ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 11, Issue, 08, pp.5994-5998, August, 2019

DOI: https://doi.org/10.24941/ijcr.36412.08.2019

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

THE VALIDITY AND RELIABILITY OF SWAYMETER IN ASSESSING POSTURAL SWAY AMONG NEUROLOGIC PATIENT POPULATION – A PRELIMINARY STUDY

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ARTICLE INFO

Article History:
Received 08th Maay, 2019
Received in revised form
10th June, 2019
Accepted 04th July, 2019
Published online 31st August, 2019

Key Words:
Postural Sway,
Swaymeter,
Reliability,
Validity,
Multi-directional Reach Test.

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ABSTRACT

Background: The delay or malfunction of any of the neuromuscular systems for postural control leads to a spontaneous oscillation of the center of mass within the position maintained by the individual, resulting in postural sway. Force-plates and dynamic posturography are been widely used in clinical settings to analyze the postural sway. Swaymeter is found to be a cost-effective and easy tool to analyze the postural sway in neurologic patients. This study identified the test-retest reliability of Swaymeter and its concurrent validity with the Multi-Directional Reach Test. ***Methods:*** Thirty patients with age ranged from 19 to 79 (19 males and 11 females) and those who can maintain one minute independent standing were assessed using Swaymeter thrice with 10 minutes rest between the tests. MDRT measurements were also assessed within these individuals. The test-retest reliability was identified using the Intraclass Correlation Coefficient (ICC) and the concurrent validity with MDRT using Pearson Correlation. ***Results:*** We identified a moderate test-retest reliability in Swaymeter (0.602-0.757) in all directions, with the right side showing moderate to good reliability with ICC of 0.757. The analysis shows a positive correlation between Swaymeter values and MDRT values, with posterior direction showing a moderate positive significant correlation (+0.463, $p<0.05$). ***Conclusion:*** The moderate to good reliability of Swaymeter makes it an effective tool in the clinical and rehabilitation settings for the benefit of the patients. The performance of static balance tests cannot be compared with that of dynamic balance, and therefore must be assessed separately in patients.

***Citation: Tittu Thomas James, Amishi Oza, Asma Parveen, Jowena Parikh, Pooja Motar, Unnati Shetty, Vrushali Bhore and Pradnya Dhargave,* 2019.** "The Validity and Reliability of Swaymeter in Assessing Postural Sway among Neurologic Patient Population – A Preliminary Study", *International Journal of Current Research*, 11, (08), 5994-5998.

INTRODUCTION

Maintaining an upright posture is a complex motor skill based on the integration of dynamic sensorimotor information.[1] Neuromuscular system controls the joints within the human body, which are linked together to contribute to the body posture. According to Massion J, there are two main functions of the postural control system; to retain balance by maintaining posture against gravity, and to move the body segments for perception and action by maintaining their orientation and position with respect to the environment (Massion, 1994). Factors that assist this dual functions include the stabilization and orientation of the body segments during voluntary movement as well as against the force of gravity, perception of sensory inputs from various systems within the body, and the postural reactions which helps in balance recovery after a perturbation (Massion, 1994). The three main sensory systems within our body which aid in postural control are visual, vestibular, and proprioceptive and tactile somatosensory systems. Integration of the inputs from these systems are necessary to maintain static posture (body schema) and also for movement (body dynamics) (Chiba *et al.,* 2016). Along with the subcortical structures of cerebrum and spinal cord which are involved in the postural control, recent studies have also identified the role of cortical structures such as cerebellar vermis, prefrontal cortex, etc. for the same (Tse *et al.,* 2013). Any insult to the sensory systems or the movement control systems can affect the maintenance of body posture (Paillard *et al.,* 2015). Paillard T et al advocated the role of cerebral cortex (spatial recognition and cognition by parietal and frontal lobe respectively), basal ganglia (control of movement and posture), cerebellum (coordination and balance), vestibular (detection of head movements), visual (helps in the orientation in space), and the capsular and ligament structures of ankle (sensitivity and stabilization of the joint) in the mechanism of postural control (Paillard *et al.,* 2015). The delay or malfunction of any of these neuromuscular systems for postural control leads to a spontaneous oscillation of the center of mass within the position maintained by the individual, resulting in postural sway (Sun *et al.,* 2018; Blaszczyk *et al.,* 2016). Although many systems contribute to the postural control in a non-specific pattern, the postural behavior expressed due to the pathology to a particular system can be specific. The assessment of posture and its components will thus help in the identification of the system which is affected. The tools and methods used for this purpose must provide reliable quantitative and qualitative variables to adequately infer the functioning of the neuromuscular components of postural control (Paillard *et al.,* 2015). Postural functions are assessed by force-platforms which are widely used both in clinical and research settings. Force-platforms comprise of load sensors mounted under a dimensionally stable board. Dynamic Posturography has also been used in clinical settings to study about the standing balance of individuals (Chaudhry *et al.,* 2011). The cost of equipments involved in the assessment and the financial constraints by the clinicians raised a need for a cheaper instrument for the same purpose. Swaymeter found to be a better alternative for assessment of postural functions and balance, and was introduced in the clinical practice, the early records found in 1991 by Lord *et al.* (1991). Swaymeter have been used in various studies as a cost effective alternative for measuring postural sway and balance. The reliability of the device to assess postural sway in neurological patient population with balance deficits have not yet identified. Thus the purpose of this preliminary study is to identify the test-retest reliability of Swaymeter in neurologic patient population. The study also correlates the values of Swaymeter with Multi Directional Reach Test Scores (MDRT), which is a well-established dynamic balance test measure identifying the limits of antero-posterior and medio-lateral displacement possible by the individual under consideration. This study will help in identifying the use of Swaymeter values in research field along with other balance measures in neurologic patient population.

MATERIALS AND METHODS

Thirty patients with age ranged from 19 to 79 (mean age = 51.9 ±15.62) participated in the study. The population consisted of 19 males and 11 females. Patients were recruited from the physiotherapy outpatient department who were referred by the neurologist for balance assessment and training. Convenient sampling was done to include the patients for the study and the criteria was limited to independent standing for 1 minute without any sort of assistive devices and orthoses. Patients with any musculoskeletal pathology of the lower limbs and those who have severe spasticity (Modified Ashworth Scale > 2) were excluded. Patients were asked to stand with feet, shoulder width apart and the Swaymeter was placed behind them at the level of PSIS and fastened with Velcro strap at the waist. Swaymeter consist of a 40 cm inflexible rod attached perpendicularly to a 20x5 cm metal plate at one end offering one degree of freedom between them. The other end is fixed with a vertical mounted pen. The metal plate is being connected with Velcro straps so that it can be fastened at the PSIS level of an individual in standing. The vertical mounted pen will be placed over a graph sheet which is fixed over a height adjustable table, allowing parallel orientation of the rod with floor (Figure 1). Signed informed consent was obtained from all the patients who were selected for the study, prior to any data collection. Patients were commanded to maintain in standing and not to move any of the limbs during this time. The rod with vertical mounted pen will be held up from the graph sheet by the therapist's finger, and the rod will be released as the stopwatch starts. The initial point of pen over the graph sheet will be noted. The therapist will lift the rod with his finger once 30 seconds have been recorded. Anteroposterior (AP) and Mediolateral (ML) sway will be assessed in millimeters by measuring the distance between the end points at the extremes of AP and ML direction (Figure 2). Each patient will be assessed thrice and the average value of the three will be considered as the postural sway. Tests were repeated thrice, providing 10 minutes rest between the tests. Thus, 9 measurements will be recorded from one patient, and a total of 3 AP and ML sway recordings. Intraclass Correlation Coefficient (ICC) analysis was done to identify the test retest reliability of Swaymeter in neurologic patient population. After the assessment of postural sway using Swaymeter, Multi-Directional Reach Test (MDRT) was assessed in all participants in anterior, posterior, right and left directions. MDRT is a common test used to assess dynamic balance in individuals with neurologic deficits. Pearson's Correlation coefficient analysis was done to identify the concurrent validity of Swaymeter with MDRT. Data was analyzed using IBM SPSS statistics version 20.0 (IBM Corp. Released 2011.IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY).

RESULTS

A total of 30 patients were taken for the study. The diagnosis of the patients distributed in the population is being depicted in the pie diagram (Figure 1). All patients successfully completed the study without any adverse incidents.

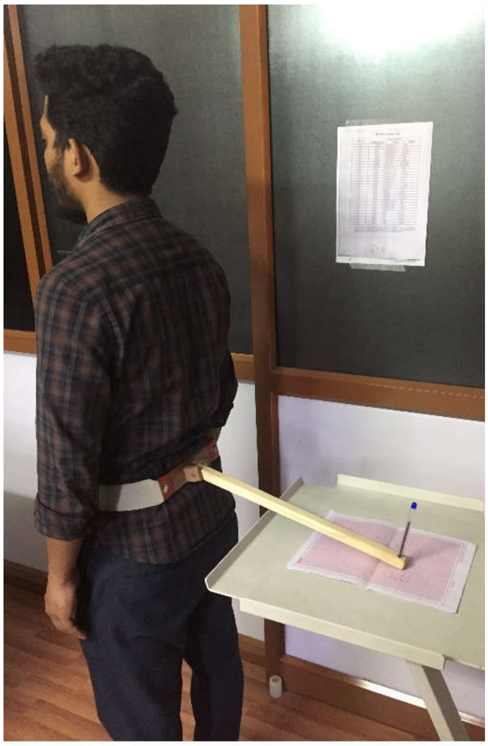

Figure 1: Assessment with Swaymeter

Test Retest Reliability: Three mean measurements were analyzed with 10 minute rest between them maintaining the same conditions and by same therapist. The Intraclass Correlation (ICC) values of Sway for anterior, posterior, right and left are provided in Table 1.ICC is a widely used statistical tool to identify the test retest reliability of instruments and scales. ICC values greater than 0.90 are indicative of excellent reliability, between 0.75 and 0.9 are considered as good, between 0.5 and 0.75 are considered as moderate and values less than 0.5 are indicative of poor reliability with 95% confidence interval.

Table 1. Intraclass Coefficient Correlation of Swaymeter values

Sway Direction	Test 1 Mean	Test 2 Mean	Test 3 Mean	ICC
Anterior (in mm)	15±11	15±12	10±6.4	0.642
Posterior (in mm)	11±10	13±10	12±7.9	0.602
Right (in mm)	18±16	15±10	16±18	0.757
Left (in mm)	16±14	20±24	16±15	0.713

Table 2. Pearson Correlation Analysis between Swaymeter and MDRT

Direction	Mean		Pearson Correlation Coefficient	Significance (p)
	Swaymeter (in mm)	MDRT (in cm)		
Anterior	13.26±7.79	21.92±6.81	0.106	0.579
Posterior	11.66±7.11	13.05±5.27	0.463	0.010
Right	16.29±12.57	18.23±6.60	0.216	0.252
Left	17.17±14.89	16.82±7.53	0.214	0.257

Table 3. Previous studies analyzing the reliability of Swaymeter

Author	Objective	Population	Age	Method	Value	Remarks
Parameyong *et al.*	Concurrent Validity (r)	15 normal children	9.7 ± 1.44	Quiet bipedal stance, 30s, 4 conditions (EO & EC on Floor & Foam)	0.637-0.979¥	Against 3D motion system
	Test Retest Reliability (ICC)	36 normal children	9.1 ± 1.66		Immediate Area = 0.74-0.87* AP = 0.51-0.75* ML = 0.57-0.81* Inter-session Area = 0.77-0.93* AP = 0.49-0.70* ML = 0.63-0.80*	Tests done in 1 week gap by same examiner
Sherrington *et al.*	Test Retest Reliability (ICC)	30 elder people with hip fracture	79.8 ± 10.0	Quiet standing, heels 10 cm apart, 30s, EO, Floor & Foam	Floor = 0.59* (0.29-0.79) Foam = 0.72* (0.46-0.86)	1 day gap for inpatients, 1 week for community dwellers
Bosewell-Ruys *et al.*	Test Retest Reliability (ICC)	30 people with SCI	35 ± 11	Measured upper body sway in sitting unsupported 30 sec	AP = 0.72* (0.49-0.86) ML = 0.51* (0.18-0.73)	3-13 days gap between two tests done by same examiner. Patient seated, fastened to the chest at level of axilla, corrected for body height
				Max Balance range (AP)	0.90* (0.81-0.95)	
Sturnieks *et al.*	Concurrent validity (r)	29 older adults & 11 young adults	78±3 & 33±9	Bipedal stance, 30s, foot shoulder width apart, 4 condition s (EO & EC on Floor & Foam)	AP = > 0.743¥ ML = > 0.692¥ Sway path = > 0.560¥	Against Kistler force-plate
	Convergent Validity (r)				0.560-0.865¥	Against Kistler force-plate
	Test retest Reliability				0.654-0.944*	1 min rest between trials

(EO-Eyes open, EC-Eyes closed, *ICC, ¥r value)

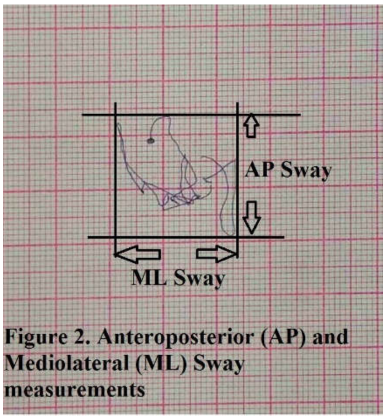

Figure 2. Anteroposterior (AP) and Mediolateral (ML) Sway

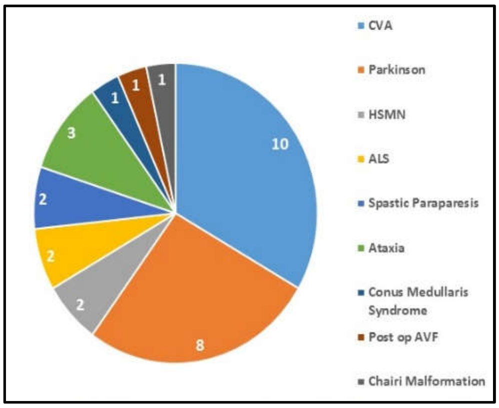

Figure 3. Distribution of neurological diagnosis within the population

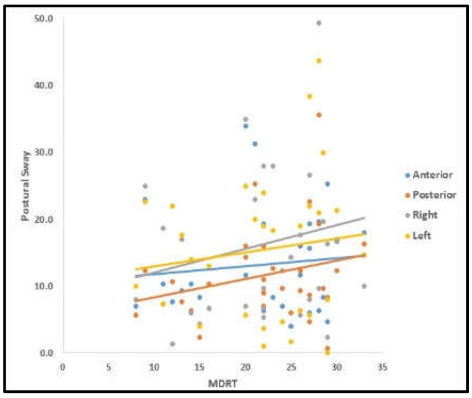

Figure 4. Correlation Analysis between Swaymeter values and MDRT in four

Our study identified a moderate test retest reliability in Swaymeter measurements identifying postural sway in all directions, in neurologic patient population. Among the 4 test directions, test retest reliability to the right side shows moderate to good reliability with ICC of 0.757.

Concurrent Validity: Table 2 shows the Pearson correlation analysis performed between Swaymeter measurements and Multi-Directional Reach Test (MDRT) for analyzing the concurrent validity between them. Figure 4 represents the scatter plot for 4 directions.

The analysis shows a presence of positive correlation between Swaymeter values and MDRT values. Measurements in all directions show a minimal correlation except for posterior direction which shows a moderate positive significant correlation (+0.463, $p<0.05$) between two measurement values.

DISCUSSION

The use of Swaymeter has been advocated by many researchers in the studies identifying the relation of balance with other factors. A literature search was conducted by us to identify studies related to the reliability of Swaymeter. We identified 9 articles in PubMed, 23 in PubMed Central, 37 in ScienceDirect, and 630 articles in Google Scholar using ‘Swaymeter’ as the keyword. Scrutinizing according to the title and abstract reading identified 4 articles which studied the reliability of Swaymeter in individuals (Parameyong *et al.,* 2018; Sherrington *et al.,* 2005; Bosewell-Ruys *et al.,* 2009; Sturnieks *et al.,* 2011). The details of these studies are summarized in Table 3. We identified no studies which shows the reliability of Swaymeter in neurologic population. This preliminary study identified a Moderate to good test retest reliability of Swaymeter (0.602-0.757) in the assessment of postural sway among neurological patient population in all directions. The values identified in this population shows less variation to the values identified in normal individuals in the previous studies. The study conducted by Rocchi *et al.* (2002) have identified an increase in mediolateral sway than anteroposterior sway in individuals with Parkinson’s disease, and a reduction in sway in the treatment with deep brain stimulation (Rocchi *et al.,* 2002). Serrador *et al.* (2009), in their study on otolith function with aging has identified an increase in mediolateral measures of sway with the loss of vestibular otolith-ocular function (Serrador *et al.,* 2009). Mahar *et al.* (1985) have identified an significant increase in postural sway in the mediolateral direction without changes in anteroposterior direction in normal individuals with leg length discrepancy (Mahar *et al.,* 1985). Thus the need of postural sway analysis is a powerful adjunct in the assessment of various neuromuscular pathologies. The availability of a low cost instrument such as the Swaymeter helps the clinicians to gain more data in a cost effective and time saving manner. The data thus obtained can be used in the diagnosis, prognosis and in the training aspect of the individuals under consideration. The moderate to good reliability of Swaymeter makes it an effective tool in the clinical and rehabilitation settings for the benefit of the patients.

The increase in postural sway in neurologic patient population can be due to many possible factors. One of those attributes to a reduction in proprioceptive feedback from the distal joints leading to an increase in oscillatory movements over the ankle joint for compensation (James and Brammatha, 2017). Various other studies have also proposed the role of proprioceptive system over postural sway, along with vestibular and other systems. This can lead to an increase in balance deficit in these individuals, with can cause an increase in fear of fall and reduction in their activity. They tend to take less risk to move their center of gravity to the extremes of base of support. This led us to a hypothesis that a negative correlation exist between postural sway and maximum reach of the patient to all directions. The statistical analysis done between postural sway and MDRT showed a positive correlation between them in all directions (r = 0.106-0.463) with posterior direction demonstrating a statistical significance (Table 2). This was in contradiction with our hypothesis expecting a reduction in MDRT values with an increase in postural sway. Postural sway is considered to be an indicative of static balance while MDRT is considered as a measure of dynamic balance. Many authors have performed a correlational analysis between static and dynamic balance measurements (Hatzitaki *et al.,* 2002; Pau *et al.,* 2005; Hrysomallis *et al.,* 2006; Sell, 2012; Karimi and Solomonidis, 2011). Static balance works under a feedback based control depending on the perception of sensory information and the ability to perceive it, whereas dynamic balance works over feed forward mechanism associated with speed of motor response to maintain equilibrium (Hatzitaki *et al.,* 2002). The study by Pau et al identified no significant correlation between static and dynamic balance in young and professional elite soccer players when assessed with single leg stance and vertical time to stabilization (TTS) respectively (Pau *et al.,* 2015). Authors concluded that the performance of static balance tests cannot be compared with that of dynamic balance. Therefore the assessment of individuals for balance must comprise of both static and dynamic components and cannot be inferred with only one of them.[20] Future studies should also consider the fact that the performance in static balance tests will not be an indicator for the dynamic balance measures. This study is a preliminary study which included different neurological conditions with balance deficits. We suggest a homogenous sample for the upcoming research to identify the effects within the population under consideration. Future studies can also correlate the Swaymeter readings with the force-plate measures to justify the findings strongly.

Conclusion

Postural sway measurements evaluated using Swaymeter has moderate to good test retest reliability in patients with neurological illness. Swaymeter can be used as a cost effective alternative in assisting the diagnosis, treatment, and assessing the prognosis among these individuals. The simplicity in the construction of the equipment makes it an easy tool to be used even in the community setup. This study could not confirm the correlation between the static and dynamic balance assessments and conclude that both tests must be done separately to make the decision upon the balance measures of the individual.

Declaration of Interest: None

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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