance Scale Timed Up and Go
Notes	Jadad = 2 Visual feedback = centre of pressure behaviour No auditory feedback Withdrawals not described

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Lee 1996

Methods	RCT Standing Biofeedback Trainer (dual force platform)
Participants	Hemiplegic stroke and TBI patients with balance problems, mean age 49.12 years, severity measured with Brunnstrom scale, time since onset not stated, but described as acute n = 30 expt, 67% male n = 30 control, 73% male
Interventions	Visual and auditory feedback on force platform with standing biofeedback trainer versus 'conventional balance trainer' (standing training table) - pulling and pushing a box with forearm suspension and pelvic fixation systems 20 minutes, 5 days per week in both groups (programs the same, but with or without feedback) 2-4 week study
Outcomes	Force platform: measure of WB symmetry: standing steadiness index (same as % of postural symmetry in Wong)
Notes	Jadad = 2 Visual feedback = stance symmetry feedback and illuminated balance scale in mirror Auditory feedback = computerized verbal warning signal and patient training instructions Auditory and visual feedback occur together Withdrawals: expt group - 11 at week 3, 16 at week 4; control group - 8 at week 3, 19 at week 4 (used data at week 2 for analysis) Expt: included 8 TBI patients Control: included 2 TBI patients

Risk of bias

Item	Authors' judgement	Description

Allocation concealment?	Unclear	B - Unclear

Sackley 1997

Methods	RCT Nottingham Balance Platform (dual force platform)
Participants	Stroke outpatients with balance problems (stand unassisted for 1 minute with abnormal stance symmetry), mean age 65.7 years, severity measured with Rivermead Motor Assessment, mean time since stroke 136.5 days n = 13 expt, 77% male n = 13 control, 77% male
Interventions	Visual feedback on force platform and conventional versus placebo visual feedback and conventional 20 minutes of 1 hour session with visual feedback or placebo feedback, 3 times per week 4-week study with follow up at 12 weeks
Outcomes	Clinical: Rivermead Motor Assessment Nottingham 10 point ADL Force platform: centre of pressure behaviour (sway), measure of stance symmetry: (balance coefficient)
Notes	Jadad = 3 Visual feedback = weight distribution between right and left feet No auditory feedback Loss to follow up = 1 in control group (due to hip fracture)

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Shumway-Cook 1988

Methods	RCT Dual force platform feedback system
Participants	Stroke rehabilitation patients with balance problems (stand unassisted for 1 minute), mean age 65 years, severity not measured, mean time since stroke 36.5 days n = 8 expt, 38% male n = 8 control, 50% male
Interventions	Visual feedback on force platform and conventional versus conventional (15 minutes each therapy hour on standard balance training or on force platform), 2 times per day 2-week study

Shumway-Cook 1988 (*Continued*)

Outcomes	Force Platform: centre of pressure behaviour (total sway area), stance symmetry (lateral displacement of sway along x-axis)
Notes	Jadad = 2 Visual feedback = centre of pressure and sway No auditory feedback

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Walker 2000

Methods	RCT Balance Master (dual force platform)
Participants	Stroke rehabilitation inpatients with balance problems (stand unassisted for 1 minute), mean age 64.5 years, severity measured with Clinical Outcome Variables (COVS), mean time since stroke 40.9 days expt, 35.1 days control n = 16 expt, 75% male n = 14 control, 50% male
Interventions	Visual feedback on force platform and conventional versus balance training and conventional, 30 minutes balance treatment with (visual feedback or 'standard' balance training added to conventional treatment, 5 times per week 3-8 week study with 1 month follow up
Outcomes	Clinical: Berg Balance Scale Timed Up and Go, gait speed Force platform: centre of pressure behaviour, centre of gravity alignment (%limits of stability) (eyes open and eyes closed)
Notes	Jadad = 2 Visual feedback = centre of pressure,stance symmetry, and sway No auditory feedback 8 withdrew prior to completion - 5 in expt group; 3 in control group (not included in analysis). 4 of those due to medical complications, 2 due to testing not completed, and 2 due to not wanting to continue study - an n = 14 'control' group with no additional balance training was added as phase 2, but was not randomized, therefore not included

Risk of bias

Item	Authors' judgement	Description

Allocation concealment?	Unclear	B - Unclear

Wong 1997

Methods	RCT Standing Biofeedback Trainer (dual force platform)
Participants	Hemiplegic stroke and TBI patients with balance problems, mean age 51.3 years, severity measured with Brunnstrom scale, time since onset not stated n = 30 expt, 70% male n = 30 control, 73% male
Interventions	Visual and auditory feedback on force platform with standing biofeedback trainer versus 'conventional balance trainer' (standing training table) - pulling and pushing a box with forearm suspension and pelvic fixation systems 60 minutes, 5 days per week in both groups (programs the same, but with or without feedback) 3-4 week study
Outcomes	Force platform: measure of WB symmetry: % of postural symmetry (same as standing steadiness index in Lee)
Notes	Jadad = 2 Visual feedback = stance symmetry feedback and illuminated balance scale in mirror Auditory feedback = computerized verbal warning signal Auditory and visual feedback occur together Withdrawals = expt group - 8 at week 3, 16 at week 4; control group - 10 at week 3, 19 at week 4 (used data at week 2 for analysis) Expt: included 3 TBI patients Control: included 2 TBI patients

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

ADL: activities of daily living
Allocation concealment 'B': unclear (not stated in all included studies)
expt: experimental group
FIM: functional independence measure
Jadad: Jadad score
RCT: randomized controlled trial
TBI: traumatic brain injury
WB: weight bearing

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Bourbonnais 2002	Not force platform
Cheng 2001	Sit to stand outcomes, not standing outcomes
Chernikova 1999	Abstract only - unable to contact author
de Seze 2001	Forceplate was not used
Fowler 1995	Sit to stand, not standing balance
Hocherman 1984	Not visual feedback
Jobst 1989	Data for those with stroke and multiple sclerosis was combined
Johannson 1993	Not visual feedback
Kitamura1996	Not RCT
Lin 1998	No explanation as to what mean score is presented, so unable to use data
Magnusson 1994	Not visual feedback
McRae 1992	Abstract only - unable to contact author
Mudie 2002	Seated weight bearing, not standing weight bearing as required in inclusion criteria
Nichols 1997	Not RCT - review article on force platform biofeedback post stroke
Petersen 1996	Not RCT
Ustinova 2002	Not RCT
Wannstedt 1978	Not RCT

RCT: randomized controlled trial

DATA AND ANALYSES

Comparison 1. Clinical outcomes

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Berg Balance Scale - visual feedback alone	2	43	Mean Difference (IV, Fixed, 95% CI)	-1.98 [-5.55, 1.59]
2 Timed Up and Go - visual feedback alone	2	42	Mean Difference (IV, Fixed, 95% CI)	7.31 [-1.32, 15.94]

Comparison 2. Forceplatform outcomes - visual feedback alone

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Centre of Pressure Position (Stance symmetry)	2	41	Std. Mean Difference (IV, Fixed, 95% CI)	-0.68 [-1.31, -0.04]
2 Centre of Pressure Behaviour (sway)	3	71	Std. Mean Difference (IV, Fixed, 95% CI)	-0.10 [-0.57, 0.36]

Comparison 3. Forceplate outcomes - concurrent auditory and visual feedback

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Centre of Pressure Position (Stance symmetry)	2	120	Mean Difference (IV, Fixed, 95% CI)	-4.02 [-5.99, -2.04]

Comparison 4. Forceplate outcomes - visual feedback alone plus concurrent auditory and visual feedback

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Centre of Pressure Position (Stance symmetry)	4	161	Std. Mean Difference (IV, Fixed, 95% CI)	-0.71 [-1.03, -0.39]

Comparison 5. Followup - 1 month or more

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Centre of Pressure Behaviour (sway) - visual feedback alone	2	71	Std. Mean Difference (IV, Fixed, 95% CI)	-0.34 [-0.81, 0.13]
2 Gross motor function - visual feedback alone	2	65	Std. Mean Difference (IV, Fixed, 95% CI)	0.16 [-0.33, 0.65]
3 Activities of Daily Living - visual feedback alone	2	65	Std. Mean Difference (IV, Fixed, 95% CI)	0.23 [-0.26, 0.73]

Analysis 1.1. Comparison 1 Clinical outcomes, Outcome 1 Berg Balance Scale - visual feedback alone.

Review: Force platform feedback for standing balance training after stroke

Comparison: 1 Clinical outcomes

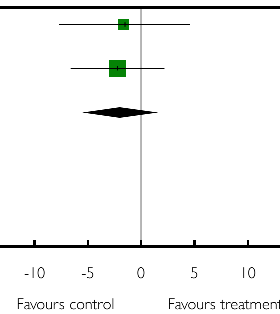
Outcome: 1 Berg Balance Scale - visual feedback alone

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Mean Difference IV,Fixed,95% CI	Weight	Mean Difference IV,Fixed,95% CI
Geiger 2001	7	50.79 (4.38)	6	52.33 (6.56)		33.5 %	-1.54 [-7.71, 4.63]
Walker 2000	16	46.6 (6)	14	48.8 (6.2)		66.5 %	-2.20 [-6.58, 2.18]
Total (95% CI)	**23**		**20**			**100.0 %**	**-1.98 [-5.55, 1.59]**

Heterogeneity: $Chi^2 = 0.03$, df = 1 (P = 0.86); I^2 =0.0%

Test for overall effect: Z = 1.09 (P = 0.28)

Test for subgroup differences: Not applicable



Analysis 1.2. Comparison 1 Clinical outcomes, Outcome 2 Timed Up and Go - visual feedback alone.

Review: Force platform feedback for standing balance training after stroke

Comparison: 1 Clinical outcomes

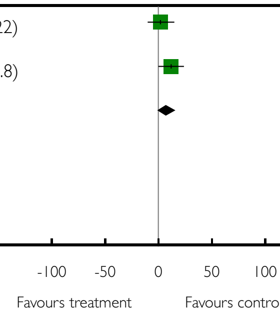
Outcome: 2 Timed Up and Go - visual feedback alone

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Mean Difference IV,Fixed,95% CI	Weight	Mean Difference IV,Fixed,95% CI
Geiger 2001	6	17.04 (11.7)	6	14.88 (10.22)		48.2 %	2.16 [-10.27, 14.59]
Walker 2000	16	33.4 (20.3)	14	21.3 (12.8)		51.8 %	12.10 [0.10, 24.10]
Total (95% CI)	**22**		**20**			**100.0 %**	**7.31 [-1.32, 15.94]**

Heterogeneity: $Chi^2 = 1.27$, df = 1 (P = 0.26); $I^2 = 21\%$

Test for overall effect: Z = 1.66 (P = 0.097)

Test for subgroup differences: Not applicable



Analysis 2.1. Comparison 2 Forceplatform outcomes - visual feedback alone, Outcome 1 Centre of Pressure Position (Stance symmetry).

Review: Force platform feedback for standing balance training after stroke

Comparison: 2 Forceplatform outcomes - visual feedback alone

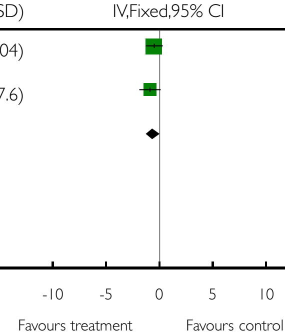
Outcome: 1 Centre of Pressure Position (Stance symmetry)

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
Sackley 1997	12	0.04 (0.03)	13	0.06 (0.04)		62.9 %	-0.54 [-1.35, 0.26]
Shumway-Cook 1988	8	17 (67.6)	8	81.5 (67.6)		37.1 %	-0.90 [-1.95, 0.14]
Total (95% CI)	**20**		**21**			**100.0 %**	**-0.68 [-1.31, -0.04]**

Heterogeneity: $Chi^2 = 0.28$, df = 1 (P = 0.59); $I^2 = 0.0\%$

Test for overall effect: Z = 2.09 (P = 0.037)

Test for subgroup differences: Not applicable



Analysis 2.2. Comparison 2 Forceplatform outcomes - visual feedback alone, Outcome 2 Centre of Pressure Behaviour (sway).

Review: Force platform feedback for standing balance training after stroke

Comparison: 2 Forceplatform outcomes - visual feedback alone

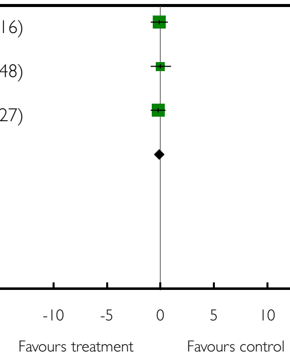
Outcome: 2 Centre of Pressure Behaviour (sway)

Study or subgroup	Treatment N	Mean(SD)	Control N	Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
Sackley 1997	12	0.02 (0.01)	13	0.03 (0.16)		35.3 %	-0.08 [-0.87, 0.70]
Shumway-Cook 1988	8	8950 (7748)	8	8700 (7748)		22.6 %	0.03 [-0.95, 1.01]
Walker 2000	16	0.21 (0.11)	14	0.25 (0.27)		42.1 %	-0.19 [-0.91, 0.53]
Total (95% CI)	**36**		**35**			**100.0 %**	**-0.10 [-0.57, 0.36]**

Heterogeneity: Chi^2 = 0.13, df = 2 (P = 0.93); I^2 =0.0%

Test for overall effect: Z = 0.44 (P = 0.66)

Test for subgroup differences: Not applicable



Analysis 3.1. Comparison 3 Forceplate outcomes - concurrent auditory and visual feedback, Outcome 1 Centre of Pressure Position (Stance symmetry).

Review: Force platform feedback for standing balance training after stroke

Comparison: 3 Forceplate outcomes - concurrent auditory and visual feedback

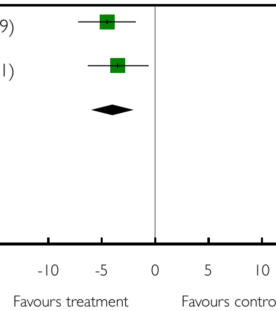
Outcome: 1 Centre of Pressure Position (Stance symmetry)

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Mean Difference IV,Fixed,95% CI	Weight	Mean Difference IV,Fixed,95% CI
Lee 1996	30	5.7 (4.9)	30	10.2 (5.9)		51.8 %	-4.50 [-7.24, -1.76]
Wong 1997	30	6.6 (5.1)	30	10.1 (6.1)		48.2 %	-3.50 [-6.35, -0.65]
Total (95% CI)	**60**		**60**			**100.0 %**	**-4.02 [-5.99, -2.04]**

Heterogeneity: $Chi^2 = 0.25$, df = 1 (P = 0.62); $I^2 = 0.0\%$

Test for overall effect: Z = 3.99 (P = 0.000067)

Test for subgroup differences: Not applicable



Analysis 4.1. Comparison 4 Forceplate outcomes - visual feedback alone plus concurrent auditory and visual feedback, Outcome 1 Centre of Pressure Position (Stance symmetry).

Review: Force platform feedback for standing balance training after stroke

Comparison: 4 Forceplate outcomes - visual feedback alone plus concurrent auditory and visual feedback

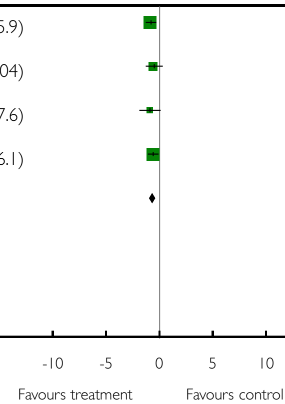
Outcome: 1 Centre of Pressure Position (Stance symmetry)

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
Lee 1996	30	5.7 (4.9)	30	10.2 (5.9)		36.7 %	-0.82 [-1.35, -0.29]
Sackley 1997	12	0.04 (0.03)	13	0.06 (0.04)		15.9 %	-0.54 [-1.35, 0.26]
Shumway-Cook 1988	8	17 (67.6)	8	81.5 (67.6)		9.4 %	-0.90 [-1.95, 0.14]
Wong 1997	30	6.6 (5.1)	30	10.1 (6.1)		38.0 %	-0.61 [-1.13, -0.10]
Total (95% CI)	**80**		**81**			**100.0 %**	**-0.71 [-1.03, -0.39]**

Heterogeneity: $Chi^2 = 0.59$, df = 3 (P = 0.90); $I^2 = 0.0\%$

Test for overall effect: Z = 4.32 (P = 0.000016)

Test for subgroup differences: Not applicable



Analysis 5.1. Comparison 5 Followup - 1 month or more, Outcome 1 Centre of Pressure Behaviour (sway) - visual feedback alone.

Review: Force platform feedback for standing balance training after stroke

Comparison: 5 Followup - 1 month or more

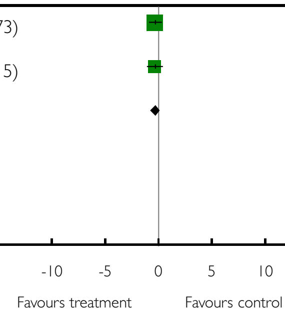
Outcome: 1 Centre of Pressure Behaviour (sway) - visual feedback alone

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
Chen 2002	23	23.47 (11.52)	18	27.99 (15.73)		57.6 %	-0.33 [-0.95, 0.29]
Walker 2000	16	0.15 (0.06)	14	0.19 (0.15)		42.4 %	-0.35 [-1.07, 0.37]
Total (95% CI)	**39**		**32**			**100.0 %**	**-0.34 [-0.81, 0.13]**

Heterogeneity: $Chi^2 = 0.00$, df = 1 (P = 0.96); I^2 =0.0%

Test for overall effect: Z = 1.40 (P = 0.16)

Test for subgroup differences: Not applicable



Analysis 5.2. Comparison 5 Followup - 1 month or more, Outcome 2 Gross motor function - visual feedback alone.

Review: Force platform feedback for standing balance training after stroke

Comparison: 5 Followup - 1 month or more

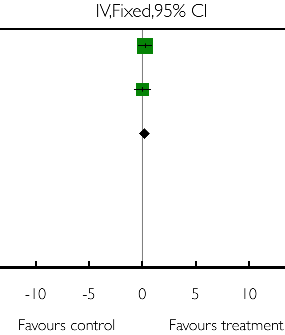
Outcome: 2 Gross motor function - visual feedback alone

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
Chen 2002	23	29.45 (5.74)	18	27.72 (7.6)		62.5 %	0.26 [-0.36, 0.88]
Sackley 1997	12	8.5 (2)	12	8.5 (2.6)		37.5 %	0.0 [-0.80, 0.80]
Total (95% CI)	**35**		**30**			**100.0 %**	**0.16 [-0.33, 0.65]**

Heterogeneity: $Chi^2 = 0.25$, df = 1 (P = 0.62); I^2 =0.0%

Test for overall effect: Z = 0.64 (P = 0.52)

Test for subgroup differences: Not applicable



Analysis 5.3. Comparison 5 Followup - 1 month or more, Outcome 3 Activities of Daily Living - visual feedback alone.

Review: Force platform feedback for standing balance training after stroke

Comparison: 5 Followup - 1 month or more

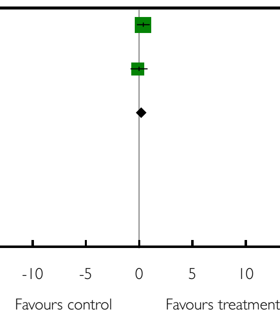
Outcome: 3 Activities of Daily Living - visual feedback alone

Study or subgroup	Treatment N	Treatment Mean(SD)	Control N	Control Mean(SD)	Std. Mean Difference IV,Fixed,95% CI	Weight	Std. Mean Difference IV,Fixed,95% CI
Chen 2002	23	44.75 (7.97)	18	40.71 (11.69)		62.2 %	0.41 [-0.22, 1.03]
Sackley 1997	12	8.3 (1.4)	12	8.4 (2.3)		37.8 %	-0.05 [-0.85, 0.75]
Total (95% CI)	**35**		**30**			**100.0 %**	**0.23 [-0.26, 0.73]**

Heterogeneity: $Chi^2 = 0.78$, df = 1 (P = 0.38); $I^2 = 0.0\%$

Test for overall effect: Z = 0.93 (P = 0.35)

Test for subgroup differences: Not applicable



APPENDICES

Appendix 1. EMBASE search strategy

The following search strategy was used for EMBASE on DIALOG and adapted to suit the other databases.

1 Cerebrovascular disease! or stroke? Or cerebrovascular? Or carotid?

2 aphasia! or dysphasia! or hemianopia! or hemiplegia! or hemiparesis! or aphasi? Or dysphasi? Or hemianop? Or hemipleg? Or hemipar?

3 s1 or s2

4 feedback system! Or (visual?(5n)(feedback? or perception? or perceiv?)) or biofeedback

5 (auditory or sound? or hear?)and visual?

6 motor performance! Or weight bearing! Or stabilography! Or body equilibrium/de or (motor(5n)(learn? or skill? Or performance or task?)) or (know?(5n)result?) or kr or weight(5n)bearing

7 balance or equilibrium or (postur?(5n)(sway? Or shift? Or symmetr? Or stabl? Or stabilit?)) or ((center or centre)(5n)(pressure? Or force? Or gravity)) or force()plate? Or balance()master or orient?

8 berg()balance or balance()scale? or ((time or timed)(2w)up(2w)go)

9 (s4 or s5) and (s6 or s7 or s8)
10 s3 and s9
11 clinical trial! or multicenter study! or phase 2 clinical trial! or phase 3 clinical trial! or phase 4 clinical trial! or randomized controlled trial! or controlled study! or meta analysis!
12 crossover procedure! or double blind procedure! or single blind procedure! or randomization! or major clinical study! or placebo! or clinical study!
13 ((singl? or doubl? or tripl? or trebl?)(25n)(blind? or mask?)) or placebo? or random?
14 s13 or s12 or s11
15 s14 and s10
16 nonhuman! Not (human! And nonhuman!)
17 s14 not s16

WHAT'S NEW

Last assessed as up-to-date: 22 December 2003.

Date	Event	Description
21 August 2008	Amended	Converted to new review format.

HISTORY

Protocol first published: Issue 2, 2003

Review first published: Issue 4, 2004

CONTRIBUTIONS OF AUTHORS

Barclay-Goddard: contributions included the development of conceptual ideas and the drafting of the protocol. Work also included the retrieval of articles, inclusion of articles, review of articles, data extraction, meta-analysis, and preparation of all drafts of the final review.

Stevenson: contributions included the retrieval of articles, inclusion of articles, review of articles, data extraction, and review of all drafts of the final review.

Poluha: contributions to this project included database searching and expertise on the development of the title specific search strategy.

Moffatt: contributions included the review and editing of both the protocol and manuscript, and provision of methodological expertise and advice.

Taback: contributions to this project included the review and editing of the protocol and manuscript, provision of methodological expertise and advice, and supervision of the statistical analysis.

DECLARATIONS OF INTEREST

None known

SOURCES OF SUPPORT

Internal sources

- Canadian Cochrane Network and Centre, Dept. of Community Health Sciences, School of Medical Rehabilitation, University of Manitoba, Canada.

External sources

- Dr Shayne Taback holds the Manitoba Medical Services Foundation Clinical Research Professorship in Population Health, Canada.

INDEX TERMS

Medical Subject Headings (MeSH)

*Stroke Rehabilitation; Biofeedback, Psychology [instrumentation; *methods]; Postural Balance [*physiology]; Randomized Controlled Trials as Topic; Stroke [physiopathology]

MeSH check words

Humans