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Research

Biofeedback improves performance in lower limb activities more than usual therapy in people following stroke: a systematic review

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KEY WORDS

Stroke
Physical therapy
Biofeedback
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Meta-analysis

CrossMark

ABSTRACT

Question: Is biofeedback during the practice of lower limb activities after stroke more effective than usual therapy in improving those activities, and are any benefits maintained beyond the intervention? **Design:** Systematic review with meta-analysis of randomised trials with a PEDro score > 4. **Participants:** People who have had a stroke. **Intervention:** Biofeedback (any type delivered by any signal or sense) delivered concurrently during practice of sitting, standing up, standing or walking compared with the same amount of practice without biofeedback. **Outcome measures:** Measures of activity congruent with the activity trained. **Results:** Eighteen trials including 429 participants met the inclusion criteria. The quality of the included trials was moderately high, with a mean PEDro score of 6.2 out of 10. The pooled effect size was calculated as a standardised mean difference (SMD) because different outcome measures were used. Biofeedback improved performance of activities more than usual therapy (SMD 0.50, 95% CI 0.30 to 0.70). **Conclusion:** Biofeedback is more effective than usual therapy in improving performance of activities. Further research is required to determine the long-term effect on learning. Given that many biofeedback machines are relatively inexpensive, biofeedback could be utilised widely in clinical practice. **[Stanton R, Ada L, Dean CM, Preston E (2016) Biofeedback improves performance in lower limb activities more than usual therapy in people following stroke: a systematic review. *Journal of Physiotherapy* 63: 11–16]**

Introduction

This is an update of a systematic review[1] that examined the effect of biofeedback in training lower limb activities after stroke. Biofeedback is equipment that transforms biological signals into an output that can be understood by the learner, providing information to the learner that is not consciously available. That is, biofeedback takes intrinsic physiological signals and makes them extrinsic, giving the person immediate and accurate feedback of information about these body functions. Biofeedback can be delivered through various senses, such as visual, auditory and tactile systems, and can provide information about the kinematics, kinetics and/or electromyography of activities. Biofeedback is available from medical equipment (eg, electromyography, force platforms and positional devices traditionally used in clinical practice); or from non-medical equipment that is increasingly available and used in stroke rehabilitation (eg, recreational games such as the Nintendo® Wii™). Biofeedback can be used in addition to verbal content; however, it also has the advantage that it can be set up for the patient to use when left to practise alone. However, biofeedback is not commonly used in stroke rehabilitation.[2]

The previous version of this review,[2] which was published in 2011, examined biofeedback broadly in training lower limb activities after stroke, including trials where any form of biofeedback was provided during practice of the whole activity (rather than part of the activity), with outcomes measured during the same activity. Twenty-two trials met the inclusion criteria and were included in the review; however, meta-analyses demonstrated significant heterogeneity that was best explained by the quality of the included trials. When analyses were limited to higher quality trials (PEDro score > 4), biofeedback had a moderate effect in the short term (10 trials, 241 participants, SMD 0.49, 95% CI 0.22 to 0.75) compared with usual therapy, which was maintained beyond intervention (five trials, 138 participants, SMD 0.41, 95% CI 0.06 to 0.75), suggesting that learning had occurred. For a direct comparison of the effect of biofeedback interventions and usual therapy (which includes therapist communication), a post hoc meta-analysis was conducted of those trials where the amount of practice was equal in each group. That is, trials where the control group practised the same activity for the same amount of time as the experimental group, with the only difference being the substitution of biofeedback for therapist communication (presumably including feedback) in the experimental group. This meta-analysis demonstrated a moderate effect of a similar magnitude to the overall analysis (eight trials, 170 participants, SMD 0.51, 95% CI 0.20 to 0.83), suggesting that biofeedback is superior to therapist communication.

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Since that review[1] was published in 2011, a number of additional trials have been published that investigated the effect of biofeedback, warranting an update of the review. In particular, the potential of using recreational games in stroke rehabilitation has gained attention. The inclusion criteria for this updated review incorporated findings from the previous review. Specifically, this meant that the updated review would include any randomised trial investigating biofeedback from any signal (position, force, EMG) via any sense (visual, auditory, tactile), delivered concurrently during whole activity practice, compared with usual therapy that was practice of the same activity for the same amount of time in the control group with no biofeedback (but presumably with therapist communication), with outcome measures at the activity level and congruent with the activity trained. This ensures a true comparison of the effect of biofeedback compared with usual therapist communication. For the biofeedback intervention, inclusion in this update was based on whether the biofeedback delivered was concurrent rather than terminal feedback. This meant that commercially available recreational games would be included if the majority of the games played within the study delivered concurrent biofeedback, rather than inclusion based on the equipment itself. In order to make recommendations based on the highest level of evidence, this review included only randomised trials with a PEDro score > 4.

Therefore, the research questions for this systematic review were:

1. In adults following stroke, is biofeedback during the practice of lower limb activities more effective than usual therapy in improving those activities in the short term?
2. Are any benefits maintained beyond the intervention?

Box 1. Inclusion criteria.

Design
- High-quality randomised trial or quasi-randomised trial (PEDro score > 4/10)

Participants
- Adults
- Diagnosis of cerebrovascular stroke
- Any level of disability and any time after stroke

Intervention
- Experimental intervention includes biofeedback using any signal (EMG, force, position) via any sensory system (visual, auditory, tactile)
- Part of intervention must be biofeedback during practice of the whole activity
- Practice of whole activity must involve movement (such as reaching in sitting or weight shift in standing)
- Groups must practice the same activity for the same amount of time as the control practice (ie, only difference is feedback delivered)

Outcome measures
- Measures of lower limb activity (sitting, standing up, standing or walking)
- Measures congruent with the activity trained
- Measures of activity must involve movement

Comparisons
- Biofeedback versus usual therapy during the same activity

Method

Identification and selection of trials

Searches were conducted of: MEDLINE (1950 to September 2015); CINAHL (1981 to September 2015); EMBASE (1980 to September 2015); PEDro (to September 2015); the COCHRANE Library (to September 2015) and the PubMed databases (to September 2015) for relevant articles without language restrictions, using words related to *stroke* and *randomised*, *quasi-randomised* or *controlled trials* and words related to *biofeedback* (such as biofeedback, electromyography, joint position, and force) during *lower limb activities* (such as sitting, sit to stand, standing and walking) (see Appendix 1 on the eAddenda for the full search strategy). Titles and abstracts (where available) were displayed and screened by one reviewer to identify relevant trials. Full paper copies of relevant trials were retrieved and their reference lists were screened. The methods of the retrieved papers were extracted and reviewed independently by two reviewers (RS and EP) using predetermined criteria (Box 1). Disagreement or ambiguous issues were resolved by consensus after discussion with a third reviewer (LA).

Assessment of characteristics of trials

Quality

The quality of included trials was assessed by extracting PEDro scores from the Physiotherapy Evidence Database (www.pedro.org.au). Two trained raters independently carried out rating of trials in this database, and disagreements were resolved by a third rater. Where a trial was not included in the database, it was independently assessed by two authors who had completed the PEDro Scale training tutorial on the Physiotherapy Evidence Database. Only trials with a PEDro rating > 4 were eligible for inclusion in the review.

Participants

Trials involving adult participants of either gender, at any level of initial disability, at any time following stroke were included. Age, gender, and time since stroke were recorded to describe the participants in each trial.

Intervention

The experimental intervention could be of any type of biofeedback, that is, using any signal (position, force, EMG) via any sense (visual, auditory, tactile). At least some of the intervention had to involve practice of the whole activity, and practice of the activity had to involve movement (such as reaching in sitting or weight shift in standing). The control intervention must have been the same activity, practised for the same amount of time, where the only difference between the groups was that the intervention group received biofeedback in addition to usual therapy (ie, therapist communication). Type of biofeedback, activity trained, and duration and frequency of the intervention were recorded to describe the trials.

Outcome measures

Measures of lower limb activity that were congruent with the activity in which biofeedback was applied were used in the analysis. Where multiple measures for one activity were reported, a measure was chosen that best reflected the aim of the biofeedback intervention (eg, step length). The measures used to record outcomes and the timing of measurement were recorded and compared to describe the trials.

Data analysis

Data were extracted from the included trials by one reviewer and crosschecked by a second reviewer. Information about the method (ie, design, participants, lower limb activity trained, intervention, measures) and data (ie, number of participants and mean (SD) of outcomes) were extracted. Post-intervention scores were used to obtain the pooled estimate of the effect of intervention in the short term (immediately following intervention) and in the longer term (some time beyond the intervention), as these were reported in a majority of studies. Since different outcome measures were used, the effect size was reported as

Cohen's standardised mean difference (95% CI). A fixed-effect model was used initially, with random effects model planned in the case of significant heterogeneity ($I^2 > 50\%$). The analyses were performed using the MIXa program.[3,4]

Results

Flow of trials through the review

The electronic search strategy identified 3768 trials. After screening titles and abstracts, 93 potentially relevant papers were retrieved in full text. An additional 20 potentially relevant trials were obtained following hand screening of the reference lists of included trials and previous systematic reviews. After being assessed against the inclusion criteria, 20 papers reporting 18 randomised trials were included in this review (Figure 1).[5–24] Table 1 (see eAddenda) provides a summary of the excluded papers.

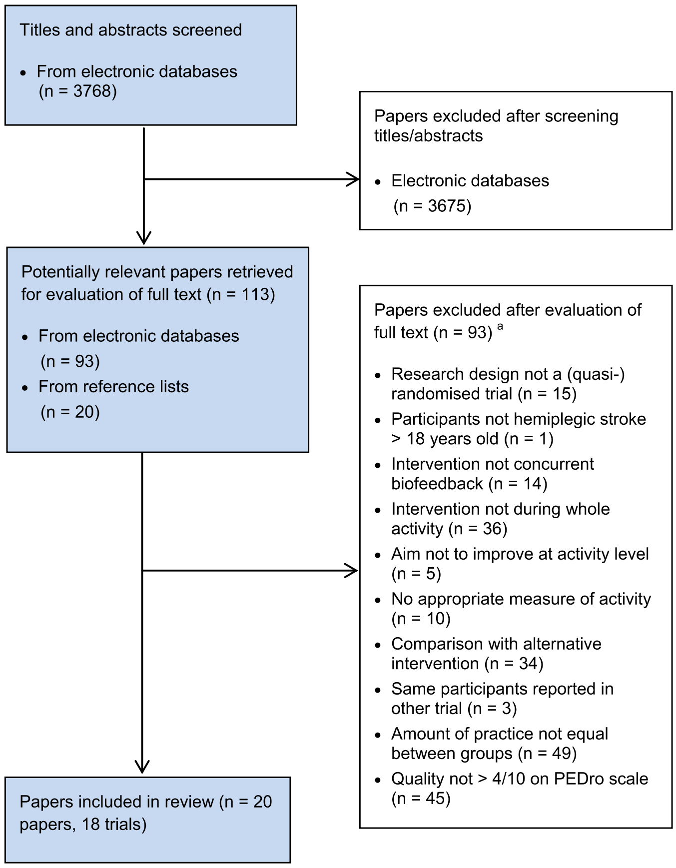

Figure 1. Identification and selection of trials.
[a] Papers may have been excluded for failing to meet more than one inclusion criteria.

Characteristics of included trials

Eighteen trials (20 papers) including 429 participants investigated biofeedback as an intervention to improve activities of the lower limb following stroke. Activities trained included standing up (one trial), standing (eight trials) and walking (nine trials). The quality of included trials is presented in Table 2 and a summary of the trials is presented in Table 3. Additional information was obtained from the authors for two trials.[15,16]

Quality

The median PEDro score of the included trials was 6 out of 10 (mean 6.2, range 5 to 8). All trials were randomised, had similar groups at baseline, and reported the between-group difference, point estimates and variability for the groups. The majority of trials had < 15% loss to follow-up (94%) and assessor blinding (61%). Only some trials concealed allocation (28%), carried out an intention-to-treat analysis (28%), blinded participants (6%), or blinded therapists (0%).

Participants

Across the trials, the mean age of participants ranged from 47 to 66 years old. Overall, 61% of participants were male and 39% female. The mean time after stroke ranged from < 1 month to 10 years, with 53% of the trials carried out within 6 months after stroke.

Intervention

Biofeedback used in the experimental interventions included: weight distribution from a force platform or sensor (11 trials); muscle activity from EMG (three trials); linear gait parameters such as step width or length from foot sensors (three trials); and joint angle from a goniometer (one trial). Visual feedback was used in seven trials; auditory in seven trials; and a combination of both in four trials. The mean duration of intervention sessions was 33 minutes (SD 17), occurring with a mean frequency of 3.7 days per week (SD 1.6), and a mean duration of 5.2 weeks (SD 2.2).

Outcome measures

For standing up, the measure was weight distribution between the lower limbs (one trial). For standing, measures were the Berg

Table 2
PEDro scores for included trials (n = 18).

Trial	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Brasiliero [5]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Byl [6]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Cozean [7]	Y	N	Y	N	N	Y	Y	N	Y	Y	6
DeNunzio [8]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Druzbicki [9]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Engardt [10–12]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Geiger [13]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Grant [14]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Intiso [15]	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Jonsdottir [16]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Jung [17]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Lee [18]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Llorens [19]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Morris [20]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Rao [21]	Y	N	Y	N	N	Y	N	N	Y	Y	5
Sackley [22]	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Sungkarat [23]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Yang [24]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8

PEDro scores from website www.pedro.org.au

Table 3
Summary of included trials (n = 18).

Trial	Design	Participants	Lower limb activity	Intervention	Outcome measure used in analysis
Brasiliero [5]	RCT	n = 20 Age *(yr)* = 55 (SD 5.5) Gender = 12 M, 8 F Time since stroke = 2 to 3 yr	Walking	Exp = Step width + symmetry from foot sensors via visual feedback 20 minutes Con = no biofeedback during walking practice 20 minutes	• Walking speed *(m/s)* • Timing = 0, 1 day
Byl [6]	RCT	n = 12 Age *(yr)* = 63 (SD 5) Gender = 4 M, 8 F Time since stroke = 6 to 10 yr	Walking	Exp = Step length + width from foot sensors via visual feedback 90 min x 1 to 2/wk x 6 to 8 wk (12 sessions) Con = no biofeedback during walking practice 90 min x 1 to 2/wk x 6 to 8 wk (12 sessions)	• Walking step length *(cm)* • Timing = 0, 6 to 8 wk
Cozean [7]	RCT	n = 16 Age *(yr)* = 55 Gender = 10 M, 6 F Time since stroke = unknown	Walking	Exp = Ankle muscle activity from EMG via visual + auditory feedback 30 min x 3/wk x 6 wk Con = placebo biofeedback during walking practice 30 min x 3/wk x 6 wk Both = usual therapy	• Walking step length *(cm)* • Timing = 0, 6 wk
DeNunzio [8]	RCT	n = 37 Age *(yr)* = 58 (SD 11)[a] Gender = 19 M, 18 F Time since stroke = unknown	Standing	Exp = Wt distr from force platform via visual/ auditory feedback 30 min x 6/wk x 2 wk Con = no biofeedback intervention during standing practice 30 min x 6/wk x 2 wk Both = usual therapy	• Unified Balance Scale *(0 to 54)* • Timing = 0, 2 wk
Druzbicki [9]	RCT	n = 50 Age *(yr)* = 60 (SD 11) Gender = 32 M, 18 F Time since stroke = 44 mth	Walking	Exp = Step length from foot sensors via auditory feedback 30 min x 5/wk x 2 wk Con = no biofeedback during walking training 30 min x 5/wk x 2 wk Both = usual therapy	• Walking speed *(m/s)* • Timing = 0, 2 wk
Engardt [10–12]	RCT	n = 40 Age *(yr)* = 65 (SD 8) Gender = 25 M, 15 F Time since stroke = 1 mth	Standing up	Exp = Wt distr from force platform via auditory feedback 45 min x 5/wk x 6 wk Con = no biofeedback during standing up practice 45 min x 5/wk x 6 wk Both = usual therapy	Load through affected leg during standing up *(% BW)* Timing = 0, 6 wk
Geiger [13]	RCT	n = 13 Age *(yr)* = 60 (SD 16) Gender = 9 M, 4F Time since stroke = 4 mth	Standing	Exp = Wt distr from force platform via visual feedback 15 min x 2 to 3 /wk x 4 wk Con = no biofeedback during standing practice 15 min x 2 to 3 /wk x 4 wk Both = usual therapy	• Berg Balance Scale *(0 to 56)* • Timing = 0, 4 wk
Grant [14]	RCT	n = 16 Age *(yr)* = 65 (SD 3) Gender = 10 M, 6 F Time since stroke = 1 mth	Standing	Exp = Wt distr from force platform via visual feedback 30 min x 5/wk (inpt) and 2/wk (outpt) x 8 wk Con = no biofeedback during standing practice 30 min x 5/wk (inpt) and 2/wk (outpt) x 8 wk Both = usual therapy	• Berg Balance Scale *(0 to 56)* • Timing = 0, 8, 12 wk
Intiso [15]	RCT	n = 16 Age *(yr)* = 57 (SD 15) Gender = 9 M, 7 F Time since stroke = 10 mth	Walking	Exp = Ankle muscle activity from EMG via auditory feedback 30 sessions over 8 wk Con = no biofeedback during walking practice 30 sessions over 8 wk Both = usual therapy	• Walking step length *(cm)* • Timing = 0, 8 wk
Jonsdottir [16]	RCT	n = 20 Age *(yr)* = 62 (SD 11) Gender = unknown Time since stroke = 4 yr	Walking	Exp = Ankle muscle activity from EMG via auditory feedback 45 min x 3/wk x 7wk Con = usual therapy 45 min x 3/wk x 7wk	• Walking step length *(cm)* • Timing = 0, 7, 13 wk
Jung [17]	RCT	n = 26 Age *(yr)* = 56 (14) Gender = 14 M, 7 F Time since stroke = 6.5 mth	Walking	Exp = Wt distr from force sensor (cane) via auditory feedback 30 min x 5/wk x 4 wk Con = no biofeedback during walking training 30 min x 5/wk x 4 wk Both = usual therapy	• Load through affected leg during walking *(% BW)* • Timing = 0, 4 wk
Lee [18]	RCT	n = 24 Age *(yr)* = 47 (SD 12) Gender = 16 M, 8 F Time since stroke = unknown	Standing	Exp = Wt distr from force platform (Wii™) via visual/auditory feedback 30 min x 5/wk x 6 wk Con = no biofeedback during standing training 30 min x 5/wk x 6 wk Both = usual therapy	• Functional Reach Test *(cm)* • Timing = 0, 6 wk
Llorens [19]	RCT	n = 20 Age *(yr)* = 57 (SD 12) Gender = 9 M, 11 F Time since stroke > 1.5 yr	Standing	Exp = Foot placement from sensor (via camera) via visual feedback 30 min x 5/wk x 4 wk Con = no biofeedback during standing training 30 min x 5/wk x 4 wk Both = usual therapy	• Berg Balance Scale *(0 to 56)* • Timing = 0, 4 wk
Morris [20]	Q-RCT	n = 26 Age *(yr)* = 64 (SD 11) Gender = 12 M, 14 F Time since stroke = 2 mth	Walking	Exp = Knee angle from goniometer via auditory feedback 30 min x 5/wk x 4 wk Con = no biofeedback during walking practice 30 min x 5/wk x 4 wk Both = usual therapy	• Walking speed *(m/s)* • Timing = 0, 4, 8 wk

Table 3 (*Continued*)

Trial	Design	Participants	Lower limb activity	Intervention	Outcome measure used in analysis
Rao [21]	RCT	n = 28 Age *(yr)* = 59 (SD 13) Gender = 21 M, 7 F Time since stroke = 13 days	Standing	Exp = Wt distr from force platform (Wii^{TM}) via visual/auditory feedback 3 sessions over 2 wk Con = no biofeedback during standing training 3 sessions over 2 wk Both = usual therapy	• Fugl-Meyer scale (balance component) • Timing = 0, 2 wk
Sackley [22]	RCT	n = 26 Age *(yr)* = 66 (SD 11) Gender = 20 M, 6 F Time since stroke = 5 mth	Standing	Exp = Wt distr from force platform via visual feedback 20 min x 3/wk x 4 wk Con = placebo biofeedback during standing practice 20 min x 3/wk x 4 wk Both = usual therapy	• Rivermead Motor Assessment (gross function component) *(0 to 13)* • Timing = 0, 4, 12 wk
Sungkarat [23]	RCT	n = 35 Age *(yr)* = 53 (SD 9) Gender = 24 M, 11 F Time since stroke = 4.5 mth	Walking	Exp = Wt distr from force platform via auditory feedback 30 min x 5/wk x 3 wk Con = no biofeedback during walking training 30 min x 5/wk x 5 wk Both = usual therapy	• Load through affected leg during walking *(% BW)* • Timing = 0, 3 wk
Yang [24]	RCT	n = 12 Age *(yr)* = 60 (SD 15) Gender = 9 M, 3 F Time since stroke = 6 mth	Standing	Exp = Wt distr from force platform (Wii^{TM}) via visual feedback 20 min x 3/wk x 3 wk (same amount practice) Con = no biofeedback during standing training (mirror) 20 min x 3/wk x 3 wk Both = usual therapy	• Berg Balance Scale *(0 to 56)* • Timing = 0, 3 wk

BW = body weight, Con = control group, EMG = electromyography, Exp = experimental group, LL = lower limb, M/F = male/female, Q-RCT = quasi-randomised clinical trial, RCT = randomised clinical trial, UT = usual therapy, wt distr = weight distribution.
[a] Only the groups related to the current review objectives report.

Balance Scale (four trials), the gross function component of Rivermead Motor Assessment (one trial), the Unified Balance Scale (one trial), Functional Reach (one trial), and the balance component of the Fugl-Meyer (one trial). For walking, measures were speed (four trials), step/stride length (three trials), and load through the affected leg (two trials). Outcomes were measured after intervention (18 trials) and from 1 to 3 months after cessation of intervention (four trials).

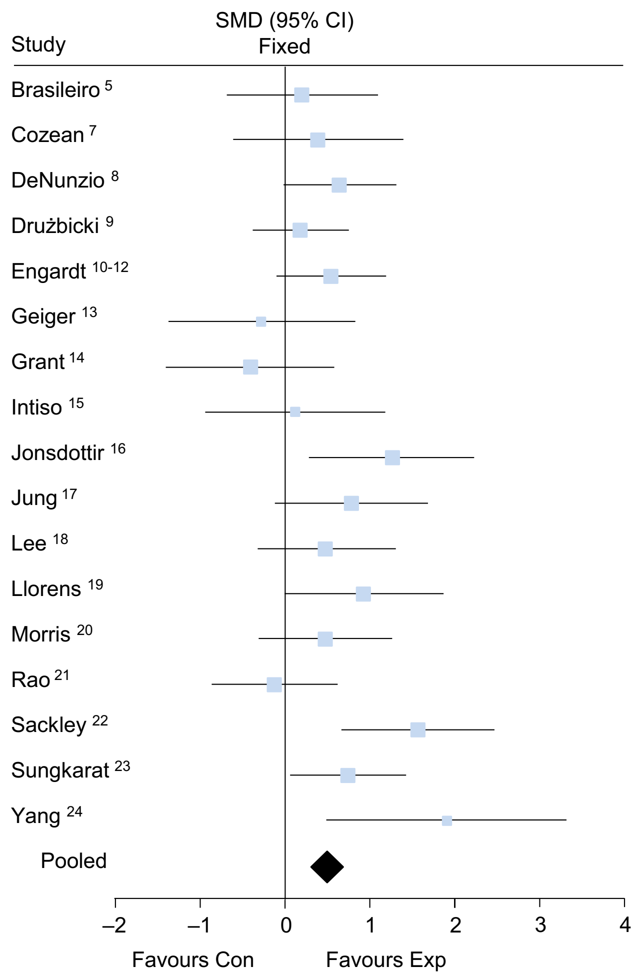

Figure 2. SMD (95% CI) of the short-term effect of biofeedback on lower limb activities immediately after intervention by pooling data from 17 trials (n = 417).

Effect of biofeedback

The short-term effect of biofeedback on activity limitations was examined by pooling data immediately following the intervention from 17 trials, comprising 417 participants, using a fixed-effect model. One study[6] was not included in the meta-analysis because post-intervention data were not reported. Biofeedback improved lower limb activities compared with usual therapy (SMD 0.50, 95% CI 0.30 to 0.70, $I^2 = 31\%$) (Figure 2; see Figure 3 on the eAddenda for a detailed forest plot).

The long-term effect of biofeedback on activity limitations could not be examined because only four trials, comprising 84 participants, reported data beyond the intervention. This represented less than 25% of the trials included in the meta-analysis immediately after intervention.

Discussion

This systematic review demonstrated that biofeedback has a moderate effect[25] in improving activities of the lower limb, such as standing up, standing and walking, in the short term when compared with usual therapy (ie, therapist communication) during the same amount of therapy. The results suggest that information feedback from biofeedback is superior to therapist communication for improving performance in people following stroke. During usual therapy, whilst therapists may provide some feedback, observational studies suggest that that the content of therapist communication during rehabilitation is more likely to be motivational statements rather than feedback.[2,26,27] Thus, biofeedback is likely to be more effective than therapist communication due to the objective and accurate information feedback available to the patient during practice. With the inclusion of an additional 10 high-quality trials, this updated review provides a consistent, but more precise, estimate of effect in the short term compared with the equivalent analysis in the previous review.[1]

However, the longer term effects are less clear. Only four of the 18 trials measured outcomes at follow-up, with none of the new trials included in this updated review including measurement of outcomes at follow-up. Given that this is only 22% of all the included trials, this was considered to be unrepresentative, and no meta-analysis was conducted on the effect in the long term. Further research (ie, large, well designed trials including outcomes at follow-up) is required to clearly estimate the long-term effect of biofeedback; that is, the effect on learning.

The mean PEDro score for the 18 trials included in this review was 6.2 out of 10. Given that the maximum achievable score for these types of trials is 8 (because it is difficult to blind therapists and participants to physical interventions), this represents moderately high quality and contributes to the credibility of the conclusions. There was some clinical heterogeneity in these trials. Participant characteristics of age and gender were similar, and the time since stroke was mixed between subacute (53%) and chronic (47%). There was a range of duration of intervention (one session to 8 weeks); however, the majority of trials were of 4 to 8 weeks in duration. Taken together, this suggests that the findings are credible and can be generalised cautiously.

This review had some potential limitations. Several of these limitations may have led to an overestimate of the effect of biofeedback. First, there was a lack of blinding of participants and therapists because this is not always possible in trials of biofeedback. Second, even after only including high-quality trials in the meta-analysis, the results were potentially affected by small trial bias, with an average number of 24 participants per trial (range 12 to 50 participants). Additionally, as is usual with trials of complex interventions, the outcome measures were not the same. This meant that a standardised mean difference had to be calculated from the meta-analysis, which is less clinically useful than a mean difference. Finally, only a small proportion of the trials measured the outcomes some time beyond the intervention, limiting conclusions of the effect of biofeedback on learning. There is a need for large, high-quality trials with adequate power and follow-up to investigate the effect of biofeedback in this population.

In conclusion, this systematic review provides evidence that augmenting feedback through the use of biofeedback is superior to usual therapy (ie, therapist communication) at improving the performance of lower limb activities in people after stroke in the short term. Further research is required to determine the effect of biofeedback on learning. Given that biofeedback is used infrequently, and that many biofeedback machines are relatively inexpensive and easily available, biofeedback could be utilised more widely in clinical practice.

What is already known on this topic: Previous reviews of the effect of biofeedback in stroke have been favourable, but have included trials with low methodological quality and trials where the amount of therapy time in the biofeedback and control group were not matched.
What this study adds: Although this review included only high-quality trials that compared equal amounts of therapy either with or without biofeedback, it was able to include many new trials. Overall, it provides a robust estimate that biofeedback has a moderately greater benefit on the performance of lower limb activities than usual rehabilitation.

eAddenda: Figure 3, Table 1 and Appendix 1 can be found online at doi:10.1016/j.jphys.2016.11.006

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