Effects of Visual Biofeedback Therapy on Postural Balance of Stroke Patients

Hamed Ghomashchi [1*]

1. Assistant Professor, Faculty of Industrial and Mechanical Engineering, Islamic Azad University, Qazvin Branch, Qazvin, Iran.

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ABSTRACT

Purpose: Postural balance deficit is one of the common post-stroke disabilities. Providing visual biofeedback while balance activities are performed is a way to improve postural balance disorders following stroke. But among the research published, there is incoherency about the positive effects of visual biofeedback therapy. The purpose of this study was to investigate the effects of using visual biofeedback as an adjunct to physical therapy exercises on recovery of postural balance of stroke patients.

Methods: A total of thirty-one hemiplegic stroke patients were included in this study and randomly assigned into case and control groups. Both groups received four weeks conventional physical therapy interventions and balance training exercises. During balance training, the case group received visual biofeedback, whereas the control group did not receive visual information. Balance performance of stroke patients were examined quantitatively using the Equi-Test testing system and Biodex stability system, walking performance was evaluated by Timed Up and Go tests, and the patients were assessed using the modified Barthel index for activities of daily living. Data were collected before starting, during, and after completion of the rehabilitation program. Repeated measure analyses of variance were performed to evaluate rehabilitation effects and independent samples T tests were done to quantify the effects of visual biofeedback.

Results: No significant differences between the groups were detected in any of the outcome variables after completion of the program. Noticeable improvements were found in dynamic balance function, mobility, and activities of daily living of both groups, whereas no statistically significant improvements were found in static balance after rehabilitation.

Conclusion: Both rehabilitation protocols created advances in the postural control system of stroke patients. Visual biofeedback balance training did not produce extra advantage for balance ability of participants who received this treatment program in comparison with those who were treated without visual biofeedback. The results showed that dynamical tasks scores and activity-based measures better than static balance measures reflect the recovery effects.

Key Words:

Stroke,
Rehabilitation,
Visual Biofeedback,
Balance,
Postural Sway.

1. Introduction

Stroke is a leading cause of death and disability for men and women of all ages, classes, and ethnic origins [1]. Most stroke survivors suffer from sensorimotor, cognitive, and emotional problems which make limitations in activities of daily living. Many attempts have been made to evaluate the changes in postural control in hemiplegic patients after stroke [2-10] . One of these post-stroke residual disabilities is postural balance impairment which significantly increases the risk of falling and may lead to dangerous consequences like hip fracture.

* Corresponding Author:
Hamed Ghomashchi, PhD
Room 205, Faculty of Industrial and Mechanical Engineering, Islamic Azad University, Qazvin Branch, Pajooheshgaran Blvd., Nokhbegan Blvd., Daneshgah Ave., Barajin, Qazvin, Iran.
Tel: +98 (912) 607 37 41 / Fax: +98 (281) 367 00 51
E-mail: ghomashchi@qiau.ac.ir

The goal of after-stroke rehabilitation programs is functional recovery of the postural control system, reestablishment of balance function, and increase of movement control. Conventional physical therapy exercises providing tactile and verbal cues do not actively engage the patient, so it is necessary to offer them more effective rehabilitation programs that recruit various mechanisms and neurophysiologic sensory systems that contribute to stability during quiet standing and respond to internal or external perturbations. Biofeedback therapy, in which visual or auditory feedback is provided while balance activities are performed, is one of these treatment programs that fully engage the patient during rehabilitation. It is shown that visual feedback forces the stroke patients to become more aware of their weight bearing asymmetry and will help them to become more symmetrical [5, 11], but the research publications reported incoherent results about the effectiveness of visual biofeedback therapy on regaining postural balance after stroke.

Many observational cohort studies showed that visual biofeedback training is an effective method for improvement of postural balance following stroke [12-14]. Additionally, some well-performed randomized controlled trial (RCT) studies, which compared the effectiveness of visual biofeedback rehabilitation program with conventional physical therapy, reported benefits for the patients who treated with augmented visual biofeedback such as its effects on closed eye posturographic measures [15], persistent improvements in dynamic stability measures and functional scores [16, 17], reduction in asymmetry and sway in task performance [18], reduction in postural sway measures [11, 19], and improvements in stance symmetry and daily living activities [11]. On the other hand, many RCT studies found that providing extra vision does not enhance the effects of conventional physical therapy and has no additional benefit for the patients [20-22].

However, since there is no certainty about the positive effects of visual biofeedback training as an adjunct to conventional physical therapy exercises of stroke patients, it is necessary to provide scientific evidence for the effectiveness of this treatment program before advising it to the patients. In this study, the effects of a combination of visual biofeedback with balance training using a variety of linear posturographic measures and clinical scores were investigated to find that whether extra vision feedback would have an added value in recovery of postural balance of stroke patients.

2. Methods

2.1. Participants

40 to 75 year-old stroke patients with a first hemispheric intracerebral infarction or hematoma and with less than one year post-stroke time who were volunteer to participate in this study were referred to the Tabassom rehabilitation clinic and examined according to our inclusion criteria. The recruited patients were physiologically stable, able to stand without assistance for at least five minutes, able to communicate with therapist and had good visual and auditory acuities. Cognitive state and distance visual acuity were measured by the mini mental state examination (MMSE) and distance acuity chart (Snellen chart), respectively [23]. The patients with a history of orthopedic or other than stroke neurological problems, hypertension and diabetes and those who used BIODEX stability system or other visual biofeedback systems before were excluded. The patients with recurrent strokes, bilateral hemispheric infarction or hematoma, cerebral or brain stem lesions, lacunar or total anterior circulation infarct (TACI), and those with significant visual field or hemi neglect problems were also excluded. Prior to participation, individuals signed an informed consent form approved by the ethics committee of the school of medicine of Tarbiat Modares University.

Table 1. Characteristics of stroke patients at the baseline assessment

Group	No.	Age (Years)	a	BMI* (Kg/m²)	a	Post-stroke Time (months)	a
Case	16	64.73 ± 7.43	0.124	24.45 ± 3.52	0.636	3.91 ± 3.27	0.142
Control	15	55.75 ± 13.96		23.37 ± 4.96		8.00 ± 3.42	

*BMI : Body mass index

a : p-value for between-group differences at baseline assessment. No significant difference was found between demographic characteristics of the groups.

Table 2. Linear posturographic measures in follow up assessment

Index	Side	Groups	Baseline	a	During	After	b
PL (Cm)	Planar	Case	41.52 ± 12.36	0.934	40.81 ± 9.83	38.21 ± 8.74	0.349
		Control	40.78 ± 21.60		40.17 ± 19.87	36.83 ± 15.01	0.328
A (Cm)	AP	Case	1.95 ± 0.84	0.351	1.99 ± 1.04	1.48 ± 0.49	0.127
		Control	1.52 ± 0.32		1.41 ± 0.77	1.29 ± 0.34	0.534
	ML	Case	1.92 ± 1.88	0.421	1.34 ± 0.86	1.06 ± 0.50	0.149
		Control	1.12 ± 0.45		1.04 ± 0.78	1.11 ± 0.45	0.855
V (Cm/S)	AP	Case	1.43 ± 0.38	0.898	1.45 ± 0.32	1.36 ± 0.32	0.412
		Control	1.40 ± 0.68		1.43 ± 0.72	1.29 ± 0.50	0.364
	ML	Case	1.23 ± 0.44	0.970	1.17 ± 0.27	1.11 ± 0.26	0.420
		Control	1.24 ± 0.66		1.17 ± 0.48	1.11 ± 0.42	0.400
CEA (Cm^2)	Planar	Case	1.13 ± 0.63	0.114	1.97 ± 1.74	1.06 ± 0.71	0.221
		Control	2.09 ± 1.54		1.11 ± 1.06	1.08 ± 0.66	0.382
f_{mean} (Hz)	AP	Case	0.44 ± 0.12	0.639	0.47 ± 0.19	0.51 ± 0.12	0.278
		Control	0.48 ± 0.24		0.61 ± 0.22	0.52 ± 0.15	0.144
	ML	Case	0.54 ± 0.25	0.473	0.61 ± 0.28	0.66 ± 0.19	0.336
		Control	0.66 ± 0.37		0.58 ± 0.16	0.54 ± 0.18	0.490
$f_{50\%}$ (Hz)	AP	Case	0.26 ± 0.11	0.525	0.26 ± 0.12	0.30 ± 0.10	0.485
		Control	0.32 ± 0.23		0.37 ± 0.24	0.29 ± 0.13	0.393
	ML	Case	0.30 ± 0.17	0.612	0.35 ± 0.14	0.35 ± 0.13	0.588
		Control	0.36 ± 0.33		0.38 ± 0.08	0.23 ± 0.16	0.406
$f_{99\%}$ (Hz)	AP	Case	2.51 ± 0.72	0.990	2.81 ± 1.22	2.89 ± 0.63	0.356
		Control	2.52 ± 1.01		4.39 ± 1.72	3.71 ± 1.68	0.075
	ML	Case	4.04 ± 3.32	0.977	5.77 ± 5.98	6.83 ± 6.16	0.279
		Control	3.99 ± 2.66		3.50 ± 1.79	6.28 ± 6.33	0.657
f_d (Hz)	AP	Case	0.19 ± 0.09	0.308	0.20 ± 0.13	0.22 ± 0.09	0.708
		Control	0.25 ± 0.15		0.15 ± 0.11	0.20 ± 0.07	0.439
	ML	Case	0.19 ± 0.11	0.372	0.22 ± 0.13	0.28 ± 0.22	0.465
		Control	0.27 ± 0.23		0.23 ± 0.02	0.15 ± 0.14	0.339
P (Cm^2)	AP	Case	9.30 ± 2.24	0.738	9.52 ± 3.69	10.56 ± 2.24	0.302
		Control	9.91 ±4.97		12.59 ± 3.86	10.80 ± 2.78	0.132
	ML	Case	11.02 ± 5.09	0.459	12.23 ± 5.51	13.65 ± 3.88	0.267
		Control	13.56 ± 7.33		16.06 ± 8.97	10.67 ± 3.88	0.469

PL: Path length, A: Sway range, V: Mean sway velocity, CEA: 95% confidence ellipse area, fmean: Mean frequency, f50%: Centeroid frequency, f99%: Frequency below which 99% of overall power of the signal is preserved, fd: dominant frequency, P: Overall power. AP: Anterior-posterior direction, ML: Medial-lateral direction.

PHYSICAL TREATMENTS

a : p-value for between-group differences at baseline assessment. No significant difference was found between the groups for each calculated measure (a >0.05).

b : p-value for within-group differences. No significant within-group difference across rehabilitation period was found for each calculated measure (b >0.05).

Table 3. The percentage of stance asymmetry in follow up assessment

Index	Groups	Baseline	a	During	After	b
LLA (%)	Case	28.42 ± 21.28	0.752	24.23 ± 19.47	20.55 ± 14.09	0.236
	Control	32.22 ± 15.93		17.00 ± 12.40	27.97 ± 18.70	0.081
NLL (%)	Total	64.72 ± 9.76		61.15 ± 8.87	61.26 ± 7.55	

LLA: Limb load asymmetry, NLL: Non-paretic limb load.

a: p-value for between-group differences at baseline assessment. No significant difference was found between the groups (a >0.05).

b : p-value for within-group differences. No significant within-group difference across rehabilitation period was found (b >0.05).

Thirty-one stroke patients were included in this study and divided into two groups, the case group (N=16) and the control group (N=15), based on consecutive random assignment by flipping a coin [24]. Detailed descriptions of these two groups are listed in Table 1.

2.2. Study Design

Patients in both groups received 12 treatment sessions over four weeks and each session lasted approximately one hour. The rehabilitation program began with conventional therapeutic interventions including massage of the paretic limbs, electrical stimulation, ultra sound therapy, and matt exercises for at least 45 minutes, and followed by 15 minutes balance training exercises. During a month of treatment period, the patients' postural control system was quantitatively assessed three times; before starting the rehabilitation program (baseline assessment), at the middle of the program (immediately after the 6th session), and after completion of the job (immediately after the 12th session), and their functional abilities were assessed before and after treatment period.

2.3. Balance Training

Balance training was performed using the Biodex stability system (BSS) (Biodex Medical System, Inc., Shirley, New York). The BSS uses a circular platform that is free to tilt about the anterior-posterior (AP) and medial-lateral (ML) axes, simultaneously. The monitor of the BSS provides visual information regarding the patient's position on the circular tilting platform. Also, it is possible to vary the stability of the platform by varying the resistance force applied to the platform. In this study, the most stable level was set. Each practice session lasted 15 minutes and consisted of two training routines: postural stability training to enhance the patient's ability to control the platform angle and maintain balance, and weight shift training to improve the patient's ability to shift weight in ML, AP, and diagonal planes. During balance training, the patients in the case group received visual biofeedback from the monitor of the BSS, but for the control group, the monitor was covered and the patients could not see the monitor, so, the BSS acted as a simple balance board.

2.4. Testing

2.4.1. Quantitative Tests

A. Steadiness

Postural fluctuations of stroke patients were evaluated using a dynamic dual force platform (SOT#1, Equi-Test testing system, NeuroCom International Inc., Clackamas, OR). The system was equipped with a movable visual surround and support surface that could rotate in the anterior-posterior plane. Two 22.9 × 45.7 cm force plates which connected by a pin joint were used to collect the AP and ML components of the center of pressure (COP) coordinates at 100 Hz. Participants were instructed to stand in an upright posture in a standardized foot placement on the platform based on each subject's height according to the manufacturer's protocol. Participants stood barefoot with their arms relaxed at their sides, their eyes open and looking straight ahead fixed on a point in front of them. During the test, they were instructed to concentrate on their stability, stand freely, and have no other mental tasks. In each assessment session, participants performed a set of 3 trials of the quiet standing task, each lasting 20 seconds and they had rest between trials if they need.

Table 4. Stability indexes in follow up assessment

Index	Groups	Baseline	a	During	After	c	b
LLA (%)	Case	2.87 ± 0.52	0.282	2.04 ± 0.72	2.00 ± 0.85	0.636	0.003
	Control	2.53 ± 0.55		1.98 ± 0.79	1.78 ± 0.64		0.006
MLSI (Deg.)	Case	2.56 ± 0.59	0.889	2.07 ± 0.87	1.84 ± 0.54	0.693	0.006
	Control	2.51 ± 0.86		2.11 ± 0.59	1.97 ± 0.49		0.131
OSI (Deg.)	Case	3.85 ± 0.78	0.550	2.78 ± 1.13	2.59 ± 0.87	0.974	0.001
	Control	3.57 ± 0.89		2.79 ± 0.89	2.58 ± 0.71		0.014

APSI: Anterior-posterior stability index, MLSI: Medial-lateral stability index, OSI: Overall stability index. PHYSICAL TREATMENTS

a : p-value for between-group differences at baseline assessment. No significant differences were found between stability indexes of two groups at base line assessment (a >0.05).

b : p-value for within-group differences. Significant within-group differences were found across rehabilitation period for all calculated measures (b <0.05), except MLSI of control group.

c : p-value for between-group differences after completion of rehabilitation period. No significant differences were found between stability indexes of two groups after rehabilitation program (c >0.05).

2.5. Posturographic Data Analysis

Prior to all analyses to remove stationary effects, the mean and linear trends of the COP time series were removed. Linear posturographic measures including sway path length (PL), sway range (A), mean sway velocity (V), and 95% confidence ellipse area (CEA), as well as frequency domain measures including overall power (P), mean (fmean), centeroid (f50%) and dominant (fd) frequencies and the frequency below which 99% of overall power of the signal is preserved (f99%), were calculated.

B. Dynamic Balance

Dynamic balance was assessed using the measures obtained from the BBS. The BSS allows the clinicians to asses a patient's neuromuscular control in a closed chain multi plane test by quantifying the ability of the patient to maintain stability on an unstable surface with minimum postural sway. The BSS calculates standard deviations of degrees of tilt of the foot placement platform from level, about AP and ML axes and reports them as anterior-posterior stability index (APSI), medial-lateral stability index (MLSI), and overall stability index (OSI). The larger standard deviation may be indicative of poor neuromuscular response and vice versa. The testing protocol was consisted of three trials of 20 seconds and the subjects were allowed to rest between the trials. If the subjects lost their balance during the testing, the trial was deleted.

C. Symmetry

Body weight distribution of stroke patients during quiet standing was examined to investigate whether or not visual biofeedback balance training enhances stance symmetry. Vertical ground reaction forces exerted by each limb in a 65-second quiet standing test were collected using the above mentioned dual force platform to calculate body weight distribution. The first five seconds data after standing of the subjects on the force platform were discarded, and the remaining sixty seconds data were used to calculate the percentages of limb load asymmetry (LLA) and non-paretic limb load (NLL).

2.4.2. Functional Scores

A. Timed Up and Go (TUG)

To evaluate mobility, the participant was seated in a standard-height armchair and then instructed to stand independently and walk as quickly and safely as possible for a distance of 3 meters (with an assistive device if needed) and to walk back and sit down again. The time from leaving the chair until they returned to the

Table 5. Functional measures, TUG and MBI, in follow up assessment

Index	Groups	Baseline	a	After	c	b
TUG (Sec.)	Case	35.27 ± 9.94	0.429	24.46 ± 8.27	0.751	0.004
	Control	39.77 ± 7.52		25.88 ± 3.80		0.011
MBI	Case	65.64 ± 18.07	0.728	84.27 ± 9.90	0.398	0.000 (4.41E-04)
	Control	62.00 ± 15.64		88.75 ± 2.50		0.044

TUG: Timed up and go, MBI: Modified Barthel index.

PHYSICAL TREATMENTS

a: p-value for between-group differences at baseline assessment. No significant differences were found between functional measures of two groups at base line assessment (a >0.05).

b: p-value for within-group differences. Significant within-group differences were found across rehabilitation period for functional measures (b <0.05).

c: p-value for between-group differences after completion of rehabilitation period. No significant differences were found between functional measures of two groups after rehabilitation program (c >0.05).

same position was recorded using a stopwatch. This test was performed before and after the rehabilitation program, in 3 trials, and the average time of the trials was calculated.

B. Modified Barthel Index (MBI)

Assessment of activities of daily living (ADL) in post stroke patients is important for quality of care and for measuring the outcomes of stroke treatment. Functional outcome measures include the Barthel Index, PULSES profile, the Katz ADL scale, and the functional independence measure (FIM). All have proven reliability in measuring disability after stroke [1]. The MBI achieved greater sensitivity and improved reliability than the original version [25, 26]. It is useful in evaluating a patient's state of independence before treatment and his progress during and after the treatment. It is composed of 10 items with varying weights to evaluate personal toilet, bathing, feeding, getting onto and off the toilet, ascending and descending stairs, dressing, controlling bowls, and controlling bladder. The MBI is a cumulative score calculated by summing each item score, and higher scores represent a higher degree of independency. This assessment was performed before and after rehabilitation.

2.6. Statistical Analysis

All statistical analysis were performed using the SPSS software package version 11.5 (SPSS Inc., Chicago, IL, USA). At baseline assessment, normality of results were checked, and independent samples T tests with 0.05 significance level were used to assure that the case and the control groups are comparable before the recovery. Sphericity of conventional posturographic measures, LLA and stability indexes as well as normality of TUG and MBI values were checked. Repeated measures analysis of variance (ANOVA) with within-subject factor Rehabilitation (three follow up levels: baseline, during, and after) and paired samples T tests with 0.05 significance level were performed to evaluate the rehabilitation effects. In case of significant differences with follow up assessments, separate independent samples T tests with 0.05 significance level were performed to quantify the effects of visual biofeedback.

3. Results

Demographic analysis shows that both groups were comparable and there was no significant difference between demographic characteristics of the groups (Table1). The results of calculating linear posturographic measures in follow up assessments and the differences of statistical analysis between the two groups and rehabilitation effects are presented in Table 2. Independent samples T tests show that the case and the control group were comparable in all posturographic characteristics at baseline assessment. The results of repeated measures ANOVA indicate that none of the linear posturographic measures were affected significantly by rehabilitation.

The percentages of LLA and pooled NLL in follow up assessments are shown Table 3. Independent samples T tests result indicate that the stance asymmetry was not different between the groups before starting the rehabilitation program, and base on the results of repeated measures ANOVA, no significant improvement was also observed in asymmetry values following rehabilitation in both groups.

Table 4 shows the stability indexes of both the case and the control groups in follow up assessments. At baseline assessment, independent samples T test results indicate that both groups have similar dynamic balance performance. The results of repeated measures ANOVA show that with follow up assessments, all stability indexes (except MLSI of the control group) decreased significantly. Although it may show significant improvement of dynamic balance after the recovery program, comparison of the groups after rehabilitation revealed that the dynamic balance characteristics of the patients in the case group were not different from characteristics of the control group.

The results of functional assessments, TUG and MBI, are reported in Table 5. Paired samples analysis revealed that both recovery programs significantly improved functional indicators. Comparison of the groups before the treatment indicates that both groups had the same level of independency and functional mobility. Independent samples analysis of these scores after rehabilitation show that both treatment programs made identical results in recovery of stroke patients, and no effect in favor of visual biofeedback training could be observed.

4. Discussion

In this study, the effects of providing visual biofeedback in balance training program, its efficacy on balance recovery and mobility of stroke patients, and the possibility of recommending it as an adjunct to rehabilitation protocols were investigated. The values of posturographic measures of elderly stroke patients who participated in our study, in both time and frequency domains, were compared with the reported values in the literature and the results indicate that our values are within the range of reported values for hemiparetics and also higher than those of healthy elderlies [2, 7, 15, 27, 28].

Pooled asymmetry values indicate that at baseline assessment, 64.72±9.76% body weight and the end of rehabilitation period, 61.26±7.55% body weight was applied on the nonparetic leg of the patients, and they applied fewer load on the paretic leg in the standing position. Similar results have been reported in many studies [5, 7, 8, 11, 12, 18, 21, 27, 29-31], and our values are approximately consistent with the values which were found by Sackley et al. and Genthon et al. [11, 31]. Also, the percentage of LLA in our study, particularly at baseline assessment is within the Marigold's et al. reported range [8]. Several reasons or a combination of them have been stated for asymmetrical weight bearing such as muscle weakness [7, 27, 32], somatosensory system deficits [6, 10], abnormality in motor control of one side of the body [33], and spatial neglect [34, 35]. These deficits may force the patients to adopt a wrong postural strategy which is a compromise between relieving (disusing) the paretic limb and overloading (overusing) the nonparetic limb [7]. So, rehabilitation [10-22, 29, 30, 36-38], sensory manipulation and stimulating one or some of above mentioned items [33, 35] may help the patients to overcome this wrong strategy, to reduce stance asymmetry and to enhance postural balance. Although both groups in the current study received physical therapy interventions aimed at improving muscle force, it seems that increasing the muscle force did not have significant impact on reduction of postural asymmetry. Thus, in agreement with many studies [29, 30, 37], we can say that muscle strengthening have minor effects on recovery of stance symmetry and balance, and mechanisms other than the restoration of muscle functions, support functions, and equilibrium reactions of the paretic leg play roles in recovery of standing balance and consequently postural asymmetry, such as more effective muscular compensation through the nonparetic leg [7, 30], adapted multisensory integration [10, 30], progressive internalization of the altered body dynamics and increased self confidence [30], and vestibular stimulation [33, 35].

Repeated measure analysis indicate that there are no statistically significant differences in any of the linear posturographic measures despite different interventions and also the stance asymmetry in neither of the groups improved significantly. But if we step back and look at the results more carefully, we will find patterns in outcome variables. There is a reduction, but not to a statistically significant level, in the values of time domain posturographic measures and asymmetry indexes in both groups after one month of rehabilitation and this may indicate a tendency for improvement in balance performance. We expected this reduction to be associated with reductions in the values of frequency domain measures especially mean, median, and 99% power frequencies, but our expectations were not granted. To shed light on this subject, it should be noted that many studies found that the mean frequency and the 95% power frequency are age-related characteristics and increase with age [28, 39]. If aging as a path to frailty [40] increases frequency characteristics of postural sway, then stroke as another way of deterioration of postural control system will do so and recovery may decrease the values of frequency measures. This pre-post steeping pattern, although not statistically significant, is seen in most of frequency domain sway characteristics of control group especially along the ML direction. This may imply that not having visual clues training program (simple balance board) better than feedback program improves balance performance (especially along the lateral direction) of stroke patients.

Our results, from a purely statistical point of view are in contradiction with the results of many workers who reported significant reductions in postural sway and stance asymmetry after rehabilitation program regardless of being associated with visual biofeedback or not [11, 15, 22, 37]. Since the results of linear posturographic measures in the time and frequency domains and also asymmetry indexes indicate that neither of the training programs could produce significant advantages, a misinterpretation may arise that not only visual biofeedback had no significant effect on postural asymmetry and stabilometric characteristics, but also balance training did not significantly affect them, whereas many works which mentioned before, found the balance training effective for reduction of inter leg differences and improvement of postural balance. First, it is worth noting that the rehabilitation period in those studies was longer than ours (3 months in DeHaart's study [37] and 2 months in Walker's study [22]), so we think that one month rehabilitation was not enough for us to get the expected results and it was a bit soon for assessment of postural recovery, because linear posturographic measures and asymmetry indexes are not sharp enough to detect subtle changes that may happen following rehabilitation; for example, Cheng et al., like us, did not receive the prompt response after 3 weeks of rehabilitation program [17]. However, our outcomes from stabilograms indicate equivalency of balance performance despite different interventions and imply that visual feedback therapy should not be favored over conventional therapy. Next, although improvements in postural balance characteristics (in terms of symmetry, steadiness and stability) are therapeutic goals of the therapists, it should be kept in mind that the type of treatment protocol will have an impact on the effectiveness of the treatment modality and the therapist needs to choose the possible measure for patient progress and then designs the treatment protocol [38]. The researchers who reported significant effects in favor of visual biofeedback therapy, except Serivasta [14], used the same training and testing equipment, so the patients became familiar with the equipment and this might be the reason for the effectiveness of their training program. However, we believe that dynamic stability training on the BSS better improves postural adjustment mechanisms, enhances the coordination of body segments during unstable standing (interactions between internal and external perturbations), and possibly better than force platform training covers the goals of balance training programs which are: i) Increasing the activity of the receptor organ in the inner ear during exercise, ii) Activating the integrating mechanism in the central nervous system by offering varying sensory inflow (by facilitating visual information for the case group or activating vestibular and somatosensory systems in the control group), and iii) Training the neuromuscular effecter system [16]. Apart from these items, Genthon et al. found that the paretic limb has a limited participation in postural stabilization [7], and Garland et al. stated that this limited participation of the paretic side results from a lower overall level of activation in the paretic muscles [29]. We believe that this limited participation can also be enhanced using BSS for weight shift training (by forcing the patients to tilt the support surface of the BSS). In parallel with Garland's findings, Genthon et al. showed that the longitudinal dispersion pattern of the COP displacements under each foot, which is due to the rotating role of ankle joint in the sagittal plane, cannot be seen under the paretic limb of stroke patients [7]. In this regard, we also believe that the BSS training improves the ankle flexor/extensor muscle functions and can modify the wrong adopted postural strategy of stroke patients. The BSS training also improves the performance of hip mechanisms which are the predominant mechanisms in controlling lateral displacements. The stability indexes in follow up assessments in Table 4 verify the above-mentioned items and demonstrate that the postural stability in both groups is improved noticeably (except MLSI in the control group which is also reduced, but not to a significant level). The possible reasons for this recovery might be: i) Increase of muscle function (large enough activation) and therefore, increasing the ability of the muscles to maintain or return back the projection of the center of gravity into the base of support, ii) Make quicker responses to internally and externally induced perturbations, because of a) fast enough switching of motor units, b) improvement in the integrating mechanism in the central nervous system in combining afferent and efferent information, iii) Increasing vestibular and somatosensory systems activity (especially in the control group), and iv) Familiarization of the patients with this type of balance exercise during the rehabilitation program because of using the same test and training procedures, and then simplification of postural reflexes. In a similar study with follow up assessment, Srivastava et al. showed that visual biofeedback balance training using BSS not only improved the balance ability of stroke patients significantly, but also left a persistent effect for a period of three months [14].

Our results do not exhibit significant improvement for MLSI in the control group after rehabilitation. This might be related to the absence of visual flow which could help the integrating mechanism of stroke patients to provide proper sensory integration for overcoming their neuromuscular deficit in the lateral direction. This may imply that visual biofeedback training can positively affect lateral stability which is more compromised following stroke, but this is not convincing enough because comparing the results of MLSI of the groups after the rehabilitation program shows no statistically significant differences between the groups.

Although, linear posturographic measures and asymmetry index do not show significant improvement following intervention in neither of the groups, the clinical score (MBI) and the functional measure (TUG) demonstrated a statistically significant improvement. The results of this study indicate that activities of daily living and mobility of stroke patients are improved in both groups but did not show extra benefits in favor of visual biofeedback therapy, although statistically greater gains were obtained for the measures of the case group. Our findings are in accordance with the results of many works indicating that the mobility of stroke patients (in terms of the 10 meters walking test and gait speed [10, 14, 22, 36], gait performance characteristics [19, 36], walking distance [15], Timed Up and Go [20-22], and Clinical Outcome Variable Scale (COVS) [29]), balance functions on Berg balance scale [14, 20-22, 29], and activities of daily living (in terms of Barthel index [14, 15], functional independent measure [15, 16], and the measure of quality of life (HRQOL)[29, 36]) improves following rehabilitation, and well agree with the results of Kerdoncuff, Chen, Geiger, Walker, and Van Peppen who showed that visual biofeedback therapy afforded no additional benefit to the stroke patients in comparison with conventional balance training and that this method should be favored [15, 16, 20-22].

Our results reveal that standing balance function and locomotion are not interrelated and changes in one might not reflect the changes in the other, but locomotor performance and activity are highly related to dynamic balance ability. Individuals who are afraid of falling when confronted with the tasks of walking and unstable standing which are sources of postural perturbations tend to adopt stiffened and more conscious strategies, whereas they use a more relaxed strategy during quiet standing. After the rehabilitation program, patients learned the proper strategies for overcoming postural perturbations or became skillful in using them, but there was no necessity for the patients to enhance their static balance because they already were able to stand for a while before starting the rehabilitation program. This might be another reason for significant improvement in stability indexes and mobility scores and not significant reduction in static balance measures. However, it seems that dynamical task sores and activity-based measures which measure the patient's ability in challenging tasks and in coping with environment better than quiet standing characteristics reflect the recovery effects.

5. Conclusion

Our findings indicate great improvements in dynamic balance function of both groups of stroke patients after rehabilitation as well as in their mobility and daily living activities. A reduction is also seen in some of static balance characteristics following rehabilitation, but it did not reach a significant level. These results imply that examining the patients via the tasks which challenge the patient's abilities may better demonstrate the effectiveness of a rehabilitation program. More importantly, our results show that inclusion of visual biofeedback in balance training of stroke patients does not make additional benefits in the sense of postural sway, stance symmetry, dynamic balance ability, mobility, and activities of daily living. Finally, the limitation of the present study is that it investigated only a short time rehabilitation period, so future studies with longer rehabilitation time span and after-treatment follow up assessment are needed to further validate of our findings and to investigate that whether the improvements in dynamic balance function are persistent.

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