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Review Article

VARIOUS STATIC AND DYNAMIC BALANCE MEASURING AND TRAINING MECHANICAL TOOLS IN PATIENTS WITH CLINICAL CONDITIONS: A LITERATURE REVIEW

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ABSTRACT

Background: Balance is defined as the ability to maintain a position within the limits of stability or base of support. It is indicated that postural control system plays an important role in maintenance of balance on the small support base. The complexity of balancing processes makes it challenging to assess balancing abilities in a concise, holistic approach. This study extends previous efforts by reviewing a large number of papers that use of various mechanical tools to assess postural balance and by providing a detailed overview of the common mechanical tools used to assess postural balance and gait.

Methods: We searched the electronic database. The literature search produced a total of 302 items. After removal of duplicates, posters, other studies not mention mechanical tools to evaluate static and dynamic balance in clinical conditions, 28 papers met the inclusion criteria for this review.

Results: This search selected 7 tools to assess trunk control in various clinical conditions: Inertial balance sensor, Computerised dynamic posturography, Biodex Balance System, Force plate., MatScan® pressure mat, Microsoft Kinect's built-in RGB-D sensor and Clinical Test of sensory integration using Chinese lantern.

Conclusion: Inertial as well as Microsoft Kinect's built-in RGB-D sensors are cost effective, time effective, does not need a specific set up, analysis static balance as well as the gait parameters. This can therefore be chosen over other mechanical tools due to its better convenience and efficiency.

KEY WORDS: Static Balance, Dynamic Balance, Mechanical tools, Posturography, Sensors, Clinical Conditions.

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INTRODUCTION

Balance is defined as the ability to maintain a position within the limits of stability or base of support. Postural control can be defined as the act of maintaining, achieving or restoring a state of balance during any posture or activity [1].

It is indicated that postural control system plays an important role in maintenance of balance on the small support base provided by the feet [2].

Instability and postural imbalance are commonly demonstrated as body sway increase in situations with impaired coordination between visual

and proprioceptive systems, decrease in threshold of stability and functional capacity, gait changes, and falling in patients with vestibular impairments. Falling (the primary consequence of postural imbalance) is associated with various impairments in neuromuscular system. This condition is resulting from an inability to maintain normal posture[3].

A balance assessment for patients with various clinical conditions is important, for it is required to set up an objective of treatment, to determine a treatment method, and suggest progression and prognosis[4].

The assessment of balancing abilities is an integral part of orthopedic and physiotherapeutic evaluation. While functional tests are practical in terms of the low number of required devices and instrumentation, they are inherently subjective as most of them do not use instrumented measurement data in the scoring process [5].

The complexity of balancing processes makes it challenging to assess balancing abilities in a concise, holistic approach. Task constraints of balancing assessments in general can be classified as: static body stability (stability to keep the body in a static position), quasi-mobility (dynamic body stability and transfer stability) and mobility (stability during locomotion) [6].

Despite the expanding body of evidence supporting the use of various mechanical tools to assess postural and dynamic balance, it is important to recognize that this area of research is still developing. As described before, several other systematic reviews have been published in the last years, focusing on postural balance assessment of sample populations affected by different balance-related pathologies. This study extends previous efforts by reviewing a large number of papers that use of various mechanical tools to assess postural balance and by providing a detailed overview of the common mechanical tools used to assess postural balance.

Need for study:

However, studies have been done on the various clinical tools for assessing static and dynamic balance, no studies have been made with the various mechanical tools for both static and dynamic tools in neurological conditions.

Balance is the most important component when it comes to recovery in patients with neurological conditions. An accurate balance measuring tool will help the patient to get a feedback about his/her present condition. It will also help in assessing and training purpose. A quicker recovery and balance will motivate them towards a physically active and healthy life.

Aim: To assess various static and dynamic balance measuring and training mechanical tools in patients with neurological conditions.

OBJECTIVES:

1. To select high-quality papers that adopt various mechanical tools for qualitatively evaluating standing balance and dynamic balance

2. To highlight the most important clinical applications including assessment, rehabilitation and biofeedback;

3. To investigate the most common mechanical tools and test protocols;

4. To describe the main parameters and level of reliability and validity of various mechanical tools

METHODOLOGY

Study type: Systemic review

Study selection:

1. Full text articles from peer-reviewed journal were included.

2. Observational studies, Randomised control trials and experimental studies were included.

Inclusion criteria:

1. Articles measuring static and dynamic balance.

2. Articles evaluating and assessing balance using mechanical tools.

3. Articles inclusive of normal subjects.

4. Observational studies, Randomised control trials and experimental studies

5. Articles published in English language

Exclusion criteria:

1. Articles in other than english.

2. Articles measuring balance using clinical tools.

3. Unpublished articles.

Outcome measures:

1. Inertial balance sensor.
2. Computerised dynamic posturography
3. Biodex Balance System
4. MatScan® pressure mat
5. Force plate.
6. Microsoft Kinect's built-in RGB-D sensor
7. Clinical Test of sensory integration using Chinese lantern

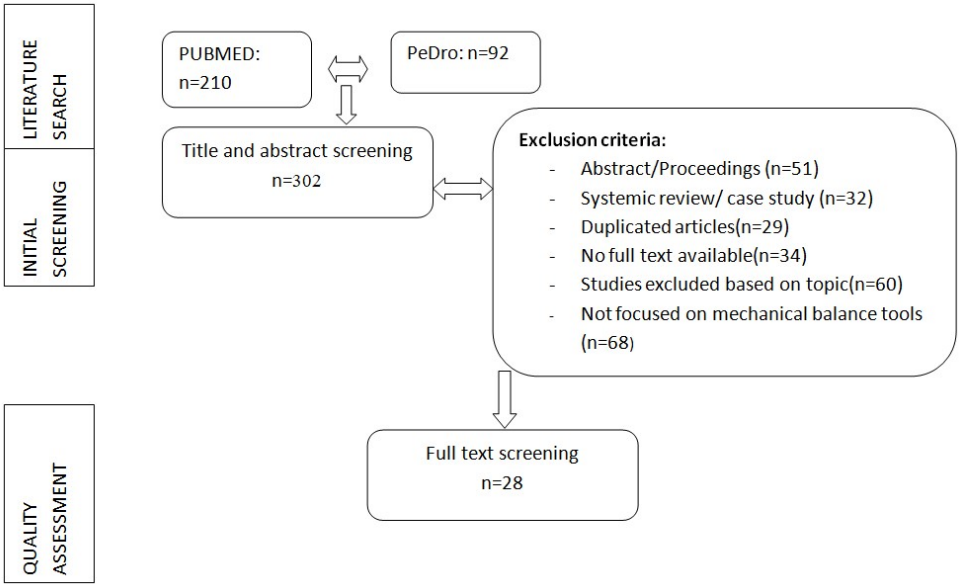
Search strategy: Articles published on online electronic database were included. The search strategy used were medical subject terms and text words for balance. PubMed and PeDro electronic databases have been interrogated in october 2019 to identify articles measuring postural and dynamic balance through various mechanical tools. The following keywords were used for the electronic database search within the title and/or the abstract: "balance", "posturography", "postural sway", "postural control", "static and dynamic balance", "mechanical tools", "assessment and training" and "neurological conditions". Speciûcally, the query that was used to search the articles in the databases was Biodex balance system, force plates, pressure mats, gait analysis, sensors, robotic devices. Observational studies, Randomised control trials and experimental studies were evaluated for the study.

Selection criteria: Articles included were the (a) Articles considering mechanical tools for measuring balance. (b) Mechanical measures that have been considered valid or reliable in measuring balance in various neurological conditions. (c) Articles reviewed only from online electronic database site. (d) Articles which were Randomised control trials and experimental studies (e) Articles published in English language only. The exclusion criteria was Articles considering clinical or any tools other than mechanical. Measures that are not valid, reliable or published. Articles published in language other than English language. Studies which included systemic reviews were excluded.

Selection of studies and data extraction: All steps in the selection and extraction processes (i.e., the study selection, data extraction, and risk of bias evaluation) were assessed independently by two reviewers. The titles and abstracts of all retrieved references were screened. The full texts of relevant publications were reviewed and were included if they met the inclusion criteria. The data from the included studies were extracted using a piloted data extraction form, which included information on the study population, design, interventions, comparison, outcome measures, and results

Data analysis: Various electronic databases were searched by the investigator and guide. The titles and abstracts of all the retrieved results were then screened for eligibility. The first screening process was aimed at narrowing down the volume of the articles by rejecting the studies that were not relevant or appropriate according to the previously stated criteria. Duplicates were removed. Full text versions of all relevant articles were evaluated by both.

Procedure



SR. NO.	BALANCE MEASURING TOOLS	PARAMETER	PARAMETER MEASURED	SAMPLING POPULATION	COMPARATIVE AGENT	TIME REQUIRED	COST	RELIABILITY/ VALIDITY	RESULT
1	**Inertial balance sensor**	CoG	Standing and walking Balance	14 elderly affected by stroke and 25 nondisabled elderly	--------	Variable	inexpensive	in individuals affected by stroke ICC=0.431–0.994	These findings suggest that the inertial sensor-based iTUG measures are useful to assess functional mobility in patients with stroke
2	**Computerised dynamic posturography**	centre of foot pressure (CFP)	Standing Balance on static abd dynamic surface	Young adults (20-22 yes)	Random motion platform	2-3 minutes	expensive	Not mentioned	CDP was more effectlive and more accurate in varying degrees of test
3	**Biodex Balance System**	CoG	Static and dynamic Standing Balance	50 obese men	Correlation with BMI	5-10 minutes	expensive	R = .94 (OSI), R = .95 (APSI), and R = .93 (MLSI) in 20 active adults	No statistical difference between posture balance and fall risk with Change in bmi.
4	**MatScan® pressure mat**	sway parameters	Static Standing Balance and Gait stability	Thirty healthy, young adults-19 female,11 male(age-18-26)	Compare COP measures with force plate	4 minutes	expensive	ICC=0.44-0.95 in 30 healthy adults	Despite systematic measurement differencesbetween devices, both devices detected comparable magnitude %-changes and effect-size changes from eyes-open to eyes-closed for all four COP measures.
5	**force plate.**	COP movement track data	Static Standing Balance	Fifteen healthy individuals, 13 male and 2 females, between the ages of 21 and 2	inertial sensor	5-6 minutes	expensive	(ICC = 0.90, 0.85, and 0.77 in healthy adults ranging from 50-70	The experimental findings suggest that it is better to use a force plate if the task is based on the visual system, whereas an inertial sensor should be used for lower limb tasks.
7	**Microsoft Kinect's built-in RGB-D sensor**	COM	Standing Balance and Walking Stability	30 out patients not more than 3 months post stroke able to stand unsupported	Balance tests	10-15 minutes	inecpensive	(ICC) > 0.80 in the same population	Instrumenting Kinect is reliable and provides insight into the dynamic balance capacity of patients living with stroke
8	**Clinical Test of sensory integration using Chinese lantern**	sway-reference	Static balance	___	Computerised dynamic posturography	3 minutes	inexpensive	(ICC = 0.91 in alziemers patients	It is a simple test that has been devised to easily and rapidly assess the dependence of a patient on various inputs and devise a rehabilitative strategy customized to a rehabilitative strategy customized to each patient

RESULTS

The literature search produced a total of 302 items. After removal of duplicates, posters, and congress abstracts, and other studies not mentioning a mechanical tools to evaluate static and dynamic balance in neurological conditions, 28 papers met the inclusion criteria for this review

This search selected 7 tools to assess trunk control in stroke:

Inertial balance sensor.

1. Computerised dynamic posturography
2. Biodex Balance System
3. Force plate.
4. MatScan® pressure mat
5. Microsoft Kinect's built-in RGB-D sensor
6. Clinical Test of sensory integration using Chinese lantern

Inertial balance sensor: A wearable inertial sensing unit typically includes accelerometers, gyroscopes, and magnetometers [7]. The accelerometers senses the acceleration signals of walking and balance motions. The uniaxial gyroscopes measures the yaw-rate of the wearable device and the biaxial gyroscopes measures the roll- and pitch-rates of the wearable device [8]. The sensors are usually wearable and are placed over the limbs and trunk. An inertial-sensor-based wearable device Is mounted on the participants body. Then the participtants are requested to maintain body balance and perform various balance ability tests. Temporal and spatio-temporal gait parameters as well as angular velocity and turn parameters were derived from the inertial sensor data [9].

A study states that the inertial-sensor-based wearable device reveals promising potential for gait and balance capability analysis and is worth of further in-depth research to identify gait and balance parameters in mild Alzhiemers Disease patients, so as to be served as indicators for early diagnosis of AD, and also as predictive clinical factors of progression towards dementia in this population [8].

In a study, it is seen, baseline inertial sensor parameters had a similar association with declining balance as age and TUG time. For higher functioning older adults, the change in inertial sensor parameters over time may reûect declining balance. These measures may be useful clinically, to monitor the balance status of older adults and facilitate earlier identiûcation of balance deûcits [9].

In a study, it was seen Excellent test-retest reliability was found for most of the iTUG metrics measured, and the inertial sensor-based iTUG is able to distinguish patients with stroke from nondisabled controls. These findings suggest that the inertial sensor-based iTUG measures are useful to assess functional mobility in patients with stroke [10].

In a study it is indicated that measuring the degree of balance and gait regularity using ûve body-worn inertial sensors during the tandem walking test provides a novel quantiûcation of movement that identiûes abnormalities in patients with vestibular impairment [11].

Computerised dynamic posturography: Computerized dynamic posturography (CDP) testing is a technique used to assess underlying sensory and motor control impairments associated with balance disorders [12].

Posturography is a general term for techniques used to measure postural stability on static or dynamic measuring platforms. The principle of static computerised posturography (SCPG) is the detection of the centre of foot pressure (CFP) in upright stance on a posturography platform [13]. Computerised posturography provides very accurate results on postural sway parameters, which cannot be obtained from clinical examination alone [14]. The NeuroCom SOT is a widely accepted CPD test used for the evaluation of a range of clinical conditions [15].

It is seen in a study that Posturographic assessment using Computerized Dynamic Posturography showed that patients with Parkinsons Disease had significantly lower LOS area and balance functional reserve values, and greater body sway area in all posturographic conditions compared with healthy subjects [14].

A study also states that t posturography is a valuable auxiliary test for balance disorders, especially given the lack of more suitable tests. According to our results, SCPG can be used for a rough differential topodiagnosis of balance

disorders in neurology [13].

Biodex balance system: The Biodex Balance System challenges an individual to main his or her balance while standing on a moveable platform that tilts a maximum of 20 degrees (from horizontal plane) in all directions. An LCD screen provides subjects with visual feedback on where their COM is in relation to the periphery of the platform. Safety handrails are attached and an optional overhead harness system can be added if more support is needed [16].

BIODEX balance training included SD balance training components starting from static training and progressing to dynamic components over the period of 8 weeks to medial-lateral and anteriorposterior direction [17].

A study is conducted in obese individuals to assess balance using Biodex Balance System. BMI is not the only determent of balance but it may be of great concern if it is added to other factors, which affect balance [18].

A study conducted on Effect of balance training with Biodex Stability System on balance in diabetic neuropathy states that balance training would improve postural stability and balance in elderly patients with DN [19].

A study also concluded Dynamic postural balance training using BIODEX SD had a positive effect on mobility and balance in healthy older individuals and can be used as a training tool to reduce fall risk and improve balance and mobility [17,20].

Forceplate: A forceplate is a mechanical tool which with the help of a software analysis the balance. COP movement track data (in mm) were collected for each subject and decomposed into mediolateral (ML) and anterior-posterior (AP) components for analysis [21]. The software acquired the data from the plate and computed total body Center of Pressure (CoP), and the location of the ground reaction force vectors in the AnteriorPosterior (A/P) and Medial-Lateral (M/L) directions [22].

In a study, the experimental findings suggest that it is better to use a force plate if the task is based on the visual system, whereas an inertial sensor should be used for lower limb tasks [21]. A study has made a Comparison of Simultaneous Static Standing Balance Data on a Pressure Mat and Force Plate in Typical Children and in Children with Cerebral Palsy. Examination of the data provided evidence that reliable and valid measures of static standing balance can be produced with both devices [23].

Force Plate measures provided reliable information on balance function in healthy older adults [24]. In parkinsons patients, to study the effectiveness of treatments for dyskinesia, an objective device that can discriminate between normal and abnormal, involuntary movements is needed. A study has demonstrated that a force plate, measuring changes in CoP under the feet of standing subjects, can closely replicate a clinical rating scale, the current gold standard measurement of LID [22].

Matscan® pressure mat: MatScan® pressure-mat (TekScan, Inc. Boston, MA, USA) is a low profile floor mat(5 mm thick) concisting of 2288 resistive sensors with a sampling frequency of 40 Hz. The mat provide measures of AP and ML sway parameters described as; area and direction of sway, distance and direction travelled by the COP [25].

A study has made a Comparison of Simultaneous Static Standing Balance Data on a Pressure Mat and Force Plate in Typical Children and in Children with Cerebral Palsy. Examination of the data provided evidence that reliable and valid measures of static standing balance can be produced with both devices [23].

In a study it is seen that the portability and ease of the use of the TekScan MatScan® pressure-mat makes it useful tool for the measurement of the postural stability in clinical and research setting. The TekScan MatScan® pressure-mat system can reliabily measure double limp quite standing in older people aged 60-80 years with Rheumatoid Arthritis [25].

It is also said that The MatScan® pressure-mat may be a viable option for clinicians to detect large magnitude changes in postural control during short duration balance trials [26].

Microsoft kinect's built-in RGB-D sensor: Microsoft Kinect uses a built-in RGB-D sensor and the skeleton tracking algorithm to capture 3-D movements of the human body [27]. Kinect sensors are capable of properly identifying posture and motion, but not body or joint rotations,

unusual postures, or occlusions [28].

Patients with concussions, strokes and neuromuscular disease such as Parkinson's disease, often have difficulties in keeping balance and suffer from abnormal gaits. A study performs assessments on dynamic balance and gaits by analyzing the skeleton frames of a subject captured by the Microsoft Kinect RGB-D sensor. Results show that the proposed system effectively scores subjects [29].

A study suggests that Kinect may be a valid, reliable, and convenient device for assessing standing balance when its measured COM parameters are properly calibrated [27].

A study shows that instrumenting gait using the Kinect is reliable and provides insight into the dynamic balance capacity of people living with stroke. This system provides a minimally invasive method of examining potentially important gait characteristics in people living with stroke [30].

Clinical test of sensory integration using chinese lantern: The Clinical Test of Sensory Interaction and Balance (CTSIB) is a timed test that was developed for systematically testing the influence of visual, vestibular, and somatosensory input on standing balance. The dome provides a sensory conflict by depriving the subject of peripheral vision and introducing a sway-reference [31].

This test is a useful in screening tool for examining static standing in subjects with vestibular disorders. Older Asymptomatic and vestibular impaired subjects had greater variation in their scores than did younger AS subjects. The test is also useful for obtaining data about patients performance before and after therapy, and thus in documenting the efficacy of treatment [31].

The CTSIB is an effective, cheap and valid alternative to the more formal Sensory Organisation Test.It is also a useful adjunct to rehabilitate the balance patients, with the CTSIB test as an objective parameter by which they may be evaluated for progress and eventual recovery [32].

CTSIB provides information about the ability to stand upright under several sensory conditions. This study was performed in Healthy Indian Children aged7–12yrs. A study states that, the CTSIB is a valid test for balance evaluation in Indian children [33].

mCTSIB seems be a valid test with simple and quick apply for verifying the effectiveness of Epley maneuver in BPPV patients [34].

DISCUSSION

Clinical assessment using validated tools for balance control is a key aspect in both clinical practice and research. This review highlights the large interest shown by clinicians and researchers in the last few years. There is a growing number of publications on the use of various mechanical tools in the area of assessment in a clinical set up or for the purpose of training in patients with various clinical conditions. A selected number of these papers dealt with the analysis of their various characteristics.

It is thought that, in clinics, the advantages of using mechanical tools outcome measures of balance, instead of clinical subjective scores, are evident and more reliable.

All the tools were classified into three major categories depending upon the component of balance that they measured. They are as follows-

Static Standing Balance: Force Plate and The Clinical Test of Sensory Interaction and Balance Standing Balance on Static and Dynamic Platforms: Computerised dynamic posturography and

Biodex Balance System: Static and Dynamic Standing Balance along with Gait Analysis: Inertial balance sensor, MatScan® pressure mat and Microsoft Kinect's built-in RGB-D sensor.

The tools measuring Static Standing Balance work majorly on the principal on measuring CoG and LoS. The force plate uses a software to decipher the COP and decompose it into mediolateral (ML) and anterior-posterior (AP) components for analysis. In this the distribution of weight bearing on the affected and non affected limb can also be deduced. It is comparatively expensive but easy to administer on the patient giving accurate results. The Clinical Test of Sensory Interaction and Balance is majorly used in subjects with balance disorders related to sensory or vestibular

affection. It assesess the visual control and challenges the vestibular system of the subject. It is inexpensive, easy to administer and is used to devise a rehabilitative strategy customized to each patient. Hence a Force Plate is preferred due to its higher reliability, effectiveness and a variety of inclusion population.

Computerised dynamic posturography measures balance using posturography which measures the LoS over the static as well as the dynamic surface. It does not provide localization to one side also it does not offer disease-specific information. It can decipher the postural control which can help the therapist understand the risk of falls in a patient. The impact of this information on diagnosing, treatment planning, and monitoring has not been clearly defined. CDP does not localize the site of a lesion or cause of balance impairment. Biodex Balance System is the only mechanical tool that is used for assessing balance as well as used as a tool for training patients with balance impairments. It is an expensive tool and not very easy to administer. This is the only tool that provides visual feedback to the patient and hence helping in the balance training protocol. It helps to find the fall in patients with balance impairment. Here, the Biodex system provides training as well as assessment and is hence preferred over Computerised dynamic posturography.

MatScan® pressure mat is majorly used for static standing balance. But it also used to assess the plantar pressure distribution during walking. The biggest advantage of the tool is that it is portable and very easy to use. It measures balance by measuring sway of the body and finding the postural stability. The findings of the mat are interpreted using a TekScan SAM software. Inertial Balance sensor are wearable sensor which not only detects static balance but also assesses falls risk as well as gait deviation analysis.it is cheap effective and has a high reliability. It is hence chosen over the other mechanical tools. It does not require much time or more space or a confined set up. It can be administered in any clinical set up. Microsoft Kinect's built-in RGB-D sensor captures 3-D movements of the human body. It is a reliable tool for patients with neurological condition. It demands for a particular programme to be installed in order to complete the balance analysis. It is low cost and convenient.

It is seen that CoG is the most common parameter of measurement in various mechanical tools. Also a vast number of Indian articles were found on inertial sensors indicating the easy availability of that mechanical tool. It also has an advantage of high reliability.

CONCLUSION

Various static and dynamic balance measuring and training mechanical tools have been assessed in patients with neurological conditions. It has been seen that various tools work differently and measures the balance. Both types of sensors are cost effective, time effective, does not need a specific set up, analysis static balance as well as the gait parameters. This can therefore be chosen over other mechanical tools due to its better convenience and efficiency.

Conflicts of interest: **None**

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