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LONG TERM EFFECTS OF AUDITORY FEEDBACK TRAINING ON RELEARNED SYMMETRICAL BODY WEIGHT DISTRIBUTION IN STROKE PATIENTS

A Follow-up Study

Margareta Engardt

From the Department of Physical Therapy, Karolinska Institute, Huddinge, Sweden

ABSTRACT. Long-term effects of auditory kinetic feedback on relearned symmetrical body weight distribution while rising and sitting down were studied in stroke patients. Thirty patients were re-tested on average 33 months after having trained with and without auditory feedback. Body weight distribution on the legs was measured with two force plates. At re-test there was a decrease from 48% to 39% of body weight distribution (%BWD) on the paretic leg in rising and in sitting down in the patients in the auditory feedback group ($p < 0.001$). In the control group the decrease was from 44 to 39 %BWD on the paretic leg ($p < 0.05$) in rising and from 44 to 42 %BWD (n.s.) in sitting down. The symmetrical body-weight distribution, acquired after auditory feedback training, was not consistent over time. Movement time, however, was significantly reduced in the auditory feedback group ($p < 0.05$). Possible reasons for the findings are discussed.

Key words: stroke, auditory feedback, kinetic, symmetry, body weight distribution, movement time, motor performance, motor learning.

Different forms of feedback have been used in physiotherapy and rehabilitation since the early 1960's. Biofeedback has been considered to play an important role in functional training, giving immediate positive results in stroke patients (2).

Reports on training with kinetic feedback via auditory and visual displays have shown enhanced body weight bearing on the paretic limb in standing (13, 9, 14), in rising (5) and in walking (7) in stroke patients directly after training. The literature fails, however, to give evidence of long term effects of a corrected asymmetrical kinetic motor behaviour in patients with stroke.

In a previous study (5) 40 stroke patients, randomly assigned to an experimental group and a control group, had trained rising up and sitting down with and without auditory feedback of body weight distribution in order to see if auditory feedback would enhance body weight bearing on the paretic leg. A force platform consisting of two electronic balances with an auditory output had been used to reinforce symmetrical body weight distribution. Training had started 1 week to 3 months after the stroke, with patients randomly allocated to an experimental or a control group. The patients of the experimental group had trained with kinetic feedback from an auditory display to reach the target of 20, 30, 40 and 50% of the total body weight, distributed on the paretic leg while rising and sitting down. Training had lasted 15 minutes, 3 times a day, for 6 weeks. The patients of the control group had trained rising and sitting down similarly without auditory feedback but with verbal instruction to put equal body weight on the two lower extremeties. After 6 weeks training, the patients in the auditory feedback group loaded their paretic leg with an average of 48% body weight in rising and in sitting down. The corresponding mean values for the patients in the control group were 44% body-weight, distributed on the paretic leg.

Clinical experience, however, shows difficulties in achieving functional transfer of training results from closed to open task situations, i.e., being consistent when performed in different environmental contexts and with different goals for the action. Had the patients in the auditory feedback group acquired a permanent symmetrical motor program for the task of rising and sitting down, or did they conduct a motor performance, easily eradicated, once the auditory feedback from vertical ground reaction forces was withdrawn?

Thus it was considered important to find out whether the motor performance gains (symmetrical body weight distribution and movement time

Table I. *Clinical data of the stroke patients in the auditory feedback (AFB) and the control (Contr.) group*

Mean and SD are given. p was calculated using the Student's un-paired two-sided t-test and the Chi-square test

	AFB ($n = 16$) Mean ± SD	Contr. ($n = 14$) Mean ± SD	p
Age (year)	67 ± 6.05	65 ± 8.46	n.s.
Height (cm)	174 ± 8.7	163 ± 7.6	< 0.01
Weight (kg)	77 ± 11.4	67 ± 10.9	< 0.05
Male/female (n)	12/4	4/10	< 0.05
Affected side l/r (n)	10/6	6/8	n.s.
Months since end of training (n)	33.2 ± 6.6	34.3 ± 5.8	n.s.

duration) were consistent after 2–3 years in the previously trained patients.

PATIENTS AND METHODS

Patients

Forty stroke patients who had taken part in a previous study were admitted (5). Ten of the 40 patients did not participate in the present study. Two patients were diseased, 3 patients had had a second stroke, 1 patient had become severely ill, 2 patients had moved and 2 patients could not be found. Thus 30 stroke patients were included.

Table I shows the clinical data of the patients at the time of the present study.

Table II shows the mean dynamic strength of the knee extensor and the knee flexor muscles of the patients directly after training in the previous study (5). Since the end of the specific auditory feedback training, all the patients had continued physiotherapy treatments once or twice a week but with no special emphasis on symmetrical body weight distribution on the legs in rising up and sitting down. At the time of the present study, 7 of the patients of the auditory feedback and 6 of the patients in the control group had discontinued their physiotherapy treatment.

Measurement of body weight distribution

Body weight distribution on the legs was measured as described in the previous study (4).

The vertical floor reaction forces under each foot was determined with two strain-gauge force transducers attached to two platforms. The recordings from the two strain-gauge force transducers were analysed with a specially designed computer program. The time integral of the vertical forces under each foot in rising and sitting down was measured. Body weight distribution was computed as the ratio between the time integrals of the vertical forces of the paretic and the non-paretic leg. The means from three tests of rising and of sitting down were calculated. The patients were sitting in a standardised position on an adjustable armless chair with a back support (Fig. 1).

The tests of the patients were performed 33.2 ± 6.6 months in the auditory feedback group and 34.3 ± 5.8 in the control group after their respective training period.

Data analysis

Differences within and between the groups were tested for significance by the Student's paired and unpaired t-tests. Nominal data were treated by the Chi-square test.

The influence of sex, height and weight on the data of body weight distribution and movement time was analysed by a 2 factor analysis of variance (ANOVA) with repeated measures on the dependent data. The level of significance chosen was 5%.

RESULTS

The influence of height, weight and sex on the data of body weight distribution and movement time is summarised as follows:

Table II. *Mean dynamic strength of the thigh muscles of the paretic leg relative to that of the non-paretic leg (%) at an angular knee joint velocity of 30°/s in the knee range of 50–75° in the patients of the auditory feedback (AFB) and the control (Contr.) group*

Measurements were taken directly after the training with and without auditory feedback. Mean ± SD are given. p was calculated using Student's un-paired two-sided t-test

	AFB ($n = 16$) Mean ± SD	Contr. ($n = 14$) Mean ± SD	p
Con. knee ext. (%)	60.5 ± 23.2	52.0 ± 30.7	n.s.
Ecc. knee ext. (%)	67.9 ± 25.8	61.5 ± 25.4	n.s.
Con. knee flex. (%)	35.0 ± 35.7	37.1 ± 40.9	n.s.
Ecc. knee flex. (%)	48.0 ± 25.6	47.2 ± 45.0	n.s.

Table III. *Body-weight distribution on the paretic leg in rising (BWD up %), in sitting down (BWD down %), movement time in rising (time up s) and in sitting down (time down s) after training (Post-test) and after ≈ 33 months (Re-test) in the patients of the auditory feedback (AFB) and the control (Contr.) group*

Mean ± SD are given. P was calculated using Student's paired two-sided t-test

	AFB ($n = 16$)			Contr. ($n = 14$)		
	Post-test	Re-test	p	Post-test	Re-test	p
BWD up (%)	47.8 ± 6.7	38.7 ± 7.1	< 0.001	44.2 ± 6.6	39.5 ± 7.0	< 0.05
BWD down (%)	47.9 ± 5.3	40.9 ± 4.8	< 0.001	43.5 ± 7.6	42.5 ± 7.1	n.s.
Time up (s)	3.1 ± 1.0	2.5 ± 0.6	< 0.01	3.2 ± 0.8	3.4 ± 1.5	n.s.
Time down (s)	3.5 ± 0.9	2.5 ± 0.6	< 0.001	2.8 ± 0.6	2.9 ± 1.1	n.s.

No main or interaction effects were observed with respect to body weight distribution and movement time data in rising up or in sitting down between tall/short patients, light-/heavy-weighted patients or male/female patients, respectively, and repeated measures.

Table III shows the body-weight distribution on the paretic leg of the patients in the auditory feedback and of the patients in the control group directly after the training (post-test) and on average 34 and 33 months, respectively, after end of training (re-test). The patients in the auditory feedback group had lost their relearned symmetric body weight distribution in rising as well as in sitting down. The patients in the control group had reduced the amount of body weight distributed on the paretic leg in rising. In sitting down the decrease of body weight distribution on the paretic leg was not statistically significant.

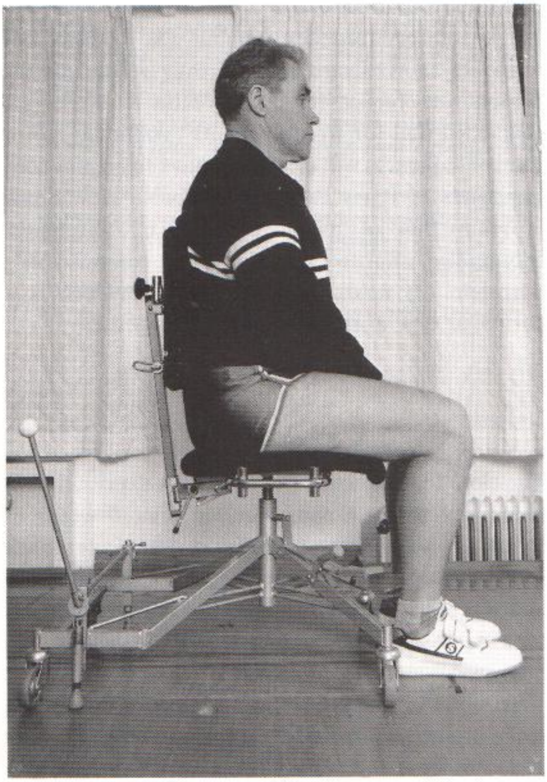

Fig. 1. The standardised position of rising from sitting to standing.

Table IV shows that the differences in body weight distribution on the paretic leg were statistically significant between the groups in sitting down but not in rising up.

Table III shows the movement time duration in rising and in sitting down in the patients of the auditory feedback and the control group at post-test and re-test. There was a reduction in movement time in the patients of the auditory feedback group in rising as well as in sitting down compared to the patients of the control group. These differences were statistically significant (Table IV).

Table IV. *Differences of body weight distribution on the paretic leg in rising (BWD up %), in sitting down (BWD down %), of movement time in rising (time up s) and sitting down (time down s) between end of training and after ≈ 33 months in the patients of the auditory feedback (AFB) and control (Contr.) group.*

Mean ± SD are given. p was calculated using Student's unpaired two-sided t-test

	AFB ($n = 16$)	Contr. ($n = 14$)	p
BWD up (%)	9.2 ± 7.9	4.7 ± 7.5	n.s.
BWD down (%)	7.1 ± 7.2	1.0 ± 6.9	< 0.05
Time up (s)	−0.6 ± 0.8	0.2 ± 1.2	< 0.05
Time down (s)	−0.9 ± 0.9	0.1 ± 0.9	< 0.01

DISCUSSION

The mean body weight distribution on the paretic leg in rising and sitting down decreased significantly after having been close to symmetrical directly after the training in the patients of the auditory feedback group. Possible reasons for the findings will be discussed.

The patients were hemiparetic. Mean peak torque of maximal voluntary knee extensions was 60% in concentric and 68% in eccentric actions of that of the non-paretic leg. Corresponding values for knee flexions were 35% and 48%. As there was such an asymmetry in strength between the thigh muscles of the two lower extremities it might not have been possible or practical for the patients to concentrate on symmetry, once the guiding and motivating auditory feedback was withdrawn. During the months after the auditory feedback training the patients probably had favoured the non-paretic leg for safety and speed, resulting in a "dis-use" of the paretic leg. This was reflected in the shorter time needed to rise as well as to sit down, possibly at the expense of the symmetrical body weight distribution.

In the early stage of learning, the auditory feedback was repeated and was appreciated during the ongoing action of rising, i.e., concurrently. In motor learning studies of young healthy adults it has been shown that the use of concurrent extrinsic feedback discourages information from the intrinsic feedback, which is needed to learn the capability to get from a feedback to a feed forward mode for task performance (8, 15, 11). Swinnen (10) showed that instantaneous provision of knowledge of results is detrimental to learning/retention, due to a blocking of spontaneous performance. The frequent and concurrent augmented feedback was used by the patients in the previous study as a "crutch" (16). The patients might have acquired an overdependence on the feedback, which prevented and blocked the development of the patients' own reference copy of loading the paretic leg. The patients relied so heavily on the extrinsic feedback that, when feedback was suddenly removed, no internal representation or internal reference had been created for loading the paretic leg while rising and sitting down. In the absence of feedback they were unable to generate the force of the appropriate magnitude and timing. They had focused so hard on making the signal heard that signalling became the goal for the action, not rising up. Practising for our patients was seen as repeating evoking the signal, a fixation on the sound instead of on the actions themselves. Vander Linden et al. (12) reported in a study on 24 non-disabled adults that concurrent kinetic feedback gave superior performance in 8 subjects during the acquisition phase compared to a second group who got feedback after each attempt, and a third group who got feedback after every other attempt. In a delayed retention phase, however, the concurrent feedback group displayed deteriorated motor performance compared to the groups who experienced 100% and 50% frequency feedback of knowledge of result.

A long time had passed since the auditory feedback training had come to an end. Rising from sitting and sitting down from standing were trained as a closed or a consistent motion task (6) reinforced by knowledge of performance (i.e., auditory feedback) to get a fixed long term movement pattern. During the last 1–3 years, however, the patients had risen up and sat down in open tasks situations, where the environment had been changing; such as rising in complex and variable surroundings from different chair-heights and chair supports.

The auditory feedback training was intensive but relatively short. Learning is directly related to the amount of practice (6). Bach-y-Rita & Baillet (1) concluded that for stroke patients "volitional motor control sequences will ultimately have to be practiced thousands of times in order to store a new motor program that is relatively fast, i.e., automatic, coordinated, effortless, functional and generalizable". Bernstein (3) holds, however, that "practice is a particular type of repetition without repetition".

CONCLUSIONS

The close to symmetrical body weight distribution in rising and sitting down, acquired after 6 weeks of training with concurrent auditory kinetic feedback seems to have been an act of motor performance and was lost after on average 33 months. Movement time in rising and sitting down, however, was improved.

To optimize the possibilities for stroke patients to make trained motor performances become learned and consistent over time, following training suggestions might be implemented: The auditory feedback should be appreciated by the patients with reduced frequency, with booster sessions over longer periods of time and during continuous training of open tasks situations.

Further studies on how to manage augmented feedback in patients with hemiparesis after stroke are recommended.

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Address for offprints:

Margareta Engardt
Department of Physical Therapy
Karolinska Institute
S-14157 Huddinge
Sweden