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ORIGINAL RESEARCH

Positive correlation of postural balance evaluation by two different devices in community dwelling women

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OBJECTIVE: To establish the convergent validity or relationship of the Balance Master® as balance assessment device by comparing its performance results with those obtained from the AccuSway Plus® force plate.
METHOD: Cross-sectional observational study, without intervention, of 126 postmenopausal women (60.3 ± 3.2 years; body mass index = 27.6 ± 4.7 kg/m²). Two devices were used for the independent assessments of static balance: (a) Static postural balance assessment (posturography) was performed on a force platform (AccuSway Plus); (b) static evaluation was performed on the Balance Master® System. The variables studied in the two devices, were: (i) the Mean Velocity of the Center of Pressure Displacement in all directions (Vavg or Mean Firm), (ii) the Anteroposterior (Mean-Y) and (iii) the Mediolateral (Mean-X) Centers of Pressure Displacement. The Spearman correlation coefficient was calculated to measure the correlation of the variables of balance obtained with the two different devices.
RESULTS: Significant correlations were obtained when the relationships between both variables were described by fitting multiple linear regression models. There was an association between the mean velocity of center of pressure displacement in both devices, with eyes open (r = 0.21) and eyes closed (r = 0.47). In the eyes open condition, Vavg increased, on average, 0.26 units, while Mean Firm increased 1.0 unit; in the Mean-Firm; in eyes closed condition, Vavg increased, on average, 1.27 units, while Mean-Firm increased by 1,0 unit.
CONCLUSION: The devices investigated presented a significant correlation for the mean velocity calculated from the total displacement of the center of pressure in all directions.

KEYWORDS: Postural balance; Center of pressure; Device; Force plate; Postmenopausal.

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INTRODUCTION

Posture control is the ability to maintain the center of mass on the base of the support, which defines the stability limits. These limits are operational areas which determine how far the center of mass can be displaced without having to change the base of support.[1] Postural stability depends upon a complex mechanism comprising the visual, vestibular and somatosensorial systems.[2] The human body is constantly subjected to external and internal forces, which accelerate the body around its center of mass. When standing, the body adjusts its balance at all times and a small postural sway can be observed. This sway can be verified by several methods, but the force plate, which evaluates the displacement of the center of pressure, is the most frequently used parameter and is considered the gold standard for the assessment of postural balance.[3-5]

There are many methods of postural balance assessment, ranging from simple observation, clinical tests, scales, platforms (posturography measures) to more complex integrated evaluation systems. All have advantages and limitations and may produce different results with multiple interpretations. This lack of consensus does not allow the use of tests in clinical practice as reliable tools for evaluating risk of falls, nor to estimate the results of therapeutic interventions.

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The available commercial force platforms (e.g. AMTI, Kistler) are devices consisting of three or four load cells that use mainly the vertical component of ground reaction force to measure the displacement of the COP. Other devices evaluate the postural balance (e.g. Balance System - Biodex, Equitest and Balance Master - Neurocom, Proprio 5000 - 4000 Perry Dynamics, Sportkat) using the integrated evaluation of visual and labyrinthic functions together with the COP displacement, seeking a more functional assessment.

The Balance Master® provides objective assessment and retraining of the sensory and voluntary motor control of balance with visual biofeedback. The System utilizes a fixed 18" x 60" dual force plate to measure the vertical forces exerted by the patient's feet. The interactive technology and clinically proven protocols allow the clinician to objectively assess patients performing tasks ranging from essential daily living activities to high-level athletic skills.[6]

The AccuSway® is the conventional force plate with a computer interface via a convenient USB connection. The platform allows different ways of data collection and parameters (e.g. frequency, frequency filter, time of acquisition and base of support), allowing an individualized analysis of each patient.

The overall goal of the present study is to establish the convergent validity or relationship of the Balance Master® as a balance assessment device by comparing its performance results with those obtained from the AccuSway Plus® force plate. The hypothesis is that the two devices would yield correlated measures of postural control emerging from the same underlying balance mechanism. The question raised in this study is to determine whether the evaluation of COP displacement using the force platform, can be matched to the assessment obtained using an integrated device.

METHODS

Ethical

The study was approved by the Ethics Committee of the Institution under case number 320/09. All participants signed an informed consent form.

Participants

This is a cross-sectional observational study, without intervention, of 126 elderly women patients (Age: 60.3 ± 3.2 years; BMI: 27.6 ± 4.7 kg/m^2) recruited from the teaching Hospital at the Faculdade de Medicina da Universidade de São Paulo, according the following inclusion criteria: participants (i) presented no pathology related to the vestibular, proprioceptive, auditory or neurological systems, (ii) used no antipsychotic medication, (iii) had no restrictions to vigorous physical activity, (iv) had not been subject to surgery, (v) had not suffered injuries to lower extremities over the past six months. Participants were excluded if found to be incapable to perform the test. After receiving an explanation about the study and the signing of the consent form, they were assessed as per the evaluation protocol.

Mesurements

The static postural balance assessment (posturography) of all participants was initially performed on a portable force platform (AccuSway Plus, AMTI®, MA, USA). For data acquisition, the force platform was connected to a signal-amplifying interface box (PJB-101) that was linked to a computer by means of an RS-232 cable. The data were collected and stored using the Balance Clinic® software, configured to a frequency of 100 Hz with a fourth-order Butterworth filter and a cutoff frequency of 10 Hz. All participants underwent the test with standardized positioning in relation to the maximum width of the support base (smaller than hip width), with arms along the body and head facing a target placed directly in front of them. The base of support was drawn on a paper on a fixed position on the force platform corresponding to the following anatomical points: distal hallux phalanx, fifth metatarsal head, lateral and medial malleolus for each foot. Three measurements were taken with the eyes open (EO) and three with the eyes closed (EC), for 60 seconds each. The arithmetic mean of the results was calculated from the three tests conducted under each condition and was processed using Balance Clinic® software. The parameters used to measure the subject's stability with eyes open and closed were: the displacement of the center of pressure (COP) (cm) and the mean velocity calculated from the total displacement of the COP in all directions (cm/s).

The second static evaluation was performed on the balance device Balance Master® System (Neurocom International, Inc. Clackamas, Oregon, USA). Participants were tested through the Modified Clinical Test of Sensory Interaction on Balance (mCTSIB); this evaluates body sway while the individual remains on the stable surface of the force platform with eyes open and closed. Each condition was repeated three times, during 10 seconds, and the moving average of the three measurements was used. The parameters used were COP displacement (degrees) and mean velocity calculated from the total displacement of the COP in all directions (degree/s). The same base of support was maintained in both devices.

The variables studied in the two devices, AccuSway Force Plate and Balance Master, were:

- Mean velocity from the total displacement of the COP in all directions (Vavg and Mean Firm);
- Anteroposterior (YSD and Mean-Y) and mediolateral (XSD and X-Mean) COP displacement.

Statistical Analysis

The Spearman correlation coefficient was calculated to measure the correlation of the variables of balance on two different devices (Balance Master® System and Accsuway plate form). When significant correlation was obtained, the relationship between both variables was described by fitting multiple linear regression models. In the multiple linear regression analysis, the assumptions of normal distribution and equality of variance of the errors were assessed by means of residual analysis. The software used in the data analysis was Minitab® (version 15) and SPSS® (version 18). The significance level was set at 0.05.

RESULTS

The Spearman correlation coefficients of postural balance variables in the two devices were calculated, and are shown in Table 1. Note that there is a significant correlation only between Vavg and Mean-Firm, both in open and closed eyes conditions.

Table 1 - Values of Spearman correlation coefficients for the postural balance variables obtained from the two equipments

	Eyes open		Eyes closed	
	r	p	r	p
ML COP displacement	0.09	0.303	0.15	0.099
AP COP displacement	0.01	0.932	-0.10	0.283
Mean velocity	0.21	0.019	0.47	< 0.001

AP COP: Anteroposterior center of pressure. ML COP: Mediolateral centrer of pressure. Mean velocity: mean velocity calculated from the total displacement of the COP in all directions. Significant ($p < 0.05$) Person's correlation coefficient (r) are represented in bold.

The association between mean velocity of COP displacement in both devices in eyes closed condition is provided in Figure 1.

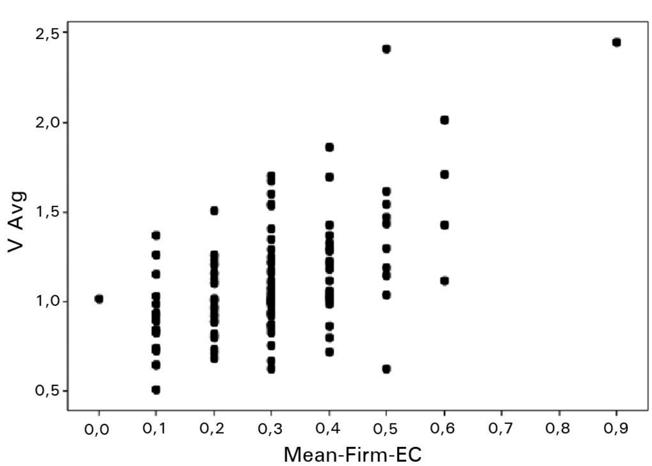

Figure 1 - Dispersion diagram of Vavg and Mean-Firm in the eyes closed condition

To describe the relationship between mean velocity of COP displacement in each condition (eyes open or closed), regression linear models were adjusted with Mean-Firm as the independent, and Vavg as the dependent variable. The adjusted models were:

Eyes open:

Vavg expected = 0.71 + 0.26 Mean-Firm;

Eyes closed:

Vavg expected = 0.73 + 1.27 Mean-Firm.

The adjusted models indicate that:

- In the open eyes condition, the Vavg increases, 0.26 units as average, with a unit increase in the Mean-Firm;
- In the closed eyes condition, Vavg increases, 1.27 units as average, with a unit increase in the Mean-Firm.

DISCUSSION

Mechanically a body is in balance when the sum of the forces (F) and the moments of the forces (M) acting on it is zero ($\Sigma = 0$ and $M = 0$). However, due to internal and external forces the body normally presents minimal displacement variations, which can be measured by a force plateform.[3] On the other hand, there are studies that show that postural balance is defined by the individual's ability to move in amplitudes within the limits of stability, without falling.[7]

Apart from concept differences, there are many methods of evaluating postural balance, ranging from simple observation, clinical tests, scales and even the quantitative evaluation on the force plateforms (kinetic measurements - posturographic), to more complex integrated evaluation systems.[8,9]

The measurement of the amount of Center of Pressure (COP) sway, and its velocity are good parameters for the evaluation of postural balance. They provide information about the spatial and temporal changes required to maintain balance in the vertical and horizontal axes; these are calculated from the displacement of the COP in the mediolateral and anteroposterior directions, as well as the velocity of the displecement and the area of the COP displacement during the evaluation.[7,10-12] Its implications may be related to risk and prevention of falls, to results of surgical procedures and rehabilitation, and to the attainment of sport performances.

However, there are several systems available in the market, which should be evaluated according to their qualities and limitations, and especially regarding the reliability, reproducibility and correlation between results.

The force platform and the Balance Master are devices used for postural balance measurements. Both use the center of pressure (COP) as the physical parameter to be measured. The portable force platform (AccuSway Plus, AMTI®) is considered reliable in some published reports[10,13,14] for the balance test with an Interclass Correlation Coefficient (ICC) > 0.75. The Balance Master® System device also uses force platforms, evaluates the center of gravity calculated by using the height of the subject, displaying an Interclass Correlation Coefficient of 0.49-0.85 for children[15] and 0.56-0.63 for patients with neurological disorders.[16]

We found no correlation between the anteroposterior and mediallateral displacement between the two devices in this study, since they assess different aspects. The force plateform (AccuSway Plus AMTI®) evaluates linear speed which is a value that indicates how a body position changes over time, in other words, how long it takes for an object to traverse a certain distance, in centimeters per second. The Balance Master® system directly evaluates angular velocity, which is a quantity that indicates how a body changes its angular position over time, in other words, how long it takes for an object to traverse a certain angular distance, in degrees per second. The two devices use different measurement units, but both provide a distance of COP displacement.

Another important difference is related to the data collection period. The literature recommends that three or four data collections of the COP sway be made in the period of data collection of 30 to 120 seconds.[3] In both devices three data collection were made, but each with a different time duration of acquisition. The force platform uses bipedal support for 60 seconds, whereas the Balance Master® System evaluates a 10 seconds period, and does not allow evaluation adjustments for longer periods.[3,13,14] Short periods, are not suitable for large oscillation of the COP during the initial adaptation of the body to the static position and very long periods can cause fatigue. So in our study this could be a bias, because we used the devices with different duration of the tests.

In this study, the velocity of the COP displacement presented a weak positive correlation between the two measurements and this correlation became higher with the increasing of test difficulty (eyes closed). This variable is of extreme importance for postural balance, being more accurate than other variables for postural balance,[17-19] but may have higher oscillation amplitudes without being necessarily associated with postural balance disorders.[20] In many situations the most important task is to quickly return to a position of stability (postural balance). However we found no reports that they make this correlation.

However we found no reports that make this correlation (Balance Master® System x Accusway force platform); in the comparison between other systems (OWN 5000 vs. the sensory organization test NeuroCom - SOT), correlational analyzes were found between output variables, which yielded significant relationships between the dynamic motional analysis score from the second 0 to 10 (r = -0.38), 10 to 20 second (r = -0.34), and 20 to 30 second (r = -0.35) intervals and the SOT composite balance score.[21]

The force platform provides information on the spatial and temporal changes in balance maintenance on vertical and horizontal axes.[7,22,23] However the evaluations are performed in a semi-static way, which offers no challenge to the labyrinth system and only a minor challenge to the sensorimotor system.

A platform with multiple protocols such as Balance Master® System comes with a software that already processes the data. This represents a major drawback in the sense that it is a "black box" solution with very little space for customization. Despite the fact that the raw signals of these two devices can be processed by programs such as Matlab (Mathworks®), these softwares are not within the domain of health professionals, and their needs further complicate the use of such devices.

Three final considerations regarding the comparison of the two devices (AccuSway Plus, AMTI® X Balance Master® System) used in this study are in order:

1) Number and quality of Load Cells: the Balance Master® System device has a smaller number of load cells, being less sensitive to load changes and platform inclinations, apart from not allowing setting adjustments. This difficulty of setting and adaptation of the system decreases the sensitivity and specificity of the system making the assessment less objective and reproducible. The Force Platform focuses on quality and number of load cells; its data collection and analysis systems use more precise mathematical parameters to show the pressure center displacement. It is a more accurate system and can be adjusted for different types of measurements.

2) Ease of use: the Balance Master® System is a more user-friendly device and allows some changes in the base of support size and dynamic testing. It is an easy and an excellent training resource, although less reliable in the most objective measurements. The use of the Force Platform is more restricted for evaluation, it is not of much use in training and requires better trained personnel.

3) Costs: both devices are expensive, but with a disadvantage for the Balance Master® System, which is a good training resource, but unreliable for evaluation; the Force Platform is a more accurate instrument for more objective and reliable evaluations of balance.

This study has some limitations, making correlations between the two devices, with similar, but not identical measurements and parameters. Furthermore, the data have not been processed and evaluated in the same data analysis software. It must however be noted that a large number of studies using computerized device to measure postural balance yield results with multiple interpretations. Thus, the need to define the characteristics of these computerized assessments has become an increasingly urgent requirement.

CONCLUSION

The devices investigated correlated with the measurement of the mean velocity calculated from the total displacement of the center of pressure in all directions with eyes open and closed conditions, but did not correlate with the anteroposterior and mediolateral center of pressure displacement measurements. The mean velocity calculated from the total displacement of the center of pressure was more stronlgy correlated in the closed eyes compared with eyes open condition.

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CONFLICTS OF INTEREST:

Authors declare no conflict of interest regarding this project.

AUTHOR CONTRIBUTIONS

Brech, GC: data collection, analysis and preparation of the paper; Luna NMS: analysis and preparation of the paper; Alonso AC: analysis and preparation of the paper; Greve JMD: Correction of the paper and Supervisor.

CORRELAÇÃO DO DESEMPENHO DO EQUILÍBRIO POSTURAL ENTRE DOIS DIFERENTES DISPOSITIVOS EM MULHERES IDOSAS

OBJETIVO: Estabelecer a validade convergente ou relação do Balance Master® como dispositivo de avaliação do equilíbrio, comparando seus resultados de desempenho com os obtidos a partir da plataforma de força AccuSway Plus®.

MÉTODO: Trata-se de um estudo observacional transversal, sem intervenção, de 126 mulheres na pós-menopausa (60,3 ± 3,2 anos; índice de massa corporal = 27,6 ± 4,7 kg/m^2). A avaliação de equilíbrio postural estático (posturografia) para todos os voluntários foi realizada inicialmente em uma plataforma de força (AccuSway Plus); uma segunda avaliação estática foi realizada em um dispositivo de equilíbrio Balance Master® Sistem. As variáveis estudadas nos dois dispositivos, foram: velocidade média do deslocamento total do centro de pressão em todas as direções (Vavg e Média-Form); ântero-posterior (YSD and Mean-Y) e médio-lateral (XSD and X-Mean) do centro de pressão de deslocamento. O coeficiente de correlação de Spearman foram calculados para medir a correlação entre as variáveis de equilíbrio obtidas nos dois dispositivos diferentes.

RESULTADOS: Foi encontrada uma correlação significativa entre as duas variáveis, e foi ajustado por um modelo de regressão linear. Houve uma associação entre a velocidade média de deslocamento do centro de pressão em ambos os dispositivos em ambas as condições, os olhos abertos (r = 0,21) e fechada (r = 0,47). Na condição de olhos abertos, os Vavg aumenta, em média, 0,26 unidades, com um aumento de uma unidade no Mean-Form; na condição de olhos fechados, Vavg aumenta, em média, 1,27 unidades, com um aumento de uma unidade no Mean-Form.

CONCLUSÃO: Os dispositivos investigados apresentaram uma correlação significativa para a velocidade média calculada a partir do deslocamento total do centro de pressão em todas as direções.

PALAVRAS-CHAVE: equilíbrio postural; centro de pressão; dispositivo; plataforma de força; pós-menopausa.

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