Reliance on Visual Information After Stroke. Part II: Effectiveness of a Balance Rehabilitation Program With Visual Cue Deprivation After Stroke: A Randomized Controlled Trial

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ABSTRACT. Bonan IV, Yelnik AP, Colle FM, Michaud C, Normand E, Panigot B, Roth P, Guichard JP, Vicaut E. Reliance on visual information after stroke. Part II: Effectiveness of a balance rehabilitation program with visual cue deprivation after stroke: a randomized controlled trial. Arch Phys Med Rehabil 2004;85:274-8.

Objective: To test the hypothesis that balance rehabilitation with visual cue deprivation improves balance more effectively than rehabilitation with free vision.

Design: Single-blind, randomized controlled trial.

Setting: Public rehabilitation center in France.

Participants: Twenty patients with hemiplegia after a single-hemisphere stroke that occurred at least 12 months before the study.

Intervention: Patients were randomly assigned to 1 of 2 balance rehabilitation programs—with and without visual cue deprivation. In all other respects, the programs were identical. Each lasted for 1 hour and was implemented 5 days a week for 4 weeks. All patients completed the program.

Mean Outcome Measures: Balance under 6 sensory conditions was assessed by computerized dynamic posturography (EquiTest), gait velocity, timed stair climbing, and self-assessment of ease of gait before and after program completion.

Results: After completing the program, balance, gait velocity, and self-assessment of gait improved significantly in all patients. The improvements in gait velocity ($P=.03$) and timed stair climbing ($P=.01$) correlated significantly with improved balance. Balance improved more in the vision-deprived group than in the free-vision group.

Conclusions: Balance improved more after rehabilitation with visual deprivation than with free vision. Visual overuse may be a compensatory strategy for coping with initial imbalance exacerbated by traditional rehabilitation.

Key Words: Balance; Posture; Rehabilitation; Stroke.

THE REHABILITATION OF BALANCE for patients with hemiplegia is poorly developed. The most commonly used method of neurologic rehabilitation, which is based on neurofacilitatory techniques and inspired by the Bobath concept, does not specifically target balance when standing. This method is designed to correct pathologic movement patterns by using reflex inhibition techniques to normalize tone. The only evaluation of this method was made by Hesse et al,[1] who found that, after a 4-week intensive inpatient training program, there was no significant improvement in gait symmetry parameters. Platform training aimed at correcting postural asymmetry is often proposed for improving balance.[2-9] It is used with and without feedback, in the upright position, or while standing up or sitting down. Platform training has been shown to improve the postural symmetry measured on the platform,[2-9] but its application to other activities is controversial; some authors[6,8] consider it effective, but others[2-5,7,9] do not. The aim of balance rehabilitation is to ensure safe ambulation. Programs have been proposed to improve the ability to walk, but they did not focus especially on the safety during ambulation. The aim of such programs was to achieve specific skill acquisition in demanding and intensive conditions. For instance, muscle strengthening and task-specific training for gait were actually shown to improve gait and lessen disability.[10-15]

However, motor control impairment is not the only factor causing poor balance after stroke. Balance control involves the integration of many types of sensory information, and several authors[16-20] recently hypothesized that disorders of sensory information organization underlie a distorted representation of the body in space, which does not favor balance recovery. Patients with poststroke hemiplegia have been shown to have difficulty in suppressing unreliable visual input because they find it very difficult to maintain balance when visually deprived. In the case of visuovestibular conflict, the difficulty is even greater.[21] Such patients exhibit excessive reliance on visual input and are unable to use somatosensory and vestibular input correctly. In our study, we attempted to establish whether this excessive reliance on visual input is reversible, by testing patients' balance before and after completing a balance rehabilitation program with or without visual deprivation. The aim of the visual deprivation was to induce patients to use somatosensory and vestibular inputs and to rely less on visual input. By using a randomized design, we compared the effectiveness of a rehabilitation program with visual cue deprivation versus a program with free vision.

METHODS

Participants

Subjects were recruited by convenience sampling in our physical medicine and rehabilitation department. To be eligible, they had to be outpatients with hemiplegia caused by a first and only cerebral hemispheric stroke, with a time since stroke of more than 12 months. Patients were excluded if they could

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not walk without human assistance or if they had an orthopedic disorder involving 1 or both lower limbs, a history of neurologic disease other than the above stroke, amblyopia, vertigo, or vestibular dysfunction. Patients with anesthesia of position joint sense in a lower limb were also excluded, to ensure that somatosensory information was given. All patients gave informed consent to participate in the study. A practitioner in our department (IVB) enrolled the participants, collected data concerning baseline demographic and clinical characteristics, and assessed the outcomes before and after program implementation. She was blinded with regard to group identity.

Design

Participants were randomly allocated to either experimental rehabilitation (the vision-deprived group) or control rehabilitation (the free-vision group) by using sealed envelopes. They were assigned to their groups by giving the envelope to the physiotherapist in charge of the program.

Rehabilitation Program

The rehabilitation program was exactly the same for the vision-deprived group and the free-vision group, except that the eyes of the vision-deprived group were blinded with a mask throughout the sessions. The program did not include balance platform training. Four trained physiotherapists (CM, EN, BP, PR) applied the rehabilitation program. The specification and sequence of the exercises were discussed and defined during a staff meeting. The length of the exercises and the rest times were specified. The program was implemented in our physical medicine rehabilitation department and comprised five 1-hour sessions a week for 4 consecutive weeks (20 sessions in all). It began with 5 minutes of spasticity inhibition, followed by 1 hour devoted to improving balance. This hour included 30 minutes of exercises performed in the following positions: during the first week, in the supine or prone position (bridging with the spine, transfer, and crawling); during the second week, in the sitting position; during the third week, on all fours or kneeling; and during the fourth week, in the upright position. Each session then included 20 minutes of balance training on a treadmill and stationary bicycle and ended with 10 minutes of walking on a foam rubber track with obstacles.

Procedure

Baseline clinical characteristics. At baseline, we recorded sex, age at stroke, type of stroke, location and side of the lesion according to the computed tomography (CT) scan performed at diagnosis, and time since stroke. Functional capacity was assessed by using the FIM™ instrument,[22] which is comprised of 18 items each noted on a 7-step scale related to self-care, bowel and bladder control, mobility, locomotion, and cognition. Lower-limb motor control and sensitivity were assessed by using the Fugl-Meyer Assessment of lower extremity.[23] It allocates 12 points to sensitivity and 34 points to motor function. Motor function examines the presence of synergistic patterns in the supine position and isolated movement in the sitting position and standing position.

Location of stroke lesion. Stroke lesion sites were located on CT scans to correlate abnormalities with lesions of the vestibular cortex. Scans were performed with a Picker unit,[a] by using a slice thickness of 4mm up to the midbrain, and of 8mm more rostrally. The stereotaxic baseline was used according to the Duvernoy atlas.[24] If the imaging plane was not parallel to the anterior commissure–posterior commissure plane, we attempted to optimize the location of the projected lesion. Anatomic lesions were noted as involving or not involving the regions of interest in the vestibular cortex, as described by Brandt et al.[25] These regions comprised the parietoinsular vestibular cortex, which lies deep in the posterior part of the insula, area 2v at the tip of the interparietal sulcus, area 3a in the anterior bank of the central sulcus, and area 7 at the superior temporalgyrus.

Audiovestibular examination by calorimetry and audiometry was conducted before balance testing, to eliminate subjects with cochleovestibular impairment.

Primary Outcomes

Balance was assessed by using the Sensory Organization Test (SOT) protocol of a computerized dynamic posturography system called the EquiTest,[b] as described in part I.[21] Briefly, the equilibrium score (ES) was tested under 6 conditions (SOT 1–6) during three 20-second trials and was recorded as ES1 through ES6. The number of falls (F) during each condition was also recorded.

Secondary Outcomes

Gait was assessed by using a set of tests designed to evaluate gait velocity, timed stair climbing, ease of gait (self-assessed with the visual analog scale [VAS]), and the need for an assistive device. Gait velocity was assessed while subjects walked at their most comfortable pace for 20m by using their usual assistive device and orthoses. Timed stair climbing was determined while subjects went up and down a set of 10 stairs.

Quality of life (QOL) was assessed by using the Nottingham Health Profile[26] (NHP). Only the global score was calculated.

Outcomes were determined at baseline and immediately after completion of the rehabilitation program.

Statistical Analysis

The percentages of improvement obtained after completion of the rehabilitation program were calculated for all the outcomes except ES1 through ES6. For ES1 through ES6, the gain value was chosen, because the percentage of improvement was impossible to calculate (initial values were sometimes equal to zero). The Student *t* test for paired data was used to compare the values obtained before and after program completion. The Mann-Whitney *U* test was used to compare the vision-deprived and the free-vision groups; patients with right- and left-hemisphere lesions; and patients with a lesion involving, or not involving, the vestibular cortex. Age and time since stroke were measured by their median and interquartile range (IQR). For these 2 parameters, the vision-deprived and the free-vision groups were compared by using the Student *t* test for unpaired data and the Fisher exact test for qualitative data (sensitivity and motor control).

The correlations between the improvement of the global score (ΣES) and the improvement of gait velocity, cadence, timed stair climbing, and quality of gait were explored by the Spearman rank correlation test. For all tests, the significance level was fixed at 5%, by using SAS StatView software,[c] or Cytel StatXact software.[d]

RESULTS

Patient Characteristics at Baseline

We recorded baseline data for 21 patients, but 1 patient was excluded for chest pain. Twenty patients were therefore assigned to the vision-deprived or to the free-vision group. All were fully evaluated, except for 1 patient in the vision-deprived group whose knowledge of French was not sufficient to enable him to understand the questions concerning self-evaluation of

Table 1: Outcome Measures Before and After the Rehabilitation Program for the Vision-Deprived and the Free-Vision Subgroups (n=10 for each)

	Free-Vision Group			Vision-Deprived Group	
	Before	After	*P**	Before	After
ES1	93 (3)	91.5 (4)	.01	91.5 (3)	94 (4)
ES2	87 (8)	88 (3)	0.4	88 (8)	92 (6)
ES3	87 (11)	87 (8)	0.9	87.5 (6)	90.5 (6)
ES4	78 (5)	79 (9)	.04	75 (16)	81 (7)
ES5	27 (52)	46 (31)	.08	28 (57)	61.5 (21)
ES6	6 (57)	32 (63)	0.5	20.5 (43)	56.5 (57)
F5	1 (2)	0.5 (1)		1 (3)	0 (0)
F6	2.5 (3)	1.5 (3)		2 (2)	0 (3)
ΣES	116.5 (82)	152.5 (77)	0.1	118 (87)	187 (69)
Gait velocity (m/s)	0.66 (0.32)	0.76 (0.29)	0.1	0.56 (0.25)	0.68 (0.12)
Timed stair climbing (s)	21.5 (15.7)	25.7 (18)	0.4	29.5 (16.3)	26.2 (5.5)
Quality of gait (VAS)	0.5 (0.2)	0.6 (0.4)	0.9	0.5 (0.2)	0.6 (0.2)
NHP	151.3 (148.7)	76.1 (105.7)		141.6 (142.0)	150.0 (217.9)

NOTE. Values are median (IQR).
Abbreviations: ES1, eyes open, fixed supporting surface; ES2, eyes closed, fixed supporting surface; ES3, sway-referenced vision, fixed supporting surface; ES4, sway-referenced supporting surface, normal vision; ES5, eyes closed, sway-referenced supporting surface; ES6, sway-referenced vision and supporting surface; F5 and F6, number of falls in conditions 5 and 6.
*Comparison of the improvement obtained between the 2 groups after completion of the rehabilitation program.

ease of gait and the QOL. The baseline characteristics of the participants were similar in the 2 groups. In the vision-deprived group, median age ± IQR was 49.5±10 years, time since stroke was 20.5±25 months, FIM score was 116.5±3, motor control was 27±2, and sensitivity was 12±2; in the free-vision group, median age was 49±17 years, time since stroke was 20.5±10 months, FIM score was 114±7, motor control was 27±5, and sensitivity was 12±2.

Comparative Improvements in Balance in the Vision-Deprived and Free-Vision Groups

The scores and the number of falls in SOT 5 and SOT 6 and gait velocity and quality improved significantly for the whole group (table 1). Under all 6 sensory conditions, the gain in the vision-deprived group was greater than in the free-vision group (fig 1). It was significantly greater in SOT 1 (*P*=.01) and SOT 4 (*P*=.04) and tended to be greater in SOT 5 (*P*=.08).

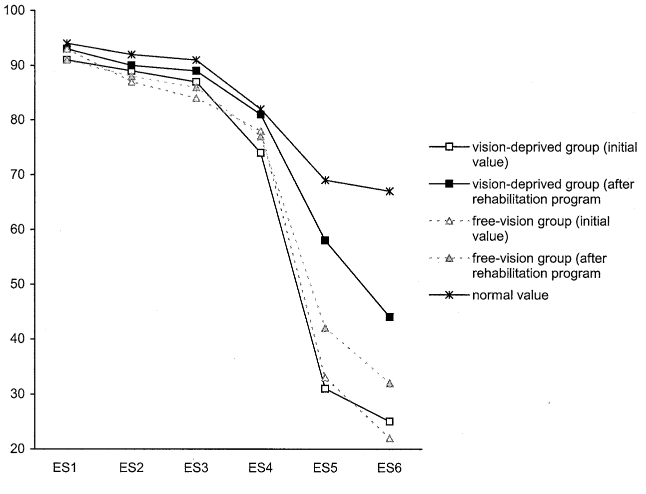

Fig 1. Equilibrium scores before and after the rehabilitation program for the 6 sensory conditions. A score of 100 means no sway, whereas 0 indicates sway beyong the limits of stability.

Comparative Improvements in Gait and QOL in the Vision-Deprived and Free-Vision Groups

The difference between the 2 groups with regard to the improvement in gait and QOL was not significant. Before implementing the program, 12 patients needed a single-point cane; at the end of the program, 1 had stopped using it.

Correlations Between Improvements in Balance and Improvements in Gait and QOL

The improvement of balance correlated with the improvements in gait velocity (r=0.4, P=.03) and timed stair climbing (r=0.5, P=.01).

Effects of Motor Control and Sensitivity, FIM Instrument, Age, Time Since Stroke, Side of Lesion, and Location of Stroke

None of these parameters affected the results of the program.

DISCUSSION

The results of the balance rehabilitation program were compared in patients with hemiplegia deprived of visual cues and in patients with free vision. Balance and gait improved significantly in all patients, but those who completed the program with visual deprivation had better balance results than those who completed it with free vision.

The choice of patients who had experienced their stroke more than 12 months before the study was intended to minimize the confounding effect of recovery on balance performance. Patients were homogeneous for age and level of recovery: all could walk without human assistance, and the range of their FIM scores was small. The same amount of rehabilitation was given to the vision-deprived and the free-vision groups, the only difference being the visual modality. This ensured that any between-group differences in the results were caused by this modality and not by the amount of rehabilitation.

The main outcome measure was balance performance, evaluated on the EquiTest. This platform is a measurement tool that is useful for community-dwelling patients because it tests their reactions to sensory perturbations that resemble those encountered in everyday life—for example, in the dark, on irregular surfaces, or during public transportation. NeuroCom has reported high intratrial reliability[27-29] and Ford-Smith et al[30] found 1-week test reliability to be fair to good, except for SOT 3. We found a link between improvements in gait velocity and timed stair climbing and improved balance in EquiTest, which supports the value of this test.

As stated earlier, balance and gait improved significantly in both the vision-deprived and the free-vision groups after completion of the rehabilitation program. The possibility of improving balance or gait a long time after stroke has been shown after specific rehabilitation,[11-15] but in our study the results are of particular interest because the methods of evaluation were independent of the method of rehabilitation. In our rehabilitation program, balance training did not take place on a platform, and gait was not specifically trained. All patients appreciated and completed the program. Among the factors that may have influenced the results of the rehabilitation, we found that they were not affected by age, time since stroke, motor and sensitivity levels, disability before training, side of hemiplegia, or vestibular cortex lesions. The possible link between the effectiveness of the rehabilitation program and a lesion involving the vestibular cortex was investigated because of the function of the vestibular cortex in the integrated vestibular information, and because of its wider importance in multisensory integration.[31-36] Nevertheless, no definite conclusions can be drawn from our results because of the small size of the subgroups.

Our findings showed that the rehabilitation program with visual-cue deprivation seemed more effective than the same program with free vision: after vision-deprived training, balance was significantly better in the SOT 1 and SOT 4. It was also better in SOT 5 and SOT 6, but the size of the sample was probably too small to reach significance. This finding suggested that the patients improved their integration of somatosensory and vestibular inputs and that the program enabled them to use the pertinent input (somatosensory, vestibular, visual) and to become less reliant on visual input.

Several mechanisms, which lead to excessive reliance on visual input for patients with hemiplegia, may be evoked.[21] The effect of impairment of somatosensory[37] or vestibular input integration[25,38-40] has already been discussed. Elementary sensory impairment (vestibular or somatosensory) as well as postural imbalance may be caused by higher-level impairment of sensory organization. Postural control is in fact built up by the integration of somatosensory, vestibular, and visual information.[41] Most of the time, these items of information are functionally redundant, but sometimes they are in conflict. A general central process has been suggested to resolve sensory conflicts, by synthesizing information from disparate sensory modalities and combining efferent and afferent information.[42]

However, we tend to think that the predominant influence of visual input constitutes a natural compensatory strategy for coping with initial imbalance and that traditional rehabilitation reinforces this excessive visual reliance by focusing on visual compensation rather than restoring the normal use of all sensory inputs. Visual influence is known to become predominant when afferent input from other sources is reduced, whatever the cause. This occurs, for example, in patients with an impaired somatosensory system after neuropathy, in patients with bilateral loss of labyrinthine function, or in healthy subjects during space flight.[43] Visual influence is also predominant in aging,[44] probably because of the global impairment of postural systems. Our suggestion that excessive reliance on vision is an attempt to compensate for defective balance is supported by our observation that this reliance is reversible after a vision-deprived balance rehabilitation program. Such a program may be the equivalent of constraint-induced movement therapy of the upper limbs.[45] This therapy, which combines immobilization of the unaffected arm with intensive training of the affected arm, is based on evidence, from studies in both animals and humans with brain lesions, that reorganization of the cortex is use dependent and task specific.[46,47] With regard to balance, one may assume that patients spontaneously continue to use compensatory visual strategy and that any intrinsic recovery that occurs remains masked. In our study, visual deprivation combined with intensive balance training may have stimulated a pathway of balance control that had not been trained until the onset of stroke, thus unmasking an existing but functionally inactive pathway.

CONCLUSIONS

Our study showed that balance rehabilitation in patients with longstanding hemiplegia may be more effective with visual deprivation than with free vision. The deprivation probably induces patients to increase their use of somatosensory and vestibular information to make up for the absence of a visual compensatory strategy. Additional studies need to be performed to confirm these results and to determine whether the improvement is maintained over time. The optimal timing for using this type of intervention has to be investigated. Our findings provide insight into balance after stroke and may help improve the rehabilitation programs. Physical therapy programs focusing on balance in patients with hemiplegia should consider including exercises to be performed under conditions of visual deprivation.

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Suppliers

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