Effects of Balance Training on Hemiplegic Stroke Patients

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Background: The purpose of this study was to evaluate the delayed effects of balance training program on hemiplegic stroke patients.

Methods: A total of 41 ambulatory hemiplegic stroke patients were recruited into this study and randomly assigned into two groups, the control group and trained group. Visual feedback balance training with the SMART Balance Master was used in the trained group. Bruunstrom staging of affected limb scores and Functional Independent Measure (FIM) scores of each patient were recorded. Quantitative balance function was evaluated using the SMART Balance Master. Data were collected before training and 6 months after completing the training program.

Results: Significant improvements in dynamic balance function measurements were found for patients in the trained group at 6 months after completing the training program. The ability of self-care and sphincter control also improved for patients in the trained group. On the other hand, no significant differences were found in static balance functions between the trained group and control group at 6 months of follow up. The locomotion and mobility scoring of FIM also revealed no differences between the groups.

Conclusion: Dynamic balance function of patients in the visual feedback training group had significant improvements when compared with the control group. Activities of daily living (ADL) function in self-care also had significant improvements at 6 months of follow up in the trained group. The results showed that balance training was beneficial for patients after hemiplegic stroke.

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Key words: balance training, SMART Balance Master, visual feedback, stroke.

To maintain balance in activities of daily living (ADL), posture control is essential, while motor, sensory and higher brain cognitive faculties all contribute to postural control.(1-5) Following stroke, patients lose functions of the motor, sensory and higher brain cognitive faculties to various degrees which leads to diminished balance. It has been documented that hemiplegic or hemiparetic stroke patients presented with more posture sway, asymmetric weight distribution, impaired weight-shifting ability and decreased stability capability.(1,6-9)

The SMART Balance Master is a system designed to provide visual presentation and clues of a client's real-time center of gravity (COG) accurate-

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ly. During the process of weight or posture shifting, the position and movement tracks of COG can be monitored; thus a client can recognize such information by visual feedback to adopt adequate strategies to keep posture control as steady as possible.[10]

Previous reports in the literature[1,11,12] all demonstrated that stance symmetry improved in stroke survivors who were provided with visual feedback training program. As for dynamic gross motor function and ADL performance, whether such training methods offered better outcome than conventional intervention remains controversial.[11,12]

As far as we know, only a few studies have mentioned about the long-term effects of balance training for stroke patients. Therefore, in this study, we evaluated the delayed effects of this training program on balance function of hemiplegic stroke patients.

METHODS

Subjects

A total of 41 hemiplegic but ambulatory stroke patients admitted to the rehabilitation ward were recruited for this study. All patients underwent image studies such as brain computed tomography (CT) or magnetic resonance imaging (MRI) to identify their stroke diagnoses during the acute stage. Those with recurrent strokes, bilateral hemispheric, cerebellar or brain stem lesions, severe spasticity or cognitive deficit, orthopedic or peripheral neuropathy, significant visual field or hemineglect problems were excluded.

All recruited patients were randomly assigned into the control group or trained group. There were 18 patients in the control group and 23 in the trained group.

Equipment

The SMART Balance Master (NeuroCom International, Inc., Clackamas, OR, USA) was used for both balance function assessment and training. It provided objective measurement of the basic components of balance control including the COG, posture alignment, limits of stability (LOS), and rhythmic weight shifts. In our study, the definition of LOS was the maximal distance the subject could lean in any direction without loss of balance.

For static stability assessment, subjects' steadiness was tested under different sensory conditions: eyes open (EO), eyes closed (EC), sway vision (SV: during this process, surroundings moved in a direction relation to the patient's anterior-posterior sway), and sway surface (SS: during this process, the surface moved in direct relation to patient's anterior-posterior sway). Maximal stability was the indicator of center of gravity stability. The absence of sway (100% of maximal stability means most stable, 0% means fall) and the greater the percentage of ankle strategy instead of hip strategy the patient used to maintain balance, the greater the stability the patient had. The COG alignment, indicating where the subject in space relation to center, was presented here with percentage of LOS; the greater the data number, the further the subject was from center.

In the dynamic assessment, axis velocity was the average speed of the subject's COG movement in a specified direction. Directional control (DCL) was defined as the ratio of the actual distance traveled by the COG from the center to endpoint excursion compared with the shortest distance between those two points (a straight line). Subtracting the off-axis distance from the on-axis distance and expressing the differences as a percentage of the actual on-axis distance, as represented by the formula below

DCL={[d-(D-d)]/d} ¡ 100%

d: on-axis distance

D-d: off-axis distance

End point excursion referred to the distance traveled by the COG on the primary attempt to reach a target moving in a different direction in 0.8 seconds. It was expressed as a percentage of 50% of LOS. The first movement was completed when progress towards the target ceased.

Training protocol

Visual feedback balance training with the Smart Balance Master was used in the trained group. Subjects in the trained group were encouraged to maintain their posture steadily and symmetric weight bearing while adapting to different static sensory conditions through verbal or tactile cues. For dynamic function training, the patients were instructed to practice controlling their weight shifts by tracing the moving targets on the screen in every main direction while the condition of LOS set at 50%.

The training protocol was 20 minutes per day, 5 days per week for 2 weeks. In addition to the training protocol, conventional physical therapy and occupational therapy programs including muscle strengthening, therapeutic exercise, and ADL training were provided to all subjects in our study.

Measurement

Bruunstrom staging of affected limbs and scores of Functional Independent Measure (FIM) for each patient were recorded. The balance function was quantitatively evaluated with the Smart Balance Master. Maximal stability, ankle strategy and COG alignment in six different sensory conditions (EO, EC, SV, EO/SS, EC/SS, SV/SS) were assessed for static balance function. Axis velocity, directional control and end point excursion were assessed for dynamic assessment.

Data of patients in the trained group were collected before training and 6 months after completing the training program.

Data analysis and statistics

Data were pooled across subjects according to group (control group and trained group). Differences in the continuous data (age, body weight, body height, and FIM scores) between groups were compared using an Independent sample *t*-test. Differences in the categorical data (gender, Bruunstrome staging, and lesion side) between groups were determined using the Chi-square test. An analysis of variance for repeated measures was performed for each of the outcome measures. The level of significance was set at 0.05.

RESULTS

All subjects' characteristics are listed in Table 1. The mean age in the control group was 55.3 years and 58.7 years in the trained group. There were no significant differences between the two groups in gender, body weight, body height, and Brunnstrom stage of affected limbs. The FIM scores in locomotion and mobility were 19.22 ¡ 7.6 in the control group and 15.05 ¡ 5.74 in the trained group. Scores in self care and sphincter control were 34.11 ¡ 11.69 in the control group and 27.25 ¡ 7.97 in the trained group. The mean duration of stroke was around 3 months in both groups.

Table 1. Characteristics of Subjects

	Control (N = 18)	Trained (N = 23)	*p*
Age (years old)	55.33 ¡ 11.78	58.70 ¡ 10.19	0.343
BW (kilogram)	66.67 ¡ 7.69	63.56 ¡ 7.70	0.233
BH (centimeter)	162.58 ¡ 7.6	164.06 ¡ 5.56	0.512
Gender: F/M	12/6	16/7	0.843
Br U/E IV-VI	7	5	
Br U/E I-III	11	18	0.231
Br L/E IV-VI	14	13	
Br L/E I-III	4	10	0.154
FIM*	34.11 ¡ 11.69	27.25 ¡ 7.97	0.04
FIM+	19.22 ¡ 7.60	15.05 ¡ 5.74	0.063
Duration (months)	3.78	3.00	
Lesions: R/L	11/7	10/13	0.262

Abbreviations: BW: body weight; BH: body height; F/M: female/male; Br: Bruunstrom stage; U/E: upper extremity; L/E: lower extremity; FIM*: Functional Independent Measure in self-care and sphincter control; FIM+: Functional Independent Measure in mobility and locomotion; R/L: right/left hemispheric lesion.

Comparisons of the training effects in static stability of stroke patients are shown in Table 2. Improvement of maximum stability was found in the trained group at 6 months of follow up, although the improvement was not statistically significant. Patients in the trained group could use more ankle strategies to maintain static balance when compared with the control group, especially in SV and SV/SS conditions ($p < 0.05$). It was also noted that the degree of COG alignment deviated to the center decreased in the trained group after training under certain sensory conditions (EC, SV and EC/SS). However, no significant differences in static balance function were found between the control group and the trained group at 6 months of follow up.

Significant improvements in dynamic balance function measurements were found in patients who received visual feedback training at 6 months of follow up. Table 3 shows that the axis velocity, directional control and end point excursion had significant improvement ($p < 0.05$) in the trained group compared with the control group in varied main movement directions at 6 months of follow up.

The mean changes of self-care, sphincter control, locomotion and mobility functions scored by

Table 2. Static Stability for Patients with Different Sensory Conditions

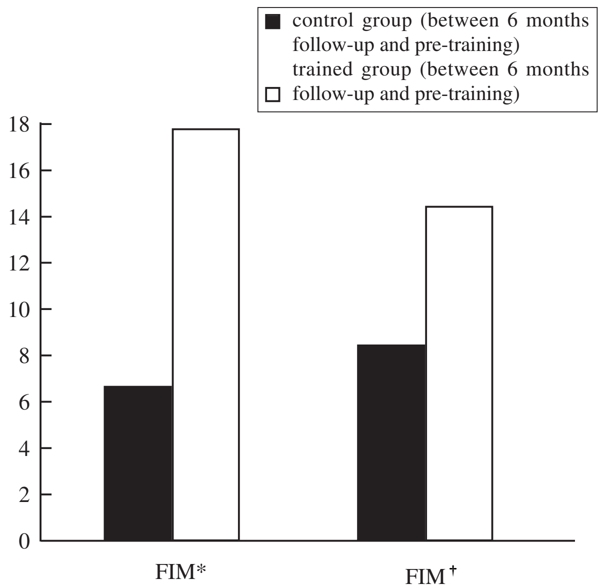
	Maximal stability					Ankle strategy (%)					COG alignment (% of LOS)				
	Pre-training		6 months of follow up			Pre-training		6 months of follow up			Pre-training		6 months of follow up		
	Control	Trained	Control	Trained	*p*	Control	Trained	Control	Trained	*p*	Control	Trained	Control	Trained	*p*
EO															
Mean	91.76	90.86	92.72	91.89	0.823	95.94	95.50	96.72	96.56	0.234	27.75	28.30	27.99	23.47	0.526
SD	4.43	3.20	2.59	6.43		1.55	2.18	2.76	4.53		11.48	11.67	15.73	11.52	
EC															
Mean	88.11	87.73	89.67	89.56	0.990	95.83	93.45	96.11	96.89	0.085	29.36	29.35	28.08	23.83	0.827
SD	5.26	4.00	3.61	5.64		1.89	6.29	2.27	3.10		13.99	14.31	15.13	12.70	
SV															
Mean	82.87	84.29	88.80	87.83	0.480	94.48	93.09	94.89	96.65	0.036	27.06	25.85	24.41	19.26	0.401
SD	11.25	7.51	5.15	3.98		3.11	3.33	3.91	2.05		12.42	10.27	11.79	12.08	
EOSS															
Mean	76.03	74.90	82.43	76.78	0.089	81.71	81.74	84.17	83.56	0.801	30.00	26.65	25.38	19.16	0.718
SD	10.69	10.56	7.91	8.90		5.06	6.73	6.02	4.27		11.62	12.51	17.62	10.04	
ECSS															
Mean	62.11	58.49	71.44	60.93	0.290	69.56	65.90	76.98	74.45	0.637	28.13	27.02	26.71	21.60	0.390
SD	9.82	10.69	10.94	11.94		12.90	14.42	8.25	8.97		10.71	12.95	18.60	11.63	
SVSS															
Mean	58.76	52.80	69.89	60.99	0.970	69.33	60.04	75.18	74.62	0.028	24.56	26.37	29.05	20.61	0.114
SD	11.29	14.85	9.75	13.79		8.46	16.89	5.81	7.28		11.56	12.70	19.88	12.78	

Abbreviations: COG: center of gravity; LOS: limits of stability; EO: eye open; EC: eye closed; SV: sway vision; SS: sway surface; SD: standard deviation

Table 3. Dynamic Stability of Movement in Different Directions

	Pre-training		6 months of follow up		
	Control	Trained	Control	Trained	*p*
Axis velocity					
Right - left	3.27 ¡ 0.97	3.25 ¡ 0.92	3.17 ¡ 1.35	4.11 ¡ 1.42	0.023
Forward - backward	1.48 ¡ 0.57	1.72 ¡ 0.70	1.99 ¡ 1.09	2.37 ¡ 0.94	0.852
Directional control					
Right - left	71.22 ¡ 9.87	67.73 ¡ 12.56	71.44 ¡ 10.84	76.53 ¡ 10.48	0.017
Forward - backward	38.88 ¡ 11.68	39.09 ¡ 18.61	44.78 ¡ 15.91	56.33 ¡ 17.89	0.033
End point excursion					
Right	51.47 ¡ 11.77	38.63 ¡ 16.75	41.00 ¡ 12.21	52.44 ¡ 13.68	0.000
Left	48.12 ¡ 16.15	44.30 ¡ 13.38	48.12 ¡ 14.12	54.00 ¡ 12.58	0.029
Forward	40.75 ¡ 13.89	31.39 ¡ 16.23	48.77 ¡ 8.22	47.94 ¡ 17.95	0.043
Backward	47.90 ¡ 27.10	46.25 ¡ 13.76	38.27 ¡ 13.26	47.80 ¡ 12.27	0.286

FIM are shown in Figure 1. Significant differences in the self-care domain ($p < 0.05$) were found between the control group and the trained group after 6 months of follow up. This indicated there were continuous functional improvements in the subjects who received extra visual feedback training.



*: Mean change scores in self-care and sphincter control of groups
†: Mean change scores in mobility and locomotion of groups

Fig. 1 Mean change scores reflecting activity daily living performance gains in groups.
FIM: Functional Independent Measure.

DISCUSSION

The proposed concept of balance training consists of increasing the activity of the receptor organ in the inner ear during exercise, activating the integrating mechanism in the central nervous system by offering varying sensory inflow including visual information, and training the neuromuscular effecter system.[13] The related experiments focused on the immediate outcome following varied interventions in hemiparetic stroke patients. Although the stance weight bearing was more symmetric after visual feedback training when compared with conventional therapy, the enhanced effects on dynamic functional balance ability were still inconclusive.[11,12,14,15]

Winstein et al.[12] collected data from two groups of 21 matched hemiparetic adults. One group received a specially designed device, which provided dynamic visual information about relative weight distribution over bilateral limbs. The other group received conventional hospital-assigned physical therapy. Their results revealed that standing balance including center of pressure position, weight distribution and stability were better in those with special augmented feedback training, but locomotor control performance was not differentially affected by the two therapy modes. Such results suggested that although standing balance and locomotion were highly interrelated, changes in one function might not reflect in changes in the other.

Another study by Walker and colleagues[14] compared the relative effectiveness of visual feedback training of COG positioning with conventional physical therapy following acute stroke. They found that all groups demonstrated marked improvements but no between-group differences were detected in the outcome measures of static and activity-based balance function. As for whether specialized intervention strategies such as visual feedback training are differentially effective in the later stage of recovery is not known. Previous authors[16-20] have suggested that the early gain might be related to the daily rehabilitation and natural disease course. In addition, most spontaneous recovery and intensive care following stroke occur during the first 3 to 6 months.

Recently, Geiger et al.[15] recruited 13 hemiplegic outpatients; the experimental group (N=7) was trained on NeuroCom Balance Master. Following 4 weeks of intervention, their major findings did not support any beneficial effects in the experimental group although both groups scored higher on functional measurements using Berg Balance Scale and Timed Up & Go Test. Another report in the literature[21] showed that the balance retraining was context or task specific. The weight-shifting tasks performed in the study could be helpful in improving stance symmetry but did not necessarily correspond to improvements in gait or other higher-level mobility and balance tasks.

Mulder[22] presented a model on human motor behavior: a moving organism is continuously bombarded by a multitude of input and picks up the essential information; thus the selection process serves to facilitate further behavioral responses and to access memory. They also explained that the most adequate movement involved the use of a motor program stored in the memory. Therefore, it was suggested that rehabilitation therapy was the acquisition of programming rules which required three crucial elements: adequate feedback, variability of practice, and design of learning situation. Patients with motor dysfunction are totally dependent on the information concerning the outcomes of the attempts to perform motor tasks especially during the acute stage. Because the tasks were new to patients, adequate and consistent feedback as well as clear instructions and models for observation learning were particularly effective to therapy. The static balance functional measurement of our stroke patients in the trained group did not significantly improve when compared with the control group after 6 months of follow up. We supposed the reason was that the training protocol especially emphasized weight shifting skills, which benefit dynamic balance function more. Consequently, there was significant improvement in dynamic balance functional measurement and self - care capacity in subjects receiving visual feedback balance training. We agreed that natural recovery and learning effects from practice were the main factors for improvement during the acute stage, so there may be significant refinement in post-training functional evaluation for the trained group. However, later in the course, the natural recovery capacity and possibility of proficiency declined, and the stored programming rule for dynamic weight shifting motor control experiences by intensive visual feedback training provided by the Balance Master appeared to be effective and could affect the ADL outcomes especially in self-care performance.

Liston[23] performed a study to measure the reliability and validity of stroke patients using the Balance Master and found the test-retest reliability was the greatest for complex tests of balance and that dynamic rather than static measurements were valid indicators of functional balance performance. Therefore, it was agreed that the good posture control in balance might be highly correlated with the outcome of functional task during ADL. Confirming their findings, our stroke patients in the training group improved their dynamic balance as well as FIM scoring in self-care, sphincter control, locomotion and mobility at 6 months of follow up. Furthermore, we found that the effects of dynamic weight shifting training via visual feedback with the Balance Master seemed to be more correlated with the ability to perform self-care tasks than locomotion and mobility function.

In conclusion, we found dynamic balance function showed significant improvements in patients with visual feedback training when compared with those receiving conventional therapy only. Patients in the trained group also showed significant improvements in the self-care ability at 6 months of follow up. Further research is needed to confirm our results. The results showed that balance training was beneficial for patients after hemiplegic stroke.

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腦中風後偏癱病患平衡訓練之成效

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背 景： 本篇研究之目的爲評估腦中風後偏癱病患接受平衡訓練之長期成效。

方 法： 本篇研究共收集了四十一位腦中風後偏癱、可以行走的病患，隨機分爲控制組及訓練組；以SMART平衡儀對訓練組提供視覺回饋之平衡訓練，每位病患之患側肢體用Bruunstrom分期做評估，日常生活功能用功能獨立量表記錄，定量化之平衡功能則採用SMART平衡儀進行施測，所有的評估及測試分別於訓練計畫前以及訓練計劃結束六個月後進行。

結 果： 研究中顯示訓練組之病患的動態平衡功能在訓練計劃結束六個月後追蹤下有明顯進步，同時在生活自理及排便功能控制方面的能力也有所進步。另一方面，在訓練計劃結束六個月後的追蹤下，我們發現在靜態平衡功能評估上，兩組病患之間並無顯著的差別，而且在行動能力及移行功能上，兩組間的進步也沒有顯著的差異。

結 論： 以上的結果顯示與控制組病患相較，接受視覺回饋訓練的患者於動態平衡功能有較明顯的進步，於訓練後六個月的追蹤下也發現訓練組病患在日常生活之自理功能方面也有明顯進步，此一結果可提供腦中風後偏癱病患平衡訓練之方針。
(長庚醫誌 2002;25:583-90)

關鍵字： 平衡訓練，SMART平衡儀，視覺回饋，腦中風。

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fl`¤œ' ƒL¥»‡B¡G G˜_‡ƒ´ fiv¡A"ł' < ' ´ | ·_ •< ¡Cfi ¶Ø¿/ 333 t/s¶m·_¿‡ 5 „¡C Tel.: (03)3281200´ 2654; Fax: (03)3281200´ 2667