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Orthostatic Balance is not Associated with Dynamic Balance Performed in Unstable Situations in Adults with and without Visual Information

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Abstract

Background: The force plate is regarded as the gold standard for measuring balance, usually analyzed in the orthostatic posture. However, disturbances and falls tend to occur in unstable situations. Therefore, it would be important to test the association between orthostatic and dynamic balance during unstable situations.

Objective: To analyze the association between variables of the orthostatic balance and of the dynamic balance in young adults with and without visual information.

Method: Thirty young adults, male and female (X=22.87, SD=3.83 years), performed the balance tasks in a quiet standing position on the force plate and a dynamic balance task on the unstable platform. The balance tasks were performed with and without vision information and on a bipedal base.

Results: The results demonstrated only five low and indirect associations between the variables of the analyzed conditions ($r<-0.398$, $p>0.007$).

Conclusion: The analysis of the static balance (orthostatic posture) does not reflect the capacity to restore balance in unstable situations. Therefore, the analysis of balance considered as the gold standard may be interpreted with caution when considering the dynamic balance, especially in conditions with perturbation that may cause falls, such as the support base instability provided by the present study.

Keywords: Postural control; Quiet standing; Unstable posture; Balance; Sensory information

Abbreviations: COP: Center of Pressure; V: Vision; NV: No Vision; BT: Balance Time; NT: Total Number of Touches; BMI: Body Mass Index; APA: Anticipatory Postural Adjustments; CPA: Compensatory Postural Adjustments; BBS: Berg Balance Scale; TUG: Timed Up and Go; IPAQ: International Physical Activity Questionnaire

Introduction

Postural control is a complex system, which has two objectives, orientation, and balance. Orientation is understood as the maintenance of the position of body segments in relation to other segments and the environment. Balance corresponds to the control of all forces that act on/at the body in dynamic and static situations [1,2]. Dynamic balance is used to maintain posture during controlled movements (unstable situations), while in orthostatic balance (stable/static situations) the maintenance of the desired position and orientation occurs [2]. Depending on the form of balance analysis, different methods are used for its evaluation. Posturography is one of the most used methods to measure postural sway to access balance [3-5], transforming the body's center of pressure (COP) behavior into electrical signals which are amplified, recorded, and calibrated [3]. Usually, this method analyses the balance in quiet standing (orthostatic position) and is considered the gold standard for the evaluation of postural control [4,5]. However, this paradigm has been questioned because falls rarely occur during quiet standing situations [6]. Thus, balance should also be analyzed in dynamic situations. Nevertheless, the association between orthostatic and dynamic balance has not been the focus of study. Despite conventional force plates being able to provide stable support, it is also possible to manipulate dynamic situations on them.

Dynamic balance on the force plate has been investigated using disturbance to analyze the strategies of stability maintenance or recovery. For example, balance can be analyzed in environments that simulate moveable-rooms [7,8], projections of scenes with movement [9], lifting unpredictable loads [10], and a support base with unstable material [7,11]. Even considering the contributions of these designs on a stable force plate, the instability provided by movement on a support base has received special attention [12], because it seems more ecological comparing to falls situations [13]. Okazaki [14], proposed a regular unstable platform that could be easily customized. This platform consists of a wooden plank with electronic sensors coupled in its side border, responsible for capturing moments when the border touches on the ground, supported on a semicircle wooden base that provides the instability. The unstable platform has been employed in studies to compare the dynamic balance of people with Down syndrome and typical development [15], to analyze the effect of visual occlusion [16], to compare balance in classical ballet practitioners, ballroom dancing, and non-practitioners of dance [17], to investigate the effect of focusing attention during unstable balance tasks [18] and to compare the effect of visual occlusion and light touch between elderly and young adult [19]. The UP-balance variables presented high inter-trial reliability. This platform seems to be very interesting for the analysis of balance because it is easy to use, has low cost, is portable, allows the different base of support configurations, and may provide a large group of variables for the analysis of unstable situations. In addition, the inter-trial reliability of this platform was tested, which exhibited moderate to high inter-trial reliability in young adults (ICC > 0.73, p < 0.05) [20]. However, despite the potential benefits of the unstable platform to evaluate balance in the unstable situations, it is not known yet if this dynamic balance provided by unstable situations reflects the same strategy used by the system to maintain balance in orthostatic condition. Therefore, it would be important to analyze balance in both conditions, stable (orthostatic or quite standing) and unstable (dynamic) conditions to test their association. This study aimed to test the association between variables of the orthostatic balance (force plate) and dynamic balance in the unstable situation (unstable platform) in young adults with and without visual information. It was hypothesized that the variables of the force plate (orthostatic or quite standing posture) would not present good association (r>0,75, P<0,05) with the variables of the unstable platform, because each condition reflects specific demands of the task. This study might provide information about the relationship between static and dynamic balance for the understanding of the common or specific mechanisms of these two conditions for balance maintenance.

Material and Methods

Participants

The study analyzed 30 young adults (20 men, 10 women). Participants reported verbally that they were not under medication that could affect their balance, that they were not using prostheses or orthoses, and that they had no previous joint injury and/or the presence of diseases that could affect their balance. Before the beginning of the tests, all participants signed the free and informed consent of participation. The experimental procedures were approved by the Ethics Committee of the State University of Londrina (Report nº. 1,336,512, CAAE nº. 50124115.4.0000.5231). R programming language (R Development Core Team, 2017) performed the sampling power based on the observed correlation values (effect size of 0.6 and P=0.05 estimate the power of 71.96%).

Experimental procedures

First, the participants signed the free and informed consent. To characterize the volunteers, they completed the short IPAQ-International Physical Activity Questionnaire [21]. Next, the weight and height measurements were realized using a WISO (Wiso, Saint Joseph, Brazil) (W721) digital weighing device and a WISO (Wiso, Saint Joseph, Brazil) (E210) compact stadiometer. For analysis of the orthostatic balance task a AMTI force plate (AMTI, Watertown, USA) (model OR6-7-2000) was used with dimensions of 464mm (length) x 508mm (width) x 82.5mm (height), a MX Giganet analog-digital amplifier of Vicon System, and Vicon Nexus software (VICON Oxford Metrics, Oxford, UK) (v. 1.8). All participants were instructed to remain on the force platform for 40 seconds. After conclusion of the quiet standing (orthostatic posture), an interval of three minutes was allowed. Subsequently, participants performed the dynamic balance task on the unstable platform with disturbance in the medial-lateral (ml) and anterior-posterior (ap) directions. The order of the platforms' tests, and the direction of the perturbation for the unstable platform, was randomized between participants. The unstable platform [14] is composed of a wooden plank (40 cm x 40 cm) 1.5 cm high, with electronic sensors coupled in its side border, responsible for capturing moments when the border touches on the ground, supported on a semicircle wooden base 4.4 cm high, 2.4 cm wide, and 2.2 cm in radius (Figure 1). The performance in the task was analyzed by means of variables that were sent through an analog-digital adapter (v. 1.5) for Dynamic Balance Task software (v. 1.0) to an ACER Aspire laptop (Acer Inc, New Taipei, Taiwan, model 4349-ZQR). For this task, participants were instructed

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to remain for 20 seconds on the unstable platform avoiding the border touching the ground. They began behind the unstable balance platform and, after authorization from the experimenter, were instructed to step on to the platform keeping the right side supported on the ground in the ml direction of disturbance, and the back supported in the ap direction. These procedures are in accordance with previous research [15-19].

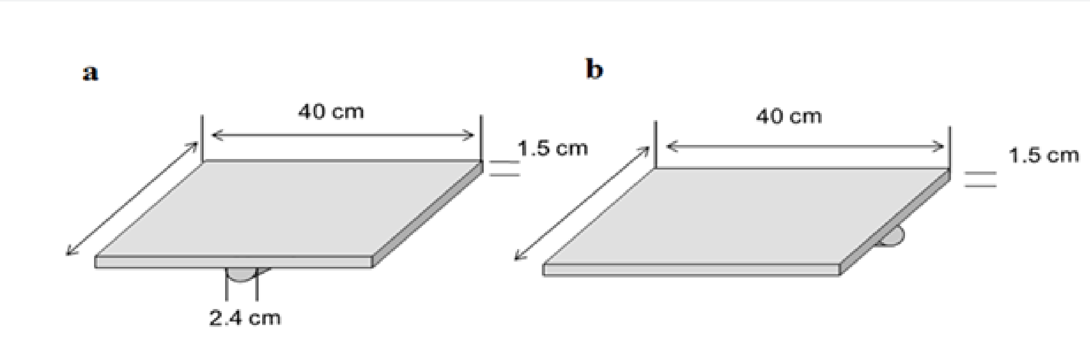

Figure 1: Schematic representation of unstable platform in the (a) anterior view, with the medial-lateral perturbation, and in the (b) anterior view, with the anterior-posterior perturbation.

Both tasks were performed with participants barefoot and with a bipedal base of support. The feet were positioned parallel to each other, separated approximately shoulder-width apart. Analysis was performed under vision (V) and no vision (NV) conditions. In the V condition, participants were instructed to look at a fixed point marked on the wall (1.80 m distance from the participants) positioned at the same height as their eyes. In the NV conditions, a blindfold was used by the participants. They were instructed to maintain the position of the head imagining that they were looking at the fixed point ahead. Participants performed one familiarization attempt for each task and visual condition. Next, participants performed three attempts for each task in each visual condition and disturbance direction (in the case of the unstable platform) with a 30 second interval between attempts. The order of conditions manipulating visual information was randomized between participants. Only 20 seconds of the task performed on the force plate were used for the analysis. Thus, the initial 10 seconds were removed due to transient components of the COP signal for posture adaptation on the platform. In addition, the final 10 seconds of the force plate analysis was removed to prevent participants compromising the accomplishment of the trial due to possible anticipation of the task ending.

Variables of study

The dependent variables of the unstable platform were: (a) balance time (BT) in seconds, which represents the sum of the periods in which each participant remained on the platform without the border touching the ground, and (b) the number of imbalances in absolute frequency, which represents the total number of touches (NT) of the platform border on the ground. The dependent variables of the force plate were: (a) COP total displacement (DOT) in mm, which represents the length of the COP trajectory on the support base, (b) Total area of COP (Area) in millimeters squared, which estimates the dispersion of the COP data through the ellipse formed by the COP behavior that covers 95% of data, (c) mean velocity (MVml and MVap) in mm/s, which represents the average of the sum of instantaneous velocity of each sample, and (d) amplitude (AMPml and AMPap) in mm, which represents the difference between the highest and lowest value of time series of displacement.

Signal processing

The signal processing of the force plate was performed in Matlab software (v.11.1, Mathworks, Natick, USA). The data acquisition of the force plate was performed with a sampling frequency of 100 Hz. The force plate provided the forces (Fx, Fy, and Fz) and moments (Mx, My, and Mz). These components were filtered by a fourth order low pass Butterworth filter with cutoff frequency established at 10Hz. Posteriorly, the components were used to calculate the COP position in the anterior-posterior and medial-lateral directions. Thus, COP was calculated based on the following equations: $COPap = (My + (zoff \times Fy)) / Fz$ and $COPml = (Mx + (zoff \times Fx)) / Fz$, for the respective directions, being that zoff (-1.632) is a constant provided by the platform manufacturer.

Statistical analysis

Initially, the average of the three attempts at each measure of balance for all conditions was calculated. As the assumptions of normality in the Shapiro-Wilk test ($P<0.05$) were not achieved, the Spearman Correlation Test [22] was used for the analysis of association between the variables of the two platforms. The degree of association was classified according to the magnitude

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(without considering the positive or negative signal) of correlation coefficient (r) into low association ($0.26<r<0,49$), moderate association ($0,5<r<0,69$), high association ($0.70<r<0,89$), and very high association [22]. Statistical analyses were performed using SPSS software (SPSS Inc., Chicago, USA) (v.18) with significance established at 5% ($P<0.05$).

Results

Participants

Table 1: Descriptive data of the participants.

Variables	Mean	SD
Age (years)	22.87	3.83
Height (m)	1.72	0.1
Body mass (kg)	71.23	12.35
BMI (kg/m^2)	23.98	3.13

SD: standard deviation. BMI: body mass index.

According to the short IPAQ, the distribution of participants regarding physical activity was moderate (11 participants), and high (19 participants). Table 1 presents the descriptive data of the participants: age, height, mass, body mass index (BMI).

Relation outcomes

In the vision condition (V), there were no association between the variables of the force plate and the unstable platform ($-0,21>r>0,04$). However, for the non-vision condition (NV), the BTml variable presented a low association with DOT ($r=-0.325$, $P=0.040$), Area ($r=-0.354$, $P=0.028$), AMPml ($r=-0.398$, $P=0.015$), and MVml ($r=-0.321$, $P=0.042$). In the anterior-posterior direction, the BTap variable presented a low association only with DOT ($r=-0.368$, $P=0.023$). There was no association between the other variables for the non-vision condition (Table 2).

Table 2: Spearman Correlation Coefficients between force plate and unstable platform variables in the vision and no vision conditions.

	BTml (CI 95%)	Btap (CI 95%)	NTml (CI 95%)	Ntap (CI 95%)
Vision Condition				
DOT	-0.041	-0.097	-0.061	-0.219
	(-0.38 / 0.35)	(-0.44 / 0.32)	(-0.45 / 0.35)	(-0.53 / 0.13)
Area	0.026	-0.02	-0.161	-0.118
	(-0.35 / 0.42)	(-0.40 / 0.37)	(-0.51 / 0.22)	(-0.46 / 0.27)
AMPml	0.039	-0.053	-0.176	-0.064
	(-0.35 / 0.42)	(-0.40 / 0.34)	(-0.54 / 0.22)	(-0.44 / 0.30)
AMPap	-0.005	0.019	-0.131	-0.205
	(-0.37 / 0.40)	(-0.35 / 0.41)	(-0.49 / 0.27)	(-0.55 / 0.18)
MVml	-0.079	-0.087	-0.098	-0.086
	(-0.44 / 0.33)	(-0.42 / 0.31)	(-0.46 / 0.28)	(-0.41 / 0.25)
MVap	0.08	-0.077	-0.058	0.012
	(-0.28 / 0.43)	(-0.41 / 0.34)	(-0.38 / 0.28)	(-0.33 / 0.33)
No Vision Condition				
DOT	-0.325*	-0.368*	-0.131	-0.179
	(-0.71 / 0.09)	(-0.68 / 0.02)	(-0.48 / 0.27)	(-0.53 / 0.20)
Area	-0.354*	-0.212	-0.006	-0.079
	(-0.68 / 0.01)	(-0.55 / 0.20)	(-0.39 / 0.38)	(-0.44 / 0.30)
AMPml	-0.398*	-0.165	-0.006	-0.036
	(-0.67 / -0.06)	(-0.48 / 0.23)	(-0.41 / 0.39)	(-0.45 / 0.38)

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AMPap	-0.229	-0.285	-0.075	-0.139
	(-0.58 / 0.15)	(-0.62 / 0.09)	(-0.45 / 0.35)	(-0.50 / 0.28)
MVml	-0.321*	-0.247	-0.126	0.013
	(-0.63 / 0.06)	(-0.62 / 0.18)	(-0.52 / 0.28)	(-0.36 / 0.39)
MVap	-0.128	-0.146	-0.028	0.24
	(-0.48 / 0.24)	(-0.51 / 0.24)	(-0.36 / 0.31)	(-0.15 / 0.53)

Note. *significant associations between vision and non-vision conditions (*P*<0.05). CI: confidence interval. BT: balance time. NT: number of touches. DOT: total displacement. AMP: amplitude. MV: mean velocity. Spearman correlation classification: low correlation: 0.26 to 0.49; moderate correlation: 0.50 to 0.69; high correlation: 0.70 to 0.89; very high: 0.90 to 1.00 [22].

Discussion

The present study aimed to test the association between variables of the orthostatic balance and dynamic balance in the unstable situation in young adults with and without visual information. The results demonstrated only five low and indirect associations between the variables of the platforms for the non-vision condition. Thus, apparently, the orthostatic posture in quiet standing analysis does not adequately reflect the ability to restore postural balance in situations of instability [23]. Thus, the hypothesis which affirmed that the force plate variables would not present a good association with the unstable platform variables was accepted. The visual system provides information about the environment and about the movement direction and speed of the individuals in relation to the environment [24]. The removed visual information almost doubled body sway during quiet standing posture. This fact is explained by the displacement of the environmental scenario on the observer's retina [25]. The corresponding body sway is produced to maintain the desired posture [26,27]. These modifications provided by the vision occlusion probably magnified the inter-participants data variability in the present study. Consequently, the non-vision presented some associations between variables of the different platforms. Although, the magnitude of the association (low) still suggests specific strategies of postural control for orthostatic and dynamic balance. Chang et al. [5] did not the observe association between force plate variables and the Balance Error Scoring System. These authors suggested that variables varied among the trials, evaluators, and experimental conditions. No correlation between the center of pressure speed (force plate) and a functional dynamic test ('Y balance test score' that analyses the range of motion with the foot in an unipodal position) was found for people with flat feet and neutral feet [28]. The lower precision of center of pressure speed outcome for static balance analysis was used to explain this absent of association. In the same way, Fransz et al. [29] showed that a single leg standing task (static balance) cannot serve as proxy for single leg drop jump (dynamic balance). Altogether, these results indicate that the information provided by the static balance (force plate) may not be used to explain the dynamic balance behavior.

In the other side, Gil et al. [4] demonstrated low correlation between the balance parameters of the force plate in the elderly and functional tests such as the "time-limit in seconds in unipodal support" and "agility and dynamic balance", which quantifies the total time to perform a task of sitting, standing, and walking around a chair as quickly as possible. Sabchuk et al. [30] verified moderate to high correlations between the Berg Balance Scale (BBS) test and the timed up and go (TUG) test with the displacement of COP variables (AMPml and AMPap). The main difference between these two studies and the present one rises on the difficulty of the dynamic task performed. Probably, the unstable situation provided by the dynamic balance task of the present study was more challengeable than these functional tests used. Therefore, despite these functional tests could also be used for dynamic balance analysis, these tests will not be able to discriminate large magnitudes of balance disturbance, as they are very generic measures. Indeed, it is important to point that fall tend to happen in more challenge situations [6], such as the unstable situations provided in the present study. Chang et al. [5] showed a high correlation (r=0.99) in performance on a Nintendo Wii balance board with the COP displacement variable measured on a force plate. However, the task performed on this board also adopted an orthostatic posture (quiet standing), as used for the force plate. On the force plate, the participant remains stationary during the task, while on the unstable platform he/she must overcome the perturbation generated by the instability, trying to maintain his/her balance. Thereby, perhaps it would be more likely to find a relation between variables of the unstable platform and a moveable force plate [12,13]. The particularities of each platform (stable x unstable) seem to demand specific strategies for balance maintenance. The disturbance of the support base in an unstable situation will require postural strategies of hip and ankle for balance maintenance. In fact, a smaller and more unstable support base seems to demand the hip strategy. This strategy is characterized by early activation of proximal muscles of the trunk and hip [31], while during the ankle strategy, the body moves as an inverted pendulum adjusting itself to small sways [1,31]. Thus, in the upright standing posture (quiet standing), the ankle strategy has been frequently applied [1]. Another specific characteristic of postural balance, on the two platforms analyzed, refers to the use of open and closed-circuit strategies [31]. Anticipatory postural adjustments (APA) were associated with the activation

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and inhibition of postural muscles before the disturbance occurs. APA aims to minimize the consequences of an expected disturbance [31,32]. It is probable that this was the predominant strategy used by the participants of the present study on the force plate. However, compensatory postural adjustments (CPA) were possibly the control mechanism used by the participants on the unstable platform. In this strategy, feedback is used to deal with disturbances by trying to restore balance in situations that are not predictable [31,32].

Conclusion

In conclusion, there was no association between the variables of the force plate and unstable platform for the vision condition. The results also demonstrated only five low and indirect associations (-0.26<r<-0,49) between the variables of the platforms for the non-vision condition. These results suggest that analysis of the quiet standing posture does not reflect the ability to restore balance in unstable situations in young adults. Indeed, as the visual occlusion harmed the balance on both platforms, greater magnitude and variability of the data between participants was used to explain the low association verified. The authors suggested that each task demand (orthostatic/stable or dynamic/unstable) provides specific strategies of postural control for the balance maintenance. The unstable platform was suggested as a potential device for the analysis of dynamic balance in unstable situations.

Conflict of Interest

No potential conflict of interest was reported by the authors.

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