Disturbance of Postural Control in Stroke Hemiplegic Patients

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ABSTRACT

The purpose of this study was to investigate the difference in performance between patients with hemiplegia and healthy control subjects on clinical tests of postural control. Weight bearing distribution and rhythmic weight shift in both groups were evaluated by using Balance Master System. Twenty hemiplegic stroke male patients (with the mean age 62.8 ± 6.4 years) participated in this study, compared with twenty age matched healthy control group. The results revealed that there was a significant difference between hemiplegic and healthy control groups on the ability to maintain balance according to sitting equilibrium, standing equilibrium and trunk control tests. Participants with hemiplegia performed poorly than control subjects in the functional reach test. Result of standing weight bearing distribution test revealed that there was statistical significance in the percentage of weight distribution on both affected and non-affected lower limbs in the hemiplegic group. Rhythmic weight shift of center of gravity at different levels was evaluated and the result indicated poor stability of the hemiplegic group. The study revealed that the ability to maintain balance in different situations is a marked problem in hemiplegic stroke patients.
Key words: *Postural control, balance, hemiplegia, stroke and physical therapy.*

INTRODUCTION

Postural control can be defined as the process by which the central nervous system generates the pattern of muscle activity required to regulate the relationship between the center of mass (COM) and the base of support (BOS)[8]. The stabilizing responses involve two facts: control COM via generation of torques at the joints of the supporting leg or legs and trunk and alterations in the BOS via stepping or grasping movements of the limbs[15]. The ability to maintain one's balance require postural control which limits body's sway and keeps its center of gravity (COG) within its BOS[2]. Balance and posture are two concepts which can not be considered in isolations as they are independent. Posture means simply position or alignment of body parts. All body parts have a role in postural alignments and maintaining good posture. Good postural control refers to a position that requires the least effort to maintain and puts the least strain on ligaments, bone and joints[30]. Balance disorders are particularly problematic because they are associated with difficulty in moving from one position to another, sustaining an upright posture and performing functional activities such as walking and turning[3]. Adequate balance relies on integration of inputs from visual, somatosensory and vestibular system[23] which are frequently disturbed in hemiplegic patients secondary to stroke[22]. Muscle weakness and spasticity further compromise the ability by affecting the sequencing and force of muscle contraction[25]. Impaired balance has specifically been reported after stroke[9,26,27]. Loss of trunk control is commonly observed in stroke patients. Impairment in trunk control may lead to: dysfunction in upper and lower limb control, potential for spinal deformity and contractures, impaired ability to interact with the environment due to visual dysfunction secondary to resultant head and neck malalignment. There was decreased independence in activities of daily living, decreased sitting and standing tolerance and impaired balance function[4]. Thus, stroke patients are more prone to falls than non-stroke subjects because of the pathologic condition imposed on their physiologic aging process[16].

Archambault et al.,[6] tested the hypothesis that cortical and subcortical brain lesions may disrupt the timing of trunk and arm endpoint motion in hemiparetic subjects. Movements in hemiparetic subjects were segmented, slower, and characterized by a greater variability and by deflection of the trajectory from a straight line if compared with healthy subjects. There was a moderate increase in the errors in movement direction and extent. Moreover, hemiparetic patients were unable to stabilize the sequence of trunk and arm endpoint movements in a set of trials.

Postural disturbances have not been rigorously investigated from different planes and phases. The purpose of this study was to investigate changes in the postural control strategy in stroke hemiplegic patients compared to healthy control subjects.

SUBJECTS, MATERIAL AND METHODS

Subjects selection

A convince sample of functionally independent, stabilized male hemiplegic stroke patients (n = 20) was recruited from the Department of Neurology, Faculty of Medicine, Cairo University. The study group compared with an age, gender, weight and hight matched healthy control group (n = 15).

All patients had hemiplegia result from single supratentorial ischemic or hemorrhagic stroke (proven by computed tomography and MRI of the brain) that had occurred at least one year before the study. Twelve patients had left sided hemiplegia and the reminder was right sided. All patients had undertaken a physical therapy program and had become functional walkers. The degree of motor deficit of the patients was similar, patients could perform joint movements only in synergy, could stand independently for at least one minute without support, spasticity of the affected lower limb was moderate according to modified Ashworth scale[1.] Patient's functional scores ranged from eight to ten according to the fugl-Meyer sensorimotor assessment[14].

The healthy control group was medication free and had no active disease at the time of testing. Exclusion criteria for both groups were: uncontrolled hypertension or an exercise blood pressure response exceeding 210/110 mm Hg; significant coronary heart disease, chronic hepatitis, congestive heart failures, rheumatoid arthritis, sever degenerative osteoarthritis, visual impairment (blindness, hemienopia, diplopia or blurred vision), major perceptual disturbance including significant peripheral sensory loss, cognitive disturbance including memory loss, marked skeletal deformity, postural hypotension, chronic alcohol abuse, neurological signs (tremors or cerebellar sign), and inner ear disease.

Instrumentation

The computerized Balance Master System (Neuron. Com International, INC, 9570) with software version 6.0 was used in this study. It is comprised of two 9M18 dual force plates. Each force plate is mounted on force transducers which measure vertical ground reaction force. Each force plate is connected to a monitor which displayed the operating instruction and give the subject continuous feedback via a video explanation and a moving cross. All test data were acquired and stored on a 486 PC.

Procedure

This procedure was done at Balance Unit, Department of Neurology, Kasr El Aini Hospital.

Both the hemiplegic patients who considered as the study group (G1) and the healthy control subjects (G2) participated in the same testing sessions. All testing sessions were conducted at the same time of day (at the morning) to control for potential diurnal effect. The environmental temperature was constant all over the study. The subjects were asked to were light suitable clothes and avoid anxiety, emotional stress, exercises and eating (at least two hours) before conducting the procedures. The tests were administrated three times in a single session (with a three minute rest interval) on three consecutive days and the mean values were calculated.

EVALUATION PARAMETERS

The patients and control subjects were interviewed guided by a neurological history taking sheet examinations. The diagnoses of the study group were proved by CT and MRI of the brain. The subject's criteria including age, weight and height were recorded in the sheet.

Degree of spasticity of the affected lower limb in the study group was measured by modified ashworth scale (score from zero, which corresponds to no increase in tone to five, the value given when the limb is rigid in the flexion or extension)[1].

Functional abilities of the patients group were identified before the study according to scores of Fugl-Meyer sensorimotor testing procedures[14].

(1) Measurement of postural control by using the validated Indexes table (1):

Table (1): Three indexes used to measure postural control.

1) The sitting equilibrium Index,[28] which evaluates sitting balance under different conditions.

0- No balance in the sitting position, requires posterior and lateral supports.
1- Sitting position possible with posterior support.
2- Sitting postural balance, maintained without posterior support, but balance lost if the subject is pushed, regardless of the direction of force.
3- Sitting postural balance, maintained without posterior support and despite destabilizing force, regardless of direction.
4- Sitting postural balance, maintained without posterior support, despite destabilizing force, and during movements of the head, trunk, and upper extremities.

11) The upright equilibrium Index[26] quantifies the ability to maintain upright standing position under different conditions.

0- No possibility of maintaining upright posture.
1- Standing possible with very inadequate shift of weight bearing to the hemiplegic leg. Requires support.
2- Upright position possible but shift of weight bearing to the hemiplegic leg still incomplete. No support necessary.
3- Proper shift of weight bearing in an upright position.
4- Standing postural balance maintained during movements of the head, trunk, and arms.

5- Standing on leg possible.

111) The trunk control test[29] which measure four components of balance.

0- Rolling to weak side.
1- Rolling to strong side.
2- Balance in sitting position.
3- Sitting up from lying down.

(2) Examination of self generated perturbation by using functional reach test[18] which measure maximum forward excursion in static double support standing. The subjects were asked to stand next to, but not touching, a wall to their right with their feet on footprints 10 cm apart. Subjects were instructed to raise their arm to 90 degrees with their hand outstretched. The distal position of the third digit was recorded on the wall with a strip of removable adhesive tap (position 1). Subjects were instructed "reach as far forward as you can without moving your feet". The new distal position of the third digit was recorded with a second piece of tap (position 2). The maximum distance reached (i.e. the difference between position 1 and 2) was recorded.

(3) Balance Master testing: Laboratory evaluations of postural stability of all subjects were done using Balance Master System through:

- Weight bearing test (percentage of the body weight distribution).
- Rhythmic weight shift tests at different levels (slow, moderate and rapid) and in two directions (front/ back and right/ left).

Each test was conducted with subjects in standing position with standard foot position as recommended by the manufactures of the equipment[21]. The outline of the subject's feet was traced onto paper to ensure the same placement in subsequent testing session. after a brief period of familiarization (five to ten minutes) with the center of gravity (COG) visual feed back utilized during the testing procedures, subjects were asked to distribute their body weight on both lower limbs as much as possible until the bares on the computer screen (in front of eyes) in the same height as nearly as possible. The data expressed as a percentage (test for weight bearing distribution).

Test of rhythmic weight shifts (front/back and right/left) were used to examine the ability to move the center of gravity (COG) reciprocally. The test graduated according to the length of each test: In assessment level one, 18 seconds, (six transitions to three seconds each). In assessment level two, 12 seconds, (six transitions at two seconds each). In assessment level three, 6 seconds, (six transitions at one second each). During the test, the location of subject's COG is displayed on a screen as a cursor providing visual feedback. The subjects were required to lean away from midline in the direction to sway reciprocally between two points either back to front or side to side at a rate indicated by an on-screen cue (blue square), fig (1), without stepping or moving their feet from the standardized position and arms by sides. The subject was asked to follow the cursor with the same speed of the square. After six excursions between the end lines, the test was completed. The speed of COG displacement represented as degree/second. High values means balance disturbance (increase rate of body swaying during the test).

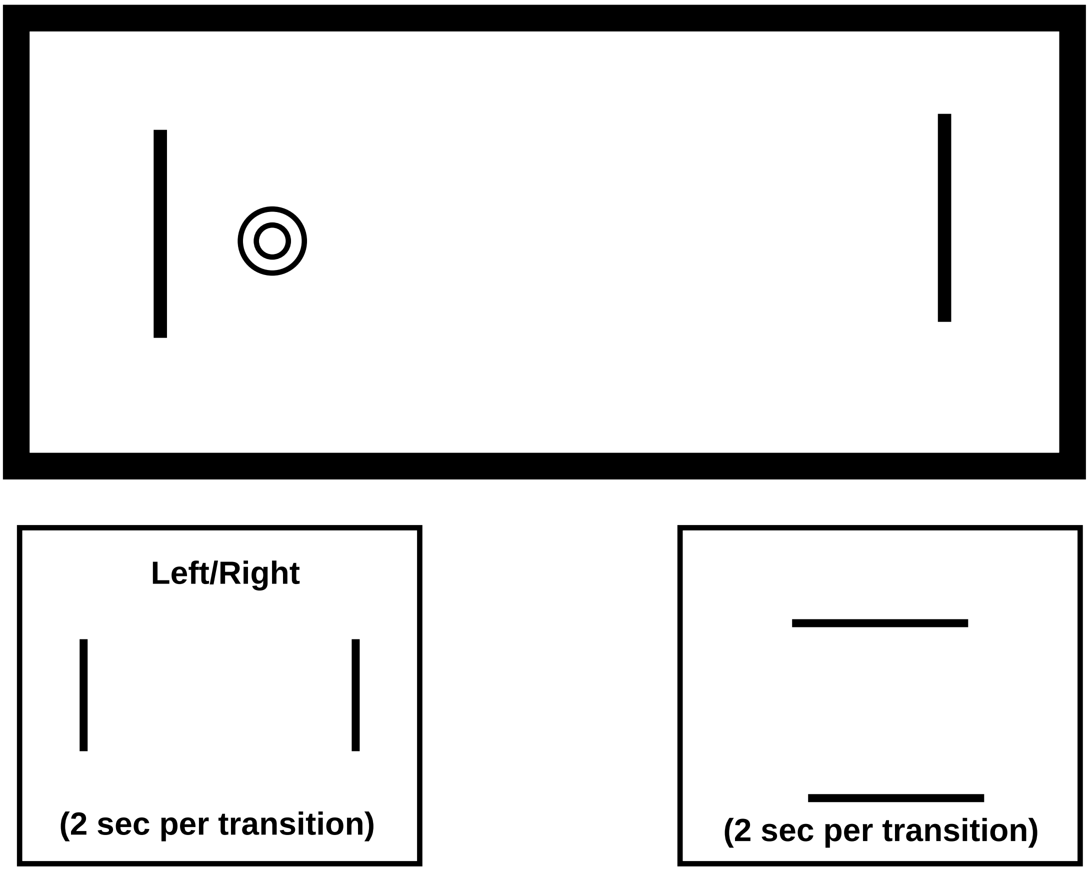

Fig. (1): Rhythmic weight shift test.

Data analysis

The data were presented as: the mean and the standard deviation. Analysis was preformed by using the non-parametric chi-square test for qualities variables and Mann-Whitney test for quantitive variables. Student "t" test was used to compare the mean percentage of the body weight distribution between both limbs within each group. Also Paired "t" test was used to compare rhythmic weight shift (deg/sec) values between both groups. The threshold of statistical significance was set at $P<0.05$.

RESULTS

The characteristics of hemiplegic group (G1), (12 left sided and 8 right sided) and healthy control group (G2) was represented in table (2). Inspection of the table revealed no significant differences in mean age, body weight and height between both groups.

Table (2): The general characteristics of both groups (G1 and G2).

Group	Age (years)		Weight (Kg)		Height (Cm)	
	Mean	SD	Mean	SD	Mean	SD
G1	62.8	6.4	75.3	6.3	168.7	5.2
G2	63.4	6.3	78.9	4.7	171.4	6.9
P- Value	0.7		0.3		0.4	

Significance* at P<0.05

Postural parameters (by using sitting equilibrium Index, upright equilibrium Index and trunk control test) were compared between both groups. The results of the control group (G2) were significantly higher compared to the hemiplegic group among the three tests, table (3) and fig (2). Inspection of the table revealed that the scores of the three tests in the hemiplegic group (G1) are less than or equal to two which means static imbalance.

Table (3): The comparison of postural control measures (sitting equilibrium Index, upright equilibrium Index and trunk control test) between both groups (G1 & G2).

Group	Sitting equilibrium Index		Upright equilibrium Index		Trunk control test	
	Mean	SD	Mean	SD	Mean	SD
G1	2.0	0.6	1.2	0.9	1.2	1.0
G2	4.7	0.9	3.4	0.5	3.3	1.4
P-Value	0.01*		0.000*		0.000*	

Significance* at P<0.05

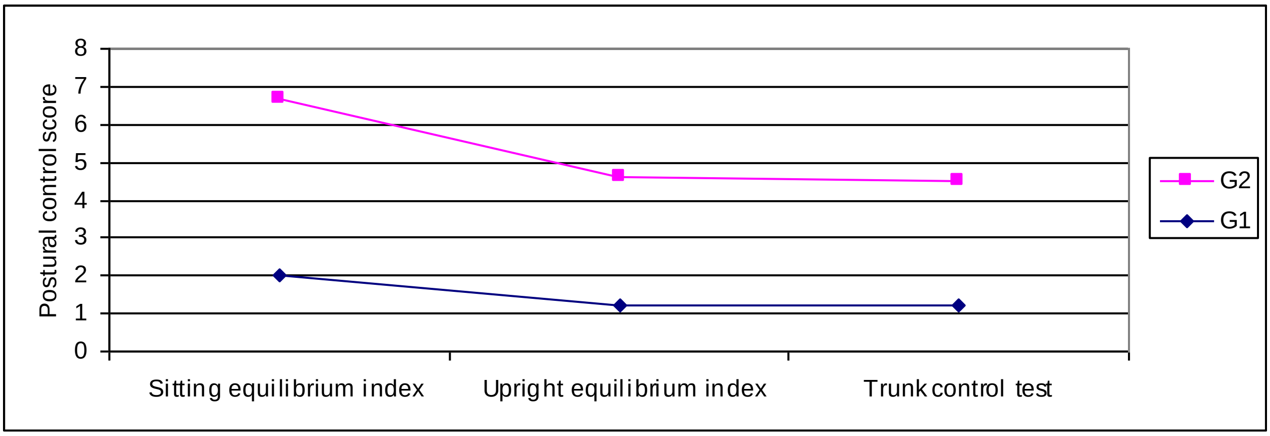

Fig. (2): The mean values of postural control measures in both groups (G1 and G2).

In this study the scores of self generated perturbations test (functional reach test) identified also statistically significance difference between both groups with the P-value less than 0.05, table (4).

Table (4): The comparison of functional reach test scores (cm) between both groups (G1and G2).

Variable	G1		G2		Significance
Functional reach test score (cm)	Mean	SD	Mean	SD	
	23.49	8.20	39.19	5.88	0.000*

Significance at P< 0.05

The mean percentage of the body weight distribution, the affected and the unaffected lower limbs of hemiplegic patients (G1) and on both lower limbs (Rt&Lt) of the healthy control group (G2) was calculated and comparisons were done within each group. The results reveled that body weight distribution was asymmetric on feet of hemiplegic group G1 with a statistically significance difference between both sides. No significance difference was found between the dominant and non-dominant limb in the healthy control group (G2), Table (5) and fig. (3).

Table (5): The comparison between the percentages of body weight distribution on both limbs in both group (G1 and G2).

	G1				G2			
	Affected		Unaffected		Rt		Lt	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	34.10	9.2	65.55	9.45	48.65	1.38	51.35	1.38
Significance	0.000*				0.20			

Significance* at P< 0.05

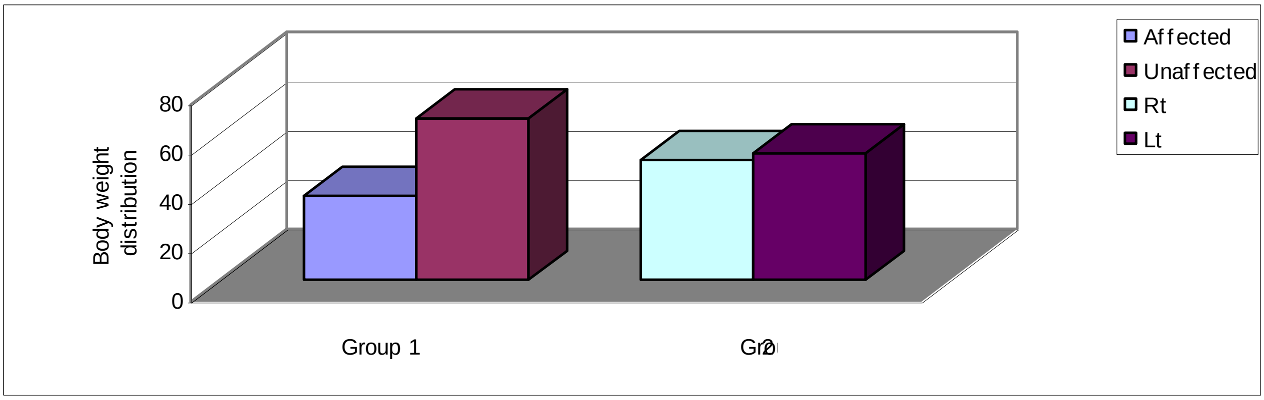

Fig. (3): The mean values of the body weight distribution percentage of the affected and the unaffected limbs of the hemiplegic group (G1) and both limbs (Rt and Lt) of the healthy control group (G2).

Hemiplegic patients (G1) showed tendency for postural sway and a more restricted area for excursion in different planes of movement at different rates (increase in the oscillation of COG when approaching the target level). In contrast the mean values of the healthy control group (G2) were significantly less during weight shifts in different movement planes (front/back and left/right), table (6) and fig. (4).

Table (6): The comparison of rhythmic weight shift (deg/sec) tests (level 1,11&111) in different planes of movement (front/back & Right/left) in both groups (G1&G2).

Test level	Planes	G1		G2		Significance
		Mean	SD	Mean	SD	
Level 1	Front/back	5.16	1.12	2.03	0.32	0.001*
	Right/left	6.40	1.22	3.33	0.57	0.001*

Significance* at P< 0.05

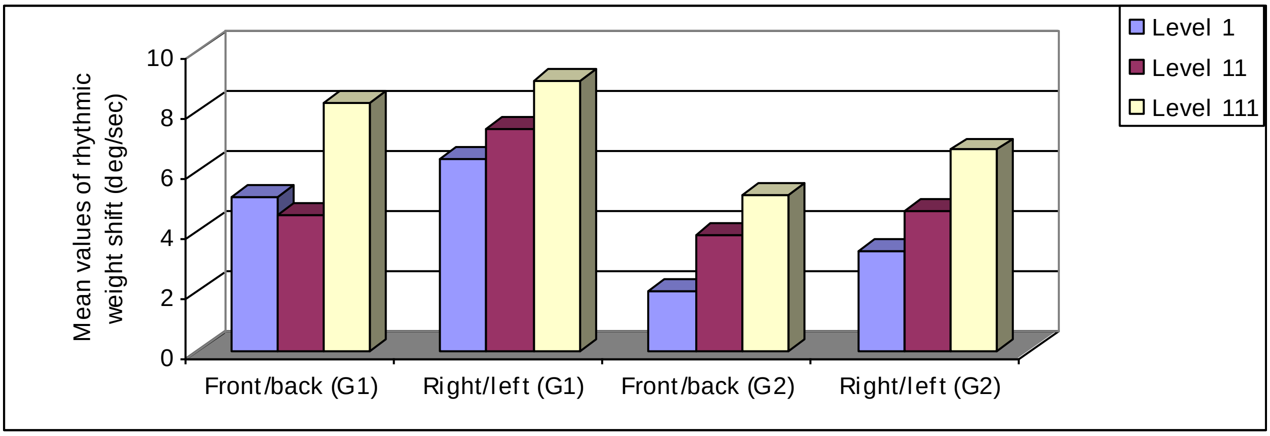

Fig (4): The mean values of rhythmic weight shift (degree/sec) in different planes (front/back and right/left) in both groups (G1 & G2).

DISCUSSION

The findings of this study showed that the hemiplegic patients secondary to stroke have poor sitting and standing postural balance than age-matched healthy control subjects. Clinical and instrumental analysis of postural performance were used to measure the difference between patients with hemiplegia and control subjects and appears to be suited to the measurement of physical therapy treatment for balance disorders. Subjects with hemiplegia showed poorly controlled responses that failed to prevent them from losing stability in different positions of the sitting equilibrium, upright equilibrium and trunk control tests while the age-matched control maintain steadiness in a range of the same positions. The results of self-induced perturbations (the functional reach test) showed also marked difference between the hemiplegic group and the healthy control group. These findings were in agreement with prior researches which reported that clinical tests of balance not only provide a measure that discriminates betweens subjects with movement disorders and healthy people but also it reflected ability to perform every-day tasks of living[13,24,31].

The findings of this study are in line with the results of the previous work[10,17,19], and confirm that in normal subjects, there is no significant difference in distribution of body weight during standing on the dominated and non-dominant limbs. The results of the body weight bearing tests in hemiplegic group revealed that the percentage of body weight was significantly different on each limb. The high percentage was displaced toward the unaffected side. These results are consistent with other studies[8,11,34] which documented asymmetric weight bearing with shifting the center of gravity over the non affected side and decreased area of stability during standing in hemiplegic patients. This asymmetric distribution of body weight may be attributed to abnormal muscle tone, abnormal movement control, discorrdination within motor strategies, loss of anticipatory postural control, reduced cutanious sensation and distorted proprioceptions of the lower limbs.

The asymmetric deficiency in weight bearing caused by hemiplegia is more pronounced when unilateral neglect complicates the hemiplegia. This pronounced degree of postural unbalance with unilateral neglect might reflect disruption of body schema which has been defined as an internal three-dimentional dynamic representation of the spatial and biomechanical properties of one's body[7,32].

The weight shift test conducted with a feet situated in the same plane showed clearly that the center of pressure was displaced toward the unaffected side in hemiplegic group in all tests. All shifts by the hemiplegics subjects were significantly different compared to the controls. These tests, therefore confirmed the findings of previous research, which demonstrated that when hemiplegic subjects are tested, their center of pressure (COP) is shifted over the unaffected side, patients posses diminished ability to shift backwards over paretic leg with decreasing area of stability[33]. The greater swaying of COP in hemiplegic patients has been attributed to the poor dynamic postural stability[20]. It was suggested that decreased sensory inputs from the somatosensory, visual and vestibular system as well as poor spatial integration, might contribute to postural sway abnormality in patients with hemiplegia[9,12]. The inability to shift and distribute body weight over both limbs in a finding that may be of a considerable important from a rehabilitation point of view, as balance function and weight bearing symmetry have been found to correlate with gait components in stroke hemiplegic patients[5].

Conclusion

This study concluded that the hemiplegic patient secondary to stroke showed poorly controlled responses that failed to prevent them from losing stability in different positions of the sitting equilibrium, upright equilibrium and trunk control. There was asymmetric weight bearing with shifting the center of gravity over the non-affected side and decreased area of stability during standing. Hemiplegic patient with balance impairment could get benefit by using the Smart Balance Master. The Smart Balance Master is a computerized balance assessment and training system that provides the user with visual information about the position of the COG within predefined (theoretical) limits of stability. By shifting the body weight and COG over the BOS, the user can track the movement of the COG on the computer screen. The visual feedback is used to match and recalibrate proprioceptive sensory information or input that may be impaired.

CLINICAL IMPLICATIONS

For clinicians who wish to perform tests of balance or evaluate patient progress during the course of balance intervention program, knowledge of the expected source of measurement error and the consistency of balance measures scores of multiple testing sessions can provide meaningful information.

Physical therapist should therefore avoid the tendency to conduct an abbreviated version of the test in order to minimize evaluation time. Conducting the complete test also provides a more comprehensive evaluation of the patient's region of stability and will better assist in identifying specific movement limitations. It is important also to provide clear test instructions and sufficient practice time for patients to better understand the relationship between the movement of the on-screen COG cursor and the actual movement of the body's COG. The type of postural strategy adapted may be more consistent as a result of such practice and more representative of the patient's actual static and dynamic balance abilities.

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الملخص العربي

اختلال التوازن في مرضى الشلل النصفي الطولي الناتج عن السكتة الدماغية

أجرى هدا البحث بهدف دراسة تأثير الشلل النصفي الطولي (الفالج) الناتج عن السكتة الدماغية على اختلال التوازن. أجريت الدراسة على مجموعة من مرضى الشلل النصفي الطولي (عشرون مريضا من الرجال) الناتج عن السكتة الدماغية. تمت مقارنتهم بمجموعة متطابقة في العمر والجنس من الأصحاء الدين لا يعانون من أمراض مزمنة .
تم تقييم المجموعتين عن طريق مجموعة من الاختبارات الخاصة بالتوازن وتحكم الجزع من مختلف الأوضاع كما تم تقيم المجموعتين باستخدام جهاز التوازن بوحدة التوازن بقسم الأعصاب بالقصر العيني لمعرفة:
- توزيع وزن الجسم على كل ساق أثناء الوقوف.
- درجه الثبات (عدم الاهتزاز) .
وقد أوضحت المعالجة الإحصائية النتائج في كلا المجموعتين انه هناك اختلال إحصائي واضح في مجموعة المرضى عنها في المجموعة الضابطة (الأصحاء) ويتضح من هذه الدراسة أهمية ضرورة تقييم الجوانب المختلفة للتوازن في مثل هذه الحالات حتى يتسنى وضع خطة علاجية ملائمة وذلك لان اختلال التوازن يؤدى إلى خلل شديد في الجوانب المركبة للجسم كالانتقال من وضع لآخر والمشي مما يؤدى إلى تحديد الأنشطة الحركية اليومية للمريض.
الكلمات الدالة : الاتزان – الشلل النصفي الطولي – السكتة الدماغية – العلاج الطبيعي.