## Original Article

# Our Experience with Posturography in Hemiparetic Patients after Stroke in Kuwait

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## ABSTRACT

**Objectives**: To study the Berg Balance Scale (BBS) as balance functional impairment of hemiparetic stroke patients after onset of stroke; to quantitatively assess control of balance by computerized dynamic posturography (CDP); to correlate composite equilibrium score (ES) with sex, side of lesion and stroke type; and to correlate ES with static and dynamic posturography in hemiparetic stroke patients.

**Design:** A retrospective case control study.

**Setting:** Outpatient clinic in Physical Medicine and Rehabilitation Hospital, Kuwait.

**Subjects:** A total of 21 hemiplegic ambulatory stroke patients and 19 age-matched healthy individuals as control group.

**Interventions:** BBS and CDP

**Main Outcome Measures:** ES and sensory organization test (SOT) 1-6.

**Results :** BBS scores of stroke patients were below the lower limit of the normal control group ($p < 0.001$). Significant reduction was observed for composite ES of stroke patients compared to control group. Although no significant difference of static balance function was observed between patients and controls, significant reduction of dynamic balance function (SOT 4, SOT 5, SOT 6) was observed in stroke patients, compared to control group ($p < 0.05$) .

In linear regression correlation ( r-) of stroke patients, no significant correlation was observed of ES with static balance function (SOT 1, SOT 2, SOT 3) in hemiparetic stroke patients ($p > 0.05$). However, there was a direct significant correlation of ES with dynamic balance function including SOT 4, SOT 5 and SOT 6 ($r = -0.71$; $p < 01$), ($r = 0.761$, $p < 0.01$) and ($r = -0.761$, $p < 0.05$) respectively in hemiparetic stroke patients.

**Conclusions:** Impaired dynamic equilibrium in stroke patients is likely to reflect reduction of muscle strength of the paretic side along with the possible impairment of sensory organization.

KEY WORDS: cerebrovascular accident, computerized dynamic posturography (CDP), postural instability (PI)

## INTRODUCTION

Stroke has been identified as the most prevalent diagnosis among adults who fall[1]. One third to one half of all people over the age of 65 years fall at least once per year[2,3]. Balance is diminished in patients with hemiplegia and hemiparesis[4,3]. Postural sway for patients with hemiplegia can be twice that of their age-matched peers[5,6]. Symmetry of weight bearing is also impaired following stroke, with patients bearing as much as 61 to 80% of their body weight through their non-paretic lower extremity[7,8]. Postural instability (PI), or impaired balance, is common in patients with stroke, especially as the disease severity advances[8].

The term 'balance' refers to a multisystem function that strives to keep the body upright while sitting or standing and while changing posture. Balance is needed to keep the body oriented appropriately while performing voluntary activity, during external perturbations and when the support surface or environment changes[9]. Horak *et al*. proposed that balance (postural stability) requires three distinct processes: (i) sensory organization, in which one or more of the orientational senses (somatosensory, visual and vestibular) are involved and integrated within the CNS; (ii) a motor adjustment process involved with executing coordinated and properly scaled neuromuscular responses; and (iii) the background tone of the muscles, through which changes in balance are effected[10].

Dynamic posturography has become an important tool for understanding standing balance in clinical settings. A key test in the NeuroCom International (Clackamas, Oregon) dynamic posturography system, the Sensory Organization Test (SOT), provides information about the integration of multiple components of balance. The SOT test leads to an outcome measure called the "Equilibrium Score" (ES), which reflects the overall coordination of the visual, proprioceptive,

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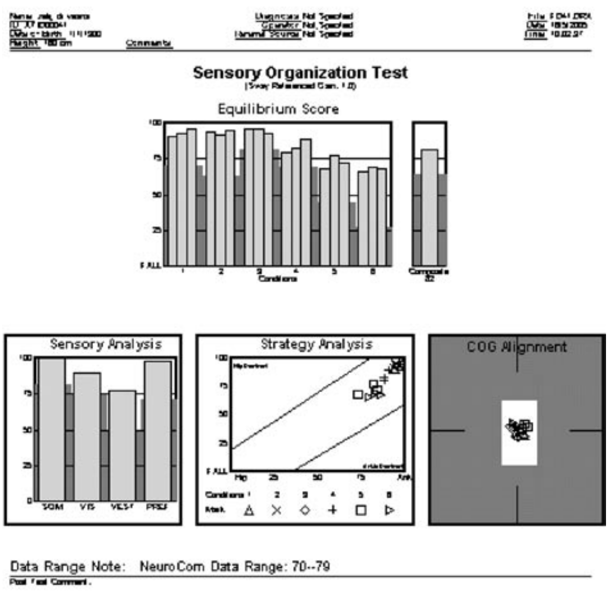

**Fig. 1:** Represents normal posturography with SOT, ES, static posturography (SOT 1, SOT 2 and SOT 3), dynamic posturography (SOT 4, SOT 5 and SOT 6)

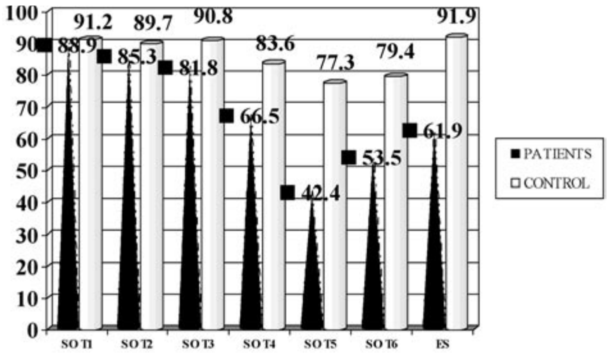

**Fig. 3:** Represents Mean (± SD) changes in The Composite ES and six tests conditions of SOT of hemiparetic stroke patients

and vestibular systems for maintaining standing posture. Researchers, therapists, and physicians often use the ES from the SOT as a clinically relevant measure of standing balance[11].

## PATIENTS AND METHODS

### Subjects

A total of 21 hemiplegic but ambulatory stroke patients and 19 age-matched healthy individuals as control group admitted to the Balance Neurocom Clinic, Physical Medicine and Rehabilitation Hospital, Kuwait were recruited for this study. All patients and healthy individuals were evaluated clinically with a brief neurological examination (Table 1). All patients underwent image studies such as brain computed tomography (CT) or magnetic resonance imaging (MRI) to identify their stroke diagnosis during the acute stage.

Inclusion criteria for the trial were the following: (1) stroke within 30 to 150 days; (2) ability to ambulate 25 ft independently; and (3) mild to moderate stroke deficits defined by BBS (BBS) of 0 to 56 for upper and lower extremities.

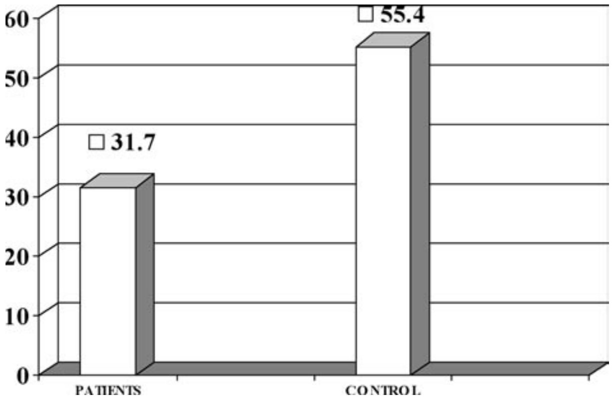

**Fig. 2:** Represents Mean (± SD) changes in BBS of hemiparetic stroke patients and control group

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. Exclusion criteria also included (1) serious cardiac conditions (hospitalization for heart disease within three months, active angina, serious cardiac arrhythmias, hypertrophic cardiomyopathy, severe aortic stenosis, pulmonary embolus, or infarction), (2) oxygen dependence, (3) severe weight-bearing pain, and (4) other serious organ system disease. After subjects passed the screening criteria, an informed consent was taken for participation in this study.

### Methods

All patients and healthy individuals were evaluated in a study of postural stability and balance using the BBS[12] and computerized dynamic posturography (CDP)[13].

### Computerized dynamic posturography[13]

All patients and healthy individuals were evaluated in a study of postural stability and sway in altered sensory conditions using CDP. The SMART Balance Master (NeuroCom International, Inc., Clackamas, OR, USA) was used for both balance function and assessment.

The SOT was performed in a clinically routine manner. The SOT included six tests conditions. The first three involved the patient standing on a fixed platform with eyes open (SOT 1), eyes closed (SOT 2), and using sway-referenced vision (SOT 3). The SOT of the patient standing on a fixed platform is called static posturography. The other three conditions ((SOT 4, SOT 5 and SOT 6) involved the patient standing on a moving platform including conditions 4 (eyes open), 5 (eyes closed), and 6 (using sway-referenced vision) and is called dynamic posturography[13].

**Table 1:** Baseline demographic & clinical characteristics of hemiparetic stroke patients and control group

| Characteristic | Stroke patients n = 21 | Control group n = 19 |
|---|---|---|
| Demographic Characteristics : | | |
| Mean ± SD Age in years | 59.17 ± 1.80 | 61.31 ± 3.09 |
| Gender- women / men | 19 / 2 | 10 / 9 |
| Clinical characteristics: | | |
| Glasgow coma scale (0–15) | 15 (15 – 15) | 15 (15 – 15) |
| Mean ± SE duration of stroke, wk | 12.38 ± 2.06 weeks | - |
| Hemianopia (0/1) | - | |
| Fifth cranial nerve palsy | 3 (14.3%) | |
| Side of involvement | Left hemisphere 13 (61.9%)<br>Right hemisphere 8 (38.1%) | |
| Hemihypothesia | Left hemisphere 3 (14.3%)<br>Right hemisphere 5 (23.8%) | |
| Urinary incontinence (0/1) | - | - |
| High blood pressure | 8 (38.1%) | |
| History of heart attack | - | |
| Diabetes | - | |
| CT scan or MRI : | | |
| Type of stroke n (%) | ischemic 16 (76.2)<br>hemorrhagic 5 (23.8) | |

**Table 3:** Numerical Mean ± SD of BBS in hemiparetic stroke patients and control group

| Mean ± SD | stroke patients | control group | Statistical analysis T- test (p-value) |
|---|---|---|---|
| Berge balance scale | 31.7 ± 1.8 | 55.4 ± 0.7 | Significant (p < 0.001) |

Fig. 1 represents normal posturography with SOT including ES, static posturography (SOT 1, SOT 2 and SOT 3) and dynamic posturography (SOT 4, SOT 5 and SOT 6).

## Statistical analysis

Study data were analyzed using the SPSS statistical package. The Student's *t* test indicates the magnitudes of the difference of means and therefore the magnitude of the observation. Thus, the unpaired *t* test was used to assess the difference between SOT scores of stroke patients and those of normal subjects. Prior to data analysis, the level of significance was established at $p < 0.05$. Linear regression correlation (r-) was also used to assess the relationship between ES and six tests conditions of SOT scores of stroke patients. A p value of ≤ 0.05 was used as level of significance.

## RESULTS

**Table 2:** Mean ± SE ES according to gender, side of involvement and type of stroke

| Mean ± SE | Mean ES n = 21 | Statistical analysis T- test (p value) |
|---|---|---|
| Gender | | |
| Male | 65,7143 ± 3.2 | NS (p > 0.05) |
| Female | 65,7143 ± 6.2 | |
| Side of involvement | | |
| Left hemisphere | 61,2000 ± 5.1 | NS (p > 0.05) |
| Right hemisphere | 63,8333 ± 2.1 | |
| Type of stroke | | |
| Ischemic | 61,4706 ± 3.6 | NS (p > 0.05) |
| Hemorrhagic | 64,0000 ± 7.2 | |

NS = not significant

**Table 4:** Numerical Mean ± SD of SOT including six tests conditions in hemiparetic stroke patients and control group

| Mean ± SD | stroke patients | control group | Statistical analysis T- test (p-value) |
|---|---|---|---|
| Composite ES (ES) | 61.9 ± 10.6 | 91.9 ± 3.2 | Significant (p < 0.05) |
| **Static posturography (standing on a fixed platform)** | | | |
| SOT 1 score | 88.9 ± 5.4 | 91.2 ± 1.9 | NS (p > 0.01) |
| SOT 2 score | 85.3 ± 4.2 | 89.7 ± 3.2 | NS (p > 0.05) |
| SOT 3 score | 81.8 ± 4.5 | 90.8 ± 1.8 | NS (p >0.05) |
| **Dynamic posturography (standing with the platform moving)** | | | |
| SOT 4 score | 66.5 ± 7.9 | 83.6 ± 5.3 | S (p < 0.05) |
| SOT 5 score | 42.4 ± 11.8 | 77.3 ± 4.6 | S (p < 0.01) |
| SOT 6 score | 53.5 ± 15.6 | 79.4 ± 3.0 | S (p < 0.05) |

NS = not significant, S = significant

The demographic and clinical characteristics of all subjects are listed in Table 1. Table 2 represents correlation of mean ± SE ES with gender, side of involvement and type of stroke in hemiparetic stroke patients. There were no significant differences of mean ± SE of ES with gender, side of involvement and type of stroke in hemiparetic patients.

Table 3 and Fig. 2 represent numerical mean ± SD score of BBS between patients and controls. BBS of stroke averaged below the lower limit of normal control group ($p < 0.001$).

Table 4 and Fig. 3 represent numerical mean ± SD score of composite ES and six tests conditions of SOT between patients and controls. Significant reduction was observed for composite ES of stroke patients as compared with control group ($p < 0.05$). No significant difference was observed for the first

**Table 5:** Linear regression (r-) correlation of Mean ± SD of the composite ES with six tests conditions of SOT in hemiparetic stroke patients

| Mean ± SD | Linear Regression ( r-) of the Composite ES |
|---|---|
| **Static posturography (standing on a fixed platform)** | |
| SOT 1 | No correlation<br>($r = 0.171$; $p > 0.051$) |
| SOT 2 | No correlation<br>($r = 0.201$; $p > 0.051$) 0,201 |
| SOT 3 | No correlation<br>($r = 0.056$; $p > 0.051$). |
| **Dynamic posturography (standing with the platform moving)** | |
| SOT 4 | direct significant correlation<br>($r = -0.710$; $p < 0.01$). |
| SOT 5 | direct significant correlation<br>($r = 0.761$, $p < 0.01$) |
| SOT 6 | direct significant correlation<br>($r = -0.667$, $p < 0.05$) |

three conditions involving SOT 1, SOT 2 and SOT 3 between stroke patients and control group in static balance function (static posturography, $p > 0.05$). However, in dynamic balance function (dynamic posturography), significant reduction was observed for the other three conditions (SOT 4, SOT 5, SOT 6) of stroke patients as compared with control group ($p < 0.05$).

Table 5 represent linear regression correlation (r-) of ES with six tests conditions of SOT scores of hemiparetic stroke patients. No significant correlation was observed of ES with the first three conditions of static posturography (SOT 1, SOT 2 and SOT 3) in hemiparetic stroke patients ($p > 0.05$). However, in dynamic posturography there was a direct significant correlation of ES with SOT 4, SOT 5 and SOT 6 ($r = -0.71$; $p < 0.01$), ($r = -0.761$, $p < 0.01$) and ($r = -.761$, $p < 0.05$) respectively in hemiparetic stroke patients.

## DISCUSSION

CDP has become an important tool for understanding standing balance in clinical settings. A key test in the NeuroCom International (Clackamas, Oregon) dynamic posturography system, the SOT, provides information about the integration of multiple components of balance. The SOT test leads to an outcome measure called the ES, which reflects the overall coordination of the visual, proprioceptive, and vestibular systems for maintaining standing posture[11].

In the sensory organization part of CDP, we have found that, the patient group showed significantly lower equilibrium performance as compared to the control group. In this study we have also found the differences between static and dynamic posturography. In static posturography, mean scores of SOT 1, SOT 2 and SOT 3 with fixed platform were not significantly different between patients with stroke and controls. By contrast, on dynamic posturography (SOT 4, SOT 5, SOT 6), stroke patients showed significantly lower values of SOT 4, SOT 5&, SOT 6 for patients with stroke as compared to controls .

Thus, the majority of stroke patients could maintain static postural stability. But, dynamic postural control was impaired in stroke patients as risk factor for falls in people with stroke. The results suggest that patients with hemiparesis tend to fall easily and that the risk of falls toward the paretic side is high in moving in platform sway referencing on dynamic posturography (SOT 4, SOT 5 and SOT 6).

This study agrees with other studies of posture instability in patients with stroke by Ikai, Tetsuo *et al*[14], de Haart M *et al*[15] and Niam S *et al*[16]. The dynamic postural control was impaired in patients with hemiparesis as compared with healthy subjects. The results suggest that patients with hemiparesis tend to fall easily and that the risk of falls toward the paretic side is high. The response latency to perturbations was longer and the response strength was weaker on the paretic side of patients with hemiparesis[14,15].

Similar to previous investigations this study shows abnormalities of static posturography in stroke compared with healthy controls. However, dynamic balance was significantly impaired in patients with stroke whereas patients with stroke performed similarly to age matched healthy controls[15] during static posturography. Significant differences in postural sway were found among different stances in eyes-open ($p = 0.00$ to $0.02$) and eyes-closed conditions ($p = 0.00$ to $0.04$) after stroke[16]. Postural stability in quiet stance, was related to functional measures of balance as well as physiologic factors relating to balance, such as visual conditions, lower-extremity peripheral sensibility, motor recovery, and simple reaction time[17].

The balance function of stroke patients was significantly worse as compared to that of the healthy subjects especially in dynamic stability. However, different from the other reports, our right hemispheric stroke patients had better balance function than left hemispheric patients. This result suggests that the motor function of the healthy limbs of stroke patients may play an important role in their balance function[18].

The maintenance of balance when standing is a complex process that involves multiple peripheral sensory inputs, central integrating pathways, and efferent outputs. Postural sway presumably reflects noise and regulatory activity within this afferent-efferent control loops and seems to increase in a non-specific fashion with impaired vestibular, somatosensory, or visual input.

Some authors reported that impaired dynamic equilibrium in stroke is likely to reflect a disruption of sensory, visual and vestibular input due to repetitive, involuntary head oscillations or motor weakness. Moving in platform sway referencing (SOT 4, 5 and 6) introduced changes in somatosensory input[15].

Also, postural sway was related to visual condition, stance position, and proprioception[16]. The response latency to perturbations was longer and the response strength was weaker on the paretic side of patients with hemiparesis. The dynamic postural control was impaired in patients with hemiparesis as compared with healthy subjects. The results suggest that patients with hemiparesis tend to fall easily and that the risk of falls toward the paretic side is high[14].

In conditions of altered somatosensory information, with visual deprivation (ES 5) or visuovestibular conflict (ES 6), the median scores for patients with hemiplegia (ES 5 - 43; ES 6 - 20) were significantly lower than those for normal subjects (ES 5 - 69; ES 6 - 67). Many patients with hemiplegia seem to rely on visual input. Rehabilitation programs of postural control for the patients with hemiplegia should take into account the possible impairment of sensory organization and should include exercises to be performed under conditions of sensory input deprivation and sensory conflict [19].

The stroke patients showed excessive postural sway and instability, particularly in the frontal plane, compared with reference values. It may be caused by weight-bearing asymmetry with disturbed sensibility or ankle[15]. Postural sway was increased with more challenging standing conditions (*i.e.*, when multiple sensory systems were manipulated) to a greater extent with the stroke group as compared to controls. Muscle strength was only correlated to sway during the most challenging conditions. Furthermore, a greater number of persons with stroke fell during the balance testing compared to controls. Impairments in re-weighting / integrating afferent information, in addition to muscle weakness, appear to contribute to postural instability and falls in persons with stroke. These findings can be used by clinicians to design effective interventions for improving postural control following stroke[20].

## CONCLUSIONS

This study represents the first attempt to use of the CDP equipment as a diagnostic tool in assessment of the dynamic equilibrium performance in post-stroke patients in Kuwait.

Significant reduction was observed for composite ES of stroke patients as compared with control group. No significant difference was observed in static balance function (static posturography). However, in dynamic balance function (dynamic posturography), significant reduction was observed in stroke patients as compared with control group ($p < 0.05$). Also, there was a direct significant correlation of ES with dynamic balance function (dynamic posturography) in hemiparetic stroke patients. Thus, our results suggest that impaired dynamic equilibrium was observed in stroke patients. This is likely to reflect reduction of muscle strength in the spine, hip and ankle of paretics along with the possible impairment of sensory organization which may be the main cause of their postural instability.

Further research in the use of this posturography equipment is needed to study the effects of visual feedback rhythmic weight-shift training on dynamic balance function in hemiplegic stroke patients.

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