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Single blind randomized controlled trial of visual feedback after stroke: effects on stance symmetry and function

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Summary

A number of before and after and single case design studies of visual feedback have shown improvements in stance symmetry after stroke, an associated improvement in function has been demonstrated. This study examines this promising technique further using a single-blind controlled trial. Twenty-six patients were recruited from a register of consecutive admissions and randomized into treatment and control groups. Both groups received additional therapy, only the treatment group received visual feedback. Assessments were carried out independently. Significant improvements were seen in the treatment group in measures of stance symmetry and sway and motor and ADL function. Between group differences had disappeared at three months. The results indicate that feedback training incorporated into functional physiotherapy treatment can improve stance symmetry and sway. Transfer of training was indicated by improvements in ADL and gross motor function. Three months later the improvement was maintained, but did not automatically continue without treatment.

Introduction

The most commonly noted consequence of motor impairment after stroke is hemiplegia,[1] which results in asymmetry of both gait and posture. Patients tend to exhibit abnormal patterns of stance and gait and these are described extensively in physiotherapy texts.[2,3] Such texts also claim that patients favour their unaffected leg for weight bearing when standing and walking.

There is now research evidence to substantiate the clinical observation that some stroke patients stand with less of their body-weight through their affected leg. In the largest study Sackley[4] described the recovery of stance symmetry after stroke in a group of 90 consecutive admissions and found that at three months post-stroke, 79% (71) demonstrated an abnormally large load on their affected leg. Other smaller studies of selected groups have described higher frequencies of over 80%.[5-7]

Sackley[4] found the mean percentage of body-weight on the unaffected leg was 66%. Again, two smaller and more selected groups of stroke patients demonstrated higher proportions of over 70%.[8,9] These percentages are far outside the normal ranges for the elderly of 43–57%.[5,10,11]

It is presumed that abnormal weight bearing through the affected limb is linked with impaired motor function and in turn decreased functional ability. This relationship has been demonstrated by Sackley[4] who described a significant correlation between stance symmetry, motor function and activities of daily living at three months post-stroke persisting at six months.

Conventional physiotherapy interventions, using neuro-facilitatory techniques (such as the Bobath approach) aim to improve stance symmetry and encourage normal movement patterns, but have not been evaluated. Other methods using external feedback have been used to enhance skill acquisition after stroke and these have shown positive results.[8,12-14] The advantage of using equipment to enhance the visual, verbal and tactile feedback from the therapist is that it is more quantifiable[15] and precise.[16]

The effects of augmented feedback on postural control have been less extensively studied. Studies from North America, utilizing postural feedback devices have demonstrated some improvements in standing posture. The first of these was by Wannstedt and Herman[17] who used augmented sensory feedback via an auditory signal, provided by the information from a limb load monitor. Of the 30 ambulatory stroke patients included, 27 (77%) corrected their symmetry of weight bearing by enhancing

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their limb loading on the paretic limb, when introduced to the feedback signal. Unfortunately there was no control group and the paper does not report any physiotherapy input to monitor standing posture.

More recently, Shumway-Cook and coworkers[8] used force plate information to provide centre of pressure feedback to 16 hemiplegic patients and to provide an accurate assessment of stance symmetry and sway characteristics. They compared this with conventional therapy in eight control group patients. The experimental group received 20 sessions of a two minute duration of feedback over two weeks, a physiotherapist also provided postural correction. The control group received 20 sessions of standing practice with a physiotherapist. The experimental group were found to significantly increase their symmetry of limb loading but no change was found in overall sway patterns. Subjects were not randomly allocated to either the control or treatment group and it is questionable whether conventional therapy (to which the patients would be very familiar) is an adequate control to the exposure to new and interesting equipment.

The above studies made the assumption that postural symmetry was linked to functional ability and that patients would automatically be able to transfer their newly learned skills to functional, task-orientated movement. Two studies have examined the transfer of skills learned from postural training to gait, with conflicting results.

In the most recent study, Winstein and co-workers[13] provided visual feedback from force plate information to an experimental group of 17 hemiplegic patients. These subjects were trained an average of 30 to 45 minutes per day, five days a week, for three to four weeks. Both the experimental group and a control group of 21 matched subjects received conventional physiotherapy during the trial period. At the end of the study the experimental group achieved a more symmetrical standing posture than the control group, but this difference did not persist for measures of gait performance. Again it is possible to question the adequacy of the control, especially as the experimental group received more therapy treatment time in total which may improve the outcome.[18]

A report of two single case 'ABAB' designs[12] described the effects of visual feedback on weight distribution and gait. Patients received EMG biofeedback to the arm in week A and visual feedback training in week B. An immediate and substantial improvement in the symmetry of weight distribution was demonstrated and this was sustained over time. Some carry over to the gait pattern was seen but there was no measurable improvement in gross motor function, ADL function was not measured. The paper does not give details of the treatment so that the frequency, timing, duration and content of treatment is unclear. Therefore, it may be unrealistic to expect changes in function. It is also difficult to generalize the results of two patients to a larger stroke population. Two patients demonstrated the ability to transfer training in two single case reports[14] using a portable, commercially available light-weight feedback monitor. Substantial improvements in stance symmetry were reflected by improvements in motor function and activities of daily living scores.

These pilot studies suggest that visual feedback may be a useful treatment for stroke patients and demonstrated large improvements quickly, but could be criticized for their design. A randomized controlled trial was carried out to assess the effectiveness of visual feedback as a method of improving stance symmetry and functional ability after stroke.

Methods

SUBJECTS

Twenty six stroke patients were identified from the Stroke Unit and Health Care of the Elderly wards at Nottingham City Hospital NHS Trust using a register of stroke admissions. Patients were included if they were able to stand for one minute and displayed an abnormal stance symmetry (outside 2 standard deviations, allowing for age and sex). Patients were excluded if they had severe receptive aphasia, a history of dementia, blindness or severe unilateral neglect.

DESCRIPTION OF STUDY GROUP

Twenty-six patients were recruited (20 men and six women), mean age 65·7 years (range 41–85, sd 11·4). Twelve had a right-side hemiplegia and 14 had a left-sided hemiplegia. The mean number of weeks since the onset of their stroke was 19·5 (range 4–63, sd 17·4). Six patients (23%) had some degree of expressive aphasia and nine (35%) were dysarthric. Ten (38%) patients exhibited signs of perceptual deficits, one had severe problems. Their length of stay in hospital ranged from 6–31 weeks, (mean 15·8, sd 6·4). Fourteen received their treatment as in-patients. Most of the patients were discharged to their own home, one went to stay temporarily with his daughter.

Two patients reported falls in the year prior to their stroke and one other complained of balance problems. Two of these used walking sticks as an aid to their pre-stroke mobility.

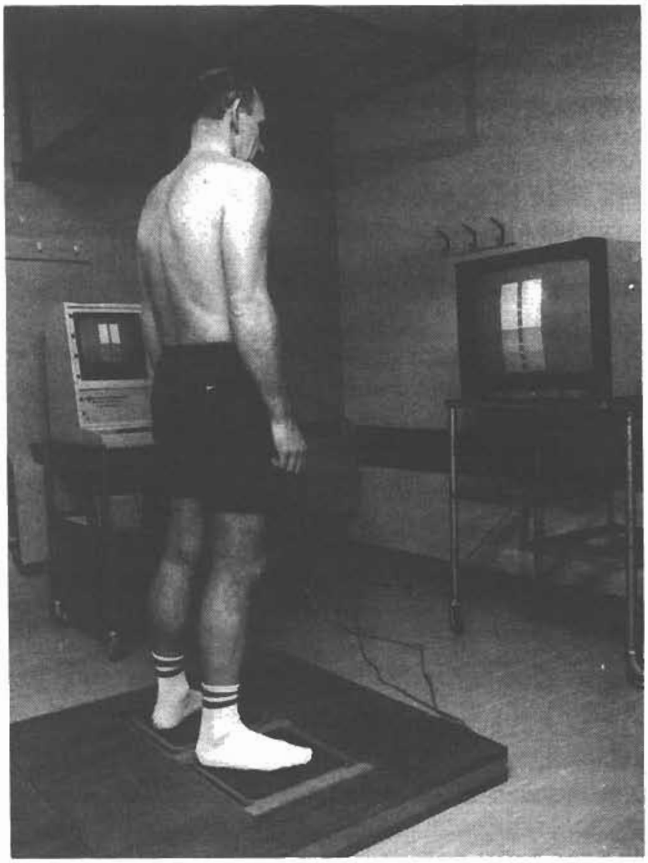

Figure 1 The Nottingham balance platform.

ASSESSMENTS

Stance symmetry and sway were measured using the Nottingham Balance Platform (NBP).[19] The NBP is a purpose-built computerized limb load monitor consisting of two load platforms stabilized in a wooden base, which forms the platform, a BBC microcomputer, a high-resolution monitor and two disc drives (Figure 1). The NBP was developed to measure bodyweight distribution between the left and right feet. The 'Data Acquisition' programme was used for assessments, which calculates the Balance Coefficient (BC) from the proportion of body weight on the left leg. If all the body weight is on the left leg, the BC would equal 1: if on the right, the BC would be 0: and if equally divided it would be 0·5.

Motor function was measured using the Rivermead Motor Assessment.[20] This Guttman scaled assessment was developed to provide a standardized, ranked assessment of motor recovery after stroke. It consists of three sections; gross function (13 items), leg and trunk (10 items) and arm function (15 items). The 'gross function' section is also reliable if administered verbally.[21]

Functional performance was recorded using the Nottingham 10 Point ADL Scale.[22] This Guttman scaled assessment is reliable if administered formally or informally. It consists of a scale of ten items, ranging from drinking and eating to dressing and bathing.

PROCEDURE

Before treatment began, fully informed consent was obtained. Patients were assessed as for conventional Bobath based therapy[3] including questions regarding their pre-stroke mobility. This is not a standardized assessment, but it gives the therapist a subjective impression of the patients muscle tone and posture as well as motor impairment.

Subjects were randomly allocated to either the feedback treatment or control group, using random number tables. Restricted randomization was used so that out of every block of ten consecutive patients five were randomly allocated to the treatment group A and five to the control group B.

The assessment with the Nottingham Balance Platform (NBP), was undertaken without any postural correction. At the first and last session the mean of three measures of 30 seconds of stance symmetry and sway were used. Single measurements were also made at the start and end of each treatment session. The patients did not receive any postural feedback during the tests, nor were they made aware of the results.

Group A received training from a physiotherapist using the feedback programme of the NBP. Treatment was given for an hour, three times a week for four weeks. Group B received the same training from a physiotherapist, but using the placebo programme. This was of the same frequency and duration as Group A. Independent assessments were undertaken at 0, 4 and 12 weeks. The Rivermead Motor Function Assessment and the Nottingham 10 Point ADL Scale were completed at each assessment and measures of stance symmetry and sway at the first two.

PHYSIOTHERAPY TREATMENT PROTOCOL

Patients in Group A and B received 12 treatment sessions, over four weeks, each of approximately one hour's duration, dependent on the patient's tolerance and medical status. The treatment and control group underwent the first and third stages and these are outlined here (for a detailed description see Sackley *et al.*[23]) only the second stage differed and that is described separately for each group. Each stage lasted approximately 20 minutes.

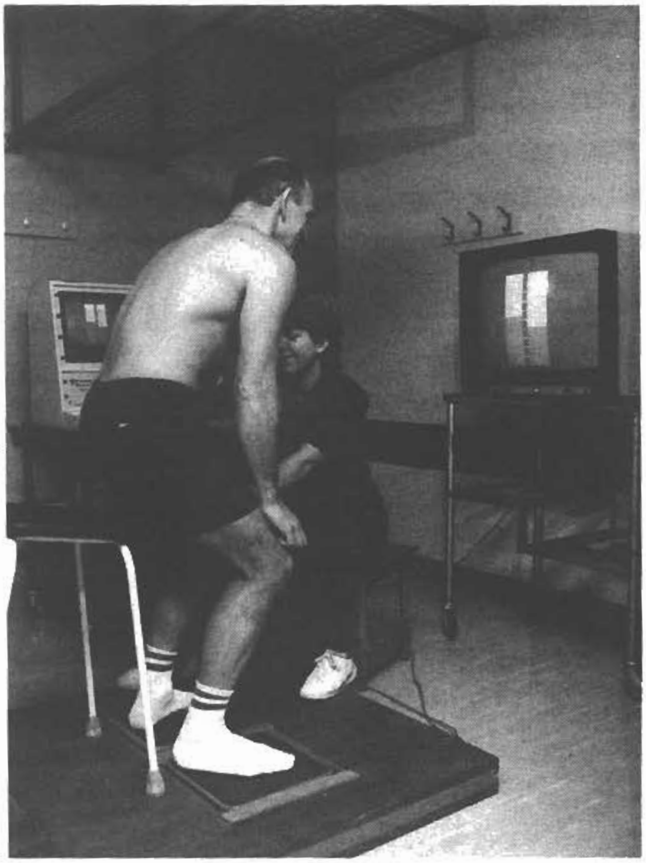

Figure 2 Sitting to standing.

Stage 1—Preparation for standing

This included activities such as practising symmetrical weight bearing while sitting, leaning forward and lifting the pelvis and trunk mobilizations.

Stage 2—Treatment with visual feedback (treatment group A)

Feedback signals displaying weight distribution and weight shift activity were continuously presented to the patient in the form of two vertical red columns. Each column moved upwards with an increase in weight on the corresponding foot. When the columns were within 5% of each other a red triangle appeared confirming that stance symmetry had been achieved. The importance of visual input in maintaining a stable standing posture has been shown in healthy adults[24-26] and stroke patients.[27] The patients practised a number of activities on the NBP with the constant supervision of at least one physiotherapist. These included:

Sitting to standing (Figure 2);

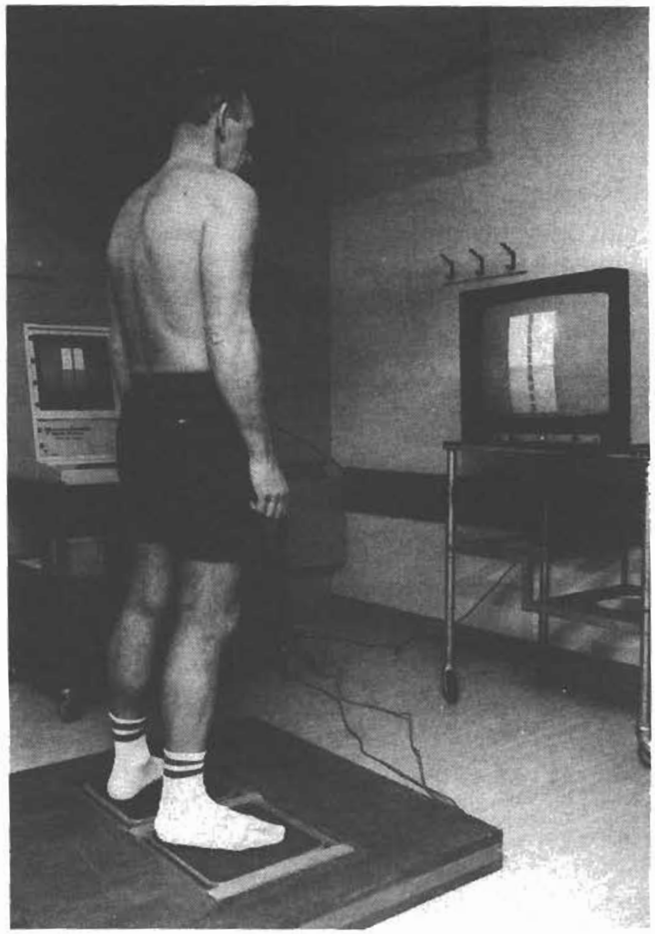

Figure 3 Standing, balancing the columns.

Standing, balancing the columns (Figure 3); and
More complicated activities such as targeting, reaching, stride standing and stepping (Figures 4 and 5).

Stage 2—Placebo programme (control group B)

The 'Placebo Programme' is used which displays two static yellow columns each half filled with red. The display does not move when there is a change in weight distribution (Figure 6). The patients practise similar activities to the treatment group, but without the visual feedback of at least one physiotherapist. Therefore the targeting and balancing the columns exercises are performed using the subjective impressions of the patient and therapist.

Stage 3—Practising new skills

Immediately after the feedback or control session the therapist practised goal orientated tasks, such as walking

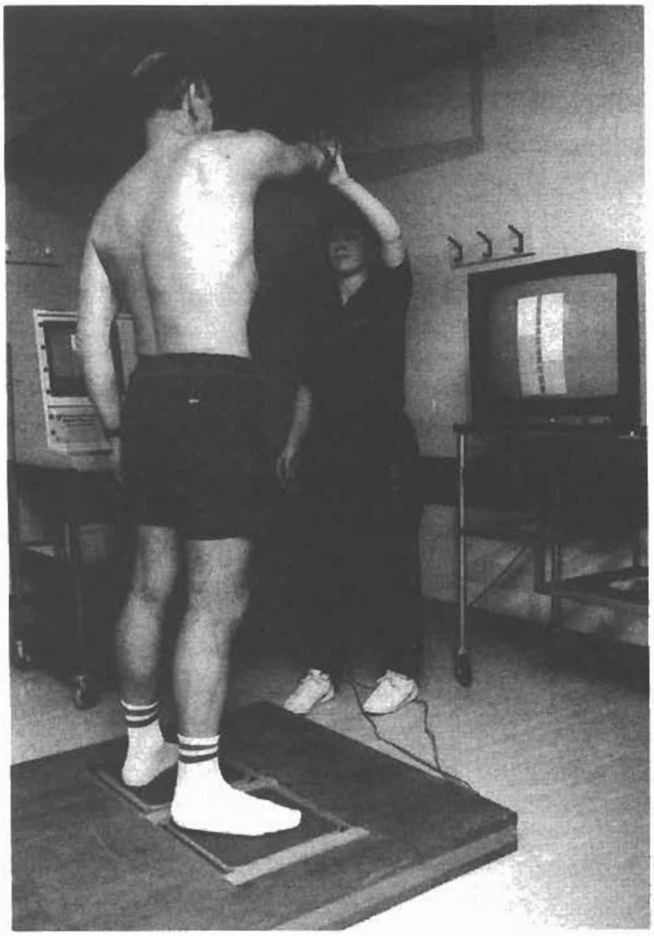

Figure 4 Practising functional activities.

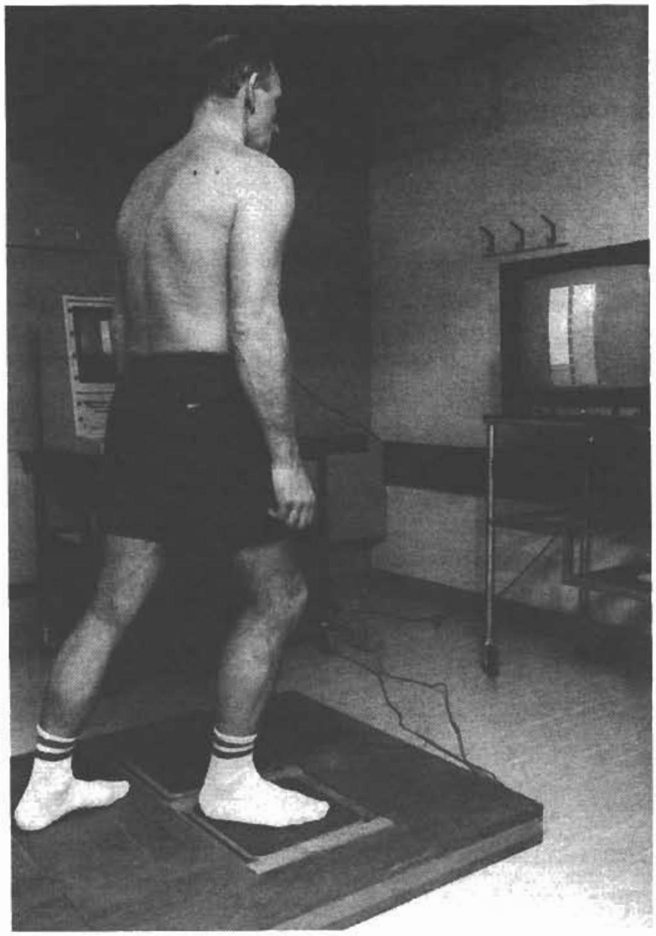

Figure 5 Practising more difficult activities.

to the bathroom or climbing stairs. The tasks incorporated the movements learned in the session with the NBP into every day activities.

DATA ANALYSIS

It was necessary to calculate the Balance Coefficient 2, $BC2 = \sqrt{(BC - 0{\cdot}5)^2}$ to investigate the relationships between variables. Pearson product moment correlations were used for parametric data and Spearman Correlations for non-parametric data. To identify differences between treatment and control groups, t-tests are used for parametric data and Mann U-tests for non-parametric data. To estimate changes over time, paired t-tests are used for interval data and Wilcoxen matched pairs signed ranks test for ordinal data. Analysis of variance is used to compare the before and after total treatment values between groups and multivariate analysis of variance is used to compare the before and after individual treatment values.

Results

SUBJECTS

Details included in 'Methods'. Two patients dropped out, one in Group A (treatment group) during the treatment stage due to medical complications and one Group B, sustained a fractured hip during the follow-up period.

DIFFERENCES BETWEEN GROUPS

Initial assessment

The range, mean and standard deviation (sd) of all the variables are given separately for both the treatment (group A) and control (group B) patients, in Table 1. The groups were compared with Mann Whitney U for non-parametric data. There were no significant differences between the groups before the study. There were no significant differences in the sample between men and women for any of the variables, nor were there any age

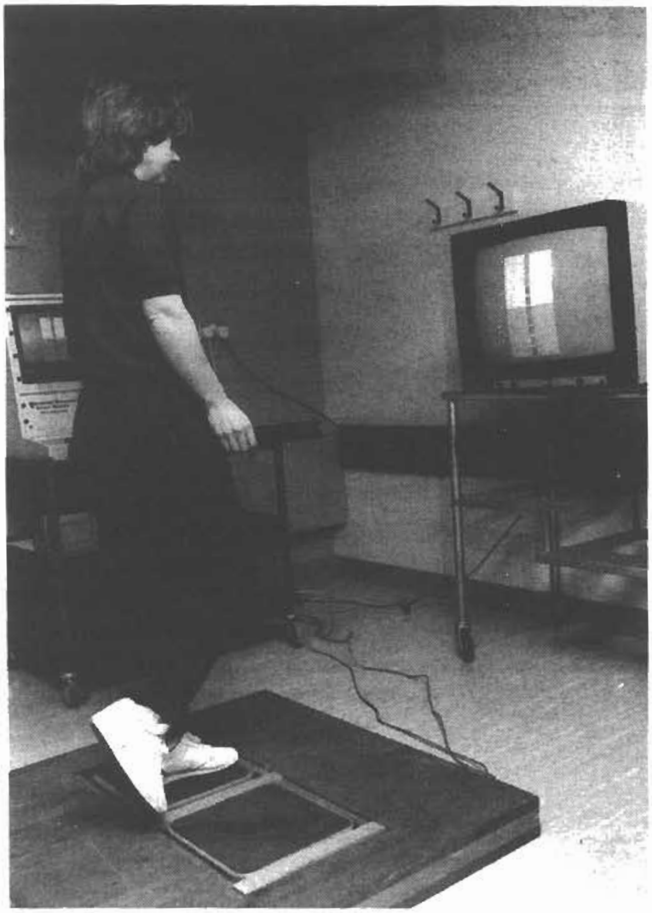

Figure 6 Placebo/control programme.

related differences. The only side of stroke differences were the balance of coefficient values, (see Table 2). There were no differences in magnitude between right and left-sided strokes.

Second assessment

Twenty-five patients completed this assessment, 12 in group A and 13 in group B. Table 3 demonstrates the differences between groups, (Mann Whitney U was used for non-parametric data and t-tests for parametric data). The results demonstrate significant improvement in motor function and ADL performance. The difference for sway values indicates a tendency for improvement in the treatment group, but does not reach a significant level.

Third assessment

Data from 24 patients was available, 12 from each group. Table 4 demonstrates no significant differences between the groups at this stage.

DIFFERENCES BETWEEN ASSESSMENTS

Table 5 gives the differences between the 1st and 2nd assessments for the BC2 and SC, using paired t-tests (24 degrees of freedom). This shows significant improvements in both groups.

Table 6 compares motor function and ADL scores at the 1st, 2nd and 3rd assessments using Wilcoxen matched pairs signed ranks test. This demonstrates a significant improvement between the 1st and 2nd, between the 1st and 3rd but not between the 2nd and 3rd.

The before and after treatment effects on the BC1 at each session were compared using t-tests (24 degrees of freedom). There were no significant differences, but the treatment group showed a tendency to improved symmetry in the first few treatments ($t = 2·0$, $p = 0·06$), but not after the first six treatments. The SC was examined in the same way and the treatment group showed a tendency to increased sway values after intervention which reached statistical significance at a number of sessions, but did not follow the same pattern as the BC1.

Analysis of variance was used to compare the before and after total treatment BC1 and SC values between groups A and B. The treatment group demonstrated a significant improvement in BC1 values ($F_{62,271}$ 11·18, $p < 0·01$) compared with the control group. Sway values demonstrated a similar improvement in the treatment group compared with the control group ($F_{563,910}$ 10·52, $p < 0·01$).

Multivariate analysis of variance was used to compare the before and after individual treatment BC1 and SC values at each treatment between groups A and B. The treatment group ($F_{184,301}$ 8·63, $p < 0·01$). Sway values demonstrated a tendency to increase in the treatment group ($F_{207,5643}$ 87, $p = 0·061$).

Discussion

As reviewed in the Introduction, research studies from North America, utilizing postural feedback devices have demonstrated improvements in standing posture.[8,13,17] Only one study examined the transfer of training to gait variables,[13] and concluded that there was no automatic carry over. Single case studies using the NBP[12] with patients late after stroke, demonstrate some improvement in weight transference during the gait cycle, but failed to show any improvement in motor function

Table 1 Comparison of treatment group (A) and control group (B) at the 1st assessment

n = 26		Group A n = 13	Group B n = 13	Differences
Sex	Men	10	10	ns
	Women	3	3	
Side of stroke	Left	9	5	ns
	Right	4	8	
Age	range	41–85	50–83	ns
	mean	60·8	67–9	
	sd	12·3	9·2	
Length of admission (weeks)	range	6–31	8–22	ns
	mean	15·9	15·7	
	sd	6·9	5·4	
Time post stroke (weeks)	range	4–48	4–63	ns
	mean	20·1	18·8	
	sd	15·8	19·3	
Gross function	range	3–9	2–10	ns
	mean	5·7	5·2	
	sd	1·9	2·3	
Leg and trunk	range	2–8	2–9	ns
	mean	4·7	5·0	
	sd	1·9	2·7	
Total motor function	range	5–15	4–19	ns
	mean	10·4	10·2	
	sd	3·5	4·1	
10 Point ADL	range	3–9	3–9	ns
	mean	5·2	6·5	
	sd	2·1	2·3	
BC2	range	0·099–0·284	0·071–0·254	ns
	mean	0·168	0·142	
	sd	0·065	0·054	
SC	range	0·0154–0·0555	0·0127–0·1132	ns
	mean	0·0310	0·0494	
	sd	0·0124	0·0364	

ns = not significant, sd = standard deviation.

Table 2 Difference in balance coefficient (1st assessment) values for right and left-sided hemiplegia for treatment and control groups

Side of hemiplegia	n	Mean	sd	t	p
Group A					
Right	4	0·704	0·030	6·1	< 0·001
Left	9	0·348	0·021		
Group B					
Right	8	0·636	0·051	6·1	< 0·001
Left	5	0·369	0·091		

sd = standard deviation.

scores. Single case studies with the Balance Performance Monitor (BPM) have shown improvements in stance symmetry and motor function and ADL.[14]

In this study the treatment group demonstrated a significantly better performance when compared with controls for stance symmetry and for functional performance (ADL and Gross Function scores), sway values showed a tendency to greater improvement. The improvement in stance symmetry is consistent with the earlier studies and confirms the observation[14] that there is an ability to transfer these skills to functional tasks. This effect is important as it would be pointless for the patient to learn new skills on the balance platform if they were unable to use them afterwards. It may have occurred because the feedback training was not done in isolation, but as part of a therapy treatment, which was orientated to practising gross motor skills.

Improvements in the postural variables of stance symmetry and sway were seen for both treatment and

Table 3 Comparison of treatment group (A) and control group (B) at the 2nd assessment

n = 25		Group A n = 12	Group B n = 13	Significance of difference
Gross function	range	7–11	3–11	
	mean	9·7	6·9	U = 20·5 $p < 0{\cdot}001$
	sd	1·2	2·2	
Leg and trunk	range	5–10	2–10	
	mean	7·4	5·9	U = 47·0 ns
	sd	2·0	2·4	
Total motor function	range	13–21	6–21	
	mean	17·0	12·7	U = 32·0 $p < 0{\cdot}05$
	sd	2·9	4·5	
10 Point ADL	range	8–10	4–10	
	mean	9·0	7·8	U = 32·0 $p < 0{\cdot}05$
	sd	0·8	2·0	
BC2	range	0·006–0·101	0·013–0·147	
	mean	0·039	0·055	$t = 2{\cdot}6$ $p < 0{\cdot}05$
	sd	0·028	0·044	
SC	range	0·0110–0·0380	0·0067–0·0662	
	mean	0·0193	0·0288	$t = 1{\cdot}9$ $p = 0{\cdot}06$
	sd	0·0078	0·163	

ns = not significant, sd = standard deviation.

Table 4 Comparison of treatment group (A) and control group (B) at the 3rd assessment

n = 24		Group A n = 12	Group B n = 12	Differences
Gross function	range	5–11	2–11	
	mean	8·5	8·5	ns
	sd	2·0	2·6	
Leg and trunk	range	1–10	4–10	
	mean	5·3	7·1	ns
	sd	3·2	2·6	
Total motor function	range	6–21	7–21	
	mean	13·8	15·5	ns
	sd	4·4	4·7	
10 Point ADL	range	5–10	2–10	
	mean	8·3	8·4	ns
	sd	1·4	2·3	

ns = not significant, sd = standard deviation.

control groups. This may have occurred because the patients were receiving more therapy, as all the treatments were done in addition to the established rehabilitation routines. This confirms the results of existing work, that the amount of therapy is important in achieving functional gains.[18,28,29] It also demonstrates the importance of including placebo treatment of the same duration for control groups. It is clearly not

Table 5 Changes in stance symmetry and sway with treatment

	Mean	sd	t	p
Group A n = 12				
BC2 1st Assessment	0·173	0·065	9·78	< 0·001
BC2 2nd Assessment	0·039	0·028		
SC 1st Assessment	0·0263	0·0098	2·76	< 0·001
SC 2nd Assessment				
Group B n = 13				
BC2 1st Assessment	0·141	0·054	7·90	< 0·001
BC2 2nd Assessment	0·054	0·044		
SC 1st Assessment	0·0494	0·0364	2·79	< 0·05
SC 2nd Assessment	0·0288	0·0163		

ns = not significant, sd = standard deviation.

enough to have a 'no treatment' group, when the experimental group are receiving extra treatment of whatever type. This was omitted in three studies.[8,13,17]

Table 6 Comparison of functional variables at each assessment

Variable	Assessment	n	− Ranks	+ Ranks	Ties	z	p
Group A							
Gross	1–2	12	0	12	0	−3·06	< 0·01
function	1–3	12	2	10	0	−2·67	<0·01
	2–3	12	7	4	1	−1·38	ns
Leg and	1–2	12	0	12	0	−3·06	< 0·01
trunk	1–3	12	6	6	0	−0·71	ns
	2–3	12	8	0	4	−1·81	ns
Total motor	1–2	12	0	12	0	−3·06	< 0·01
function 10	1–3	12	4	8	0	−2·40	< 0·05
point ADL	2–3	12	8	3	1	−1·80	ns
	1–2	12	0	12	0	−3·05	< 0·01
	1–3	12	0	12	0	−3·06	< 0·01
	2–3	12	6	2	4	−1·82	ns
Group B							
Gross	1–2	13	3	9	1	−2·47	< 0·05
function	1–3	12	1	11	0	−2·98	< 0·01
	2–3	12	1	8	3	−2·03	ns
Leg and	1–2	13	3	9	0	−2·65	< 0·01
trunk	1–3	12	1	6	4	−0·75	ns
	2–3	12	1	0	4	−1·81	ns
Total motor	1–2	13	0	9	4	−2·66	< 0·01
function 10	1–3	12	0	10	2	−2·80	ns
point ADL	2–3	12	1	7	4	−2·31	ns
	1–2	13	0	9	4	−2·66	< 0·01
	1–3	12	1	9	2	−2·56	< 0·01
	2–3	12	4	5	3	−0·82	ns

ns = not significant.

The observation that functional ability improved, but specific leg and trunk motor skills did not suggests that physiotherapy may provide adaptive strategies to reduce disability rather than impairment. This has important implications for the treatment concepts presently used, especially the most frequently used approach the Bobath approach,[30] as it would indicate a shift in the emphasis of treatment from rather passive abstract movements to goal-orientated functional tasks. If the primary aim is to enable the patient to be independent in self-care activities, it would seem reasonable to concentrate on the retraining of functional tasks. An added advantage would be that the patient would be able to understand the goals of treatment and be able to measure their own success in achieving them. Patients in the experimental group of this trial commented that they enjoyed the NBP treatment for that reason, they knew exactly what they were required to achieve and could judge the results for themselves. Knowledge of the results of their efforts appeared to improve motivation.

The NBP has the advantage of also providing the therapist with accurate feedback. This aspect of feedback has not been examined, but may be important as it enables the therapist to encourage the patients towards the limits of their ability. As with any treatment technique, there are limitations to the application of visual feedback with the NBP. The most obvious being the cost of the equipment and the space it occupies. Therapeutically, the major limiting factor is the static nature of the measuring platforms and future developments must look at methods of providing feedback during walking. another consideration is that in its present form, the patient needs constant supervision by a physiotherapist to prevent the use of abnormal postures to produce symmetrical weight distribution. This does not cut down on the input of staff, but patients may need fewer treatment sessions to achieve the same results.

Multivariate analysis indicated a tendency for treatment patients to differ from controls in that their sway values increased after individual treatment sessions, although they decreased over the treatment period. If an increase in sway values is linked with an increased tendency to fall as suggested by Sackley 1991,[31] there may be a disadvantage in using this system. However the small number of patients in this study prevents the analysis of this relationship and a much larger trial is indicated. The increase in sway values had disappeared by the next treatment and may be a sign of treatment fatigue. As a precaution when using NBP feedback, patients would be advised to rest for an hour after treatment. Clinically, it is normal practice to allow the patients a rest period after therapy and it would be interesting to assess the patients after this period.

The relationship between sway and physiological efficiency has not been examined, even in healthy adults. Yet, it is possible to suggest that sway values may have increased because the physiological cost of the treatment was higher. The patient and therapist had accurate feedback of the results and therefore could safely estimate the threshold of the patient's abilities and work closer to those limits. Another explanation is that stance asymmetry is an adaptive change, increasing the patient's postural stability and as the treatment group demonstrated a greater increase in symmetry, it decreased their stability.

Some of the difficulties which were expected did not materialize, both staff and patients enjoyed the feedback and found it easy to use. Even elderly patients were not frightened by the exposure to new, 'high-tech' equipment. Communication impairments did not inhibit the use of the NBP, surprisingly, many patients with quite severe communication problems found the visual information easy to understand and grasped the concept of weight transference more effectively than with conventional treatment.

In conclusion, although all of the studies using postural feedback can be criticized for having small groups of specially selected and ill defined patient groups, the overall tendency shown seems to support the further use of feedback techniques to improve standing posture after stroke. Especially, considering the paucity of research evidence to support other treatment regimens. Larger and or more tightly controlled studies in this area are needed. If this approach to treatment is adopted by more physiotherapy departments a multi-centre collaborative study is more feasible.

Acknowledgement

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