COMPARISON BETWEEN FIELD BALANCE TESTS AND FORCE PLATFORM

ORIGINAL ARTICLE

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ABSTRACT

Several balance tests have been used to identify postural control and the risk of falls in the elderly. However, it is not known which tests better reflect effectively the ability to maintain balance. The objective of this study was to compare a number of field tests (FT) designed to determine balance with stabilometric tests using force platforms (FP) to determine whether these tests are able to discriminate differences in balance between young and older adults. Twenty-one young (21.7±2.0 years) and 18 older adults (69.3±7.0 years) of both genders volunteered to participate in the study. The field tests were: Berg Balance Scale (BBS), Performance Oriented Mobility Assessment (POMA), Functional Reach (FR) and Timed Up and Go Test (TUGT). The variables analyzed in the FP were: center of pressure displacement in the antero-posterior (AMP-AP) and medio-lateral direction (AMP-ML) and total sway of the center of pressure (TRAJ-CP). The subjects were evaluated in five conditions of 60s each. One-way ANOVA was applied to determine differences in balance tests between groups (young x elderly). In addition, the Spearman correlation test was used to identify the correlation between FT and FP. The FTs were able to discriminate young from elderly ($p \leq 0.05$). The FP tests also discriminated groups, except for AMP-AP in two experimental conditions. The correlation coefficients indicated that the tests BBS ($r = -0:43 \pm 0.04$) and TUGT ($r = 0.45 \pm 0.10$) showed the largest correlation with the FP tests ($p \leq 0.05$). Thus, these field tests should be preferred among the other balance tests. The results of the other tests are questionable since they seemed unable to discriminate the balance performance between young and elderly subjects.

Keywords: postural control, posturography, field balance tests.

INTRODUCTION

Accidental falls reach one third of the population older than 65 years[1,2] and have been related, among other factors, to alterations in the systems responsible for the posture control derived from aging and include eyesight and hearing decrease, vestibular disturbs and proprioceptive reduction[3-5].

Balance maintenance depends on the coordinated action of the central nervous system to generate muscular responses able to regulate the correlation between the center of mass and base of support. When in balance, the body remains in a desired position or move in a controlled manner. This control process depends on a complex relationship between the sensory and motor systems, and when it does not suitably occur, the risk of falls may be higher[4]. Thus, evaluation protocols which allow identifying individuals with balance disturbs may contribute to the choice of the best treatment and prevention strategies for falls in elderly subjects.

Generally, balance is evaluated by a variety of field tests (FT) which involve different protocols and methodologies[3,6] and may be classified in static, timed, functional, observational and subjective[7]. Among these tests, the most used are the balance scale and the performance oriented mobility assessment -POMA[8,9], the timed up and go test TUGT[3,10], the functional reach -FR[11,12] and the Berg balance scale -BBS[13,14].

The majority of these tests has been chosen for their easiness and low cost; however, little is known about these tests correlation between each other and how they correlate with objective measurements set by posturography tests through a force platform (FP). The posturography tests for assessment of the posture control are based on the determination of variables associated with the center of pressure (CP) displacement which is the application point of the result of the vertical forces which act on the base of support[15]. Balance measurements on FP allow identifying slight alterations in posture and have been described as highly sensitive and are applied as reference for determination of alterations in posture control[3].

The present study has the aim to compare a set of field tests applied for balance determination, besides to compare them with quantitative data obtained on a force platform. Additionally, it tries to verify whether the field and force platform tests are able to identify differences in the ability to keep posture control in young and elderly subjects.

METHODS

The present study was assessed and approved by the Ethics in Research Committee of the Sector of Health Sciences of the Federal University of Paraná (CEP/SD 0835.0.000.091-10). The subjects signed the Free and Clarified Consent Form after having been informed on the procedures and aims of the study. 21 young (11 men; 22.2 ± 1.6 years and 10 women, 21.2 ± 2.4 years) and 18 elderly subjects (six men, 66.8 ± 4.6 years and 12 women, 70.6 ± 7.9 years) volunteers to participate in this study. The young ones were physical education

university students and free from musculoskeletal problems which could hamper their daily activities. The elderly ones were recruited from the community, were independent and did not participate in any structured physical exercise program. The participants agreed on voluntarily participating in the experiment after having received information on the adopted procedures. Volunteers with vestibular problems (e.g. labyrinthitis) or any other known disorders which could influence on balance were excluded. Moreover, the elderly were submitted to a pre-participation clinical evaluation, which was conducted by a doctor and it had the aim to analyze the general health status of the participants and avoid inclusion of subjects with neurological and/or physical restrictions, with difficulty in remaining at orthostatic position.

The participants were present in two experimental sessions: on the first session four field balance tests were randomly applied, namely: the BBS-Berg balance scale, the FR -functional reach test, the POMA-performance oriented mobility assessment and the TUGT-timed up and go test. The tests were performed with a three-minute rest between them, during which the participants remained seated to avoid fatigue. The protocols were applied by a single evaluator and their details can be found in the literature. Nevertheless, a brief description follows here:

The Berg balance scale (BBS) is based on 14 ordinary items of daily life, such as standing, standing up, sitting, leaning forward, transferring, turning, among others, which evaluate posture control, including the stable, the anticipatory and which require different forces, dynamic balance and flexibility[13]. The evaluation occurs by observation and each item has an ordinal scale of five alternatives which range from 0 to 4 points. The maximum score in the test is 56. The points are subtracted in case time or distance to complete a task is not reached or the subject needs supervision to perform the task. The test is considered simple, easy to be applied and safe for evaluation of elderly subjects[14].

The performance oriented mobility assessment (POMA) is a simple scale whose protocol is divided in two parts: one evaluates balance and the other evaluates gait[8]. Only balance assessment was used for this study, which consists of 13 tasks with three levels of qualitative responses, where maximum score for the test is 39 points. The tasks for balance evaluation include activities which are performed during the activities of daily living such as sitting, standing, spinning around one's own axis -360º, reaching for an object on a high shelf, standing on one leg, picking an object on the floor[9].

The functional reach test (FR)[11] comprises the positioning of the evaluee close to a measuring tape horizontally stuck on the wall. The subjects should be with feet parallel to the ground at a comfortable position, shoulders flexed at 90º and fingers flexed (closed fist); the subject was told to lean forward reaching for maximal reach. The subject could not lose heel contact with the ground and could not step forward or lose balance. The mean of three reach attempts is considered. In the present study, reach was normalized for stature, being a factor which influences on the determination of the functional reach[12].

In the timed up and go test (TUGT), the participants were evaluated by the time required to raise from a chair (~ 46cm of height), walk and spin around a cone positioned at three meters, return to the chair and sit again[10]. The test is initiated after verbal command and finished after the subject returns to initial position with back leaned against the back of the chair. The best time was recorded from two attempts[3].

On the second experimental session, the participants performed tests of static balance on a force platform (FP). For balance assessment on the FP, the participants were positioned at 2 meters away from a steady point placed at approximately 1.6 meters high (individually adjusted for the eyes level), and they were told to look at that point during the test with feet position standardized along the x axis of the FP. The participants remained in the center of the FP with arms relaxed along the trunk, barefoot, and were told to keep static posture at five experimental conditions. The tests had duration of 60s and had interval of one minute between each condition, which were randomly tested. The conditions were : 1) feet apart at a comfortable position and eyes open – EO; 2) feet apart at a comfortable position and eyes closed – EC; 3) feet together and eyes open – TO; 4) feet together and eyes closed – TC; and 5) tandem position with eyes open (toes of the dominant foot touching the heel of the non-dominant foot) – TD. The balance variables were determined with the use of a force platform (AMTI model OR6-7, USA) with data acquisition at frequency of 200Hz. Subsequently to the data acquisition, a low-pass filter of 10Hz of second order was performed and the variables were obtained through procedures in a routine especially developed in the MatLab 7.5 software (Matlab 2007, MathWorks Inc., USA) which was applied to determine the CP trajectory (TRAJ-CP – center of pressure displacement) and the amplitude of the CP displacement (AMP-AP and AMP-ML – maximum amplitude of the center of pressure distance in the anteroposterior and mediolateral directions, respectively). Five conditions were tested and three variables obtained at each condition; hence, 15 variables/conditions were determined for data analysis.

The Shapiro-Wilk test was applied and it corroborated data normality. Many one-way ANOVA tests were applied for comparison of the field tests and force platform results between groups (young and elderly). The Bonferroni strategy was applied to reduce the probability of beta error. The Spearman correlation test was applied for identification of the correlations between the field and force platform tests. The procedures were performed in the Statistica software, version 7.0 and the significance level adopted was $p \leq 0.05$.

RESULTS

The results found in this study demonstrate that both field and force platform tests were able to differentiate young and elderly subjects. The elderly consistently presented lower performance in the balance tests ($p \leq 0.05$; see figure1) and greater oscillations of the center of pressure in the force platform test compared to young subjects ($p < 0.05$; figure 2). Correlations both between the field tests and on the force platform have been found ($p \leq 0.05$; tables 1 and 2).

Figure 1 presents the results of the balance field test between young and elderly subjects. The Berg balance scale (BBS) (young 55.95 ± 0.21; elderly 54.77 ± 2.07, $p \leq 0.05$) and the performance oriented mobility assessment (POMA) (young 38.9 ± 0.3; elderly 38.27 ± 1.07, $p \leq 0.05$) were able to discriminate young from elderly subjects ($p \leq 0.05$), demonstrating that subjects older than

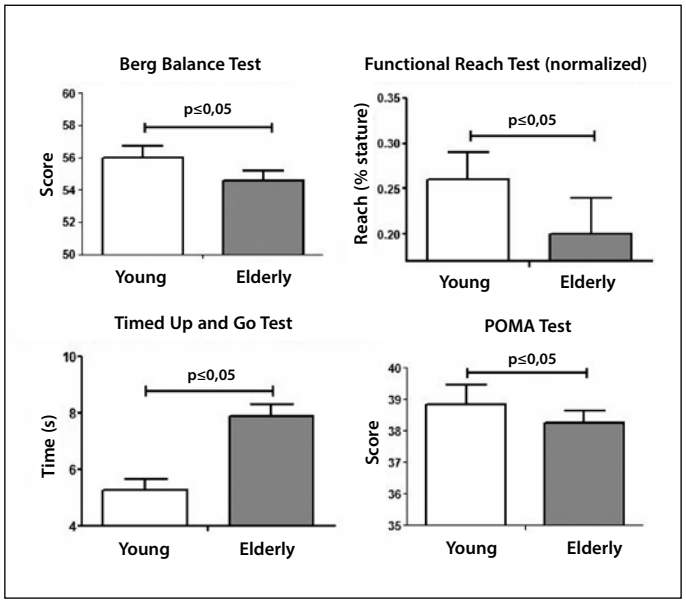

Figure 1. Comparison of the BBS, normalized FR test: (reach/100)/stature), TUGT and POMA between young and elderly subjects.

60 years present lower ability to keep balance when compared to younger subjects. The elderly subjects (32.72cm ± 7.87cm) obtained lower functional reach (FR) than younger ones (44.59cm ± 5.33cm) ($p \leq 0.05$) and demanded longer time in the timed up and go test (TUGT) (young 5.22s ± 0.67s; elderly 7.93s ± 1.97s, $p \leq 0.05$).

The results of the FP tests differentiated the groups of subjects in almost all assessed variables (trajectory of CP (TRAJ-CP), antero-posterior amplitude (AMP-AP) and mediolateral amplitude (AMP-ML)) at the five experimental conditions (EO, EC, TO, TC and TD). The only variable which was not able to differentiate groups was the AMP-AP when tested at the EO and TO conditions ($p \leq 0.05$).

Table 1 illustrates where the significant correlations took place between the field tests. Significant correlation between BBS and POMA was observed ($r = 0.77$; $p \leq 0.05$). The BBS was positively correlated with the FR test ($r = 0.50$; $p \leq 0.05$) and negatively with the TUGT ($r = -0.57$; $p \leq 0.05$). The POMA test negatively correlated with the TUGT ($r = -0.55$; $p \leq 0.05$). The FR and TUGT tests negatively correlated ($r = -0.67$; $p \leq 0.05$). Only POMA and FR did not presente correlation.

The results demonstrated that part of the field tests analyzed obtained higher number of significant correlations with the force platform variables. The BBS presented average negative correlation ($r = -0.44 \pm 0.04$) ($p \leq 0.05$) in eight out of the 15 variables/conditions analyzed on the force platform (TRAJ-CP, AMP-AP and AMP-ML at the five experimental conditions). The TUGT test was positively correlated with seven variables /conditions of the force platform (mean correlation, $r = 0.46 \pm 0.10$; $p \leq 0.05$).

The POMA test correlated with ($p \leq 0.05$) six variables/conditions of the force platform ($r = -0.38 \pm 0.05$; $p \leq 0.05$), while the FR test correlated with five variables/conditions of the force platform ($r = -0.43 \pm 0.07$; $p \leq 0.05$). Table 2 summarizes the correlations found between the field and on force platform tests.

It was possible to observe that the TUGT and BBS field tests obtained higher number of significant correlations with other field tests. These tests also presented higher number of correlations with the posturographic variables determined by the force platform.

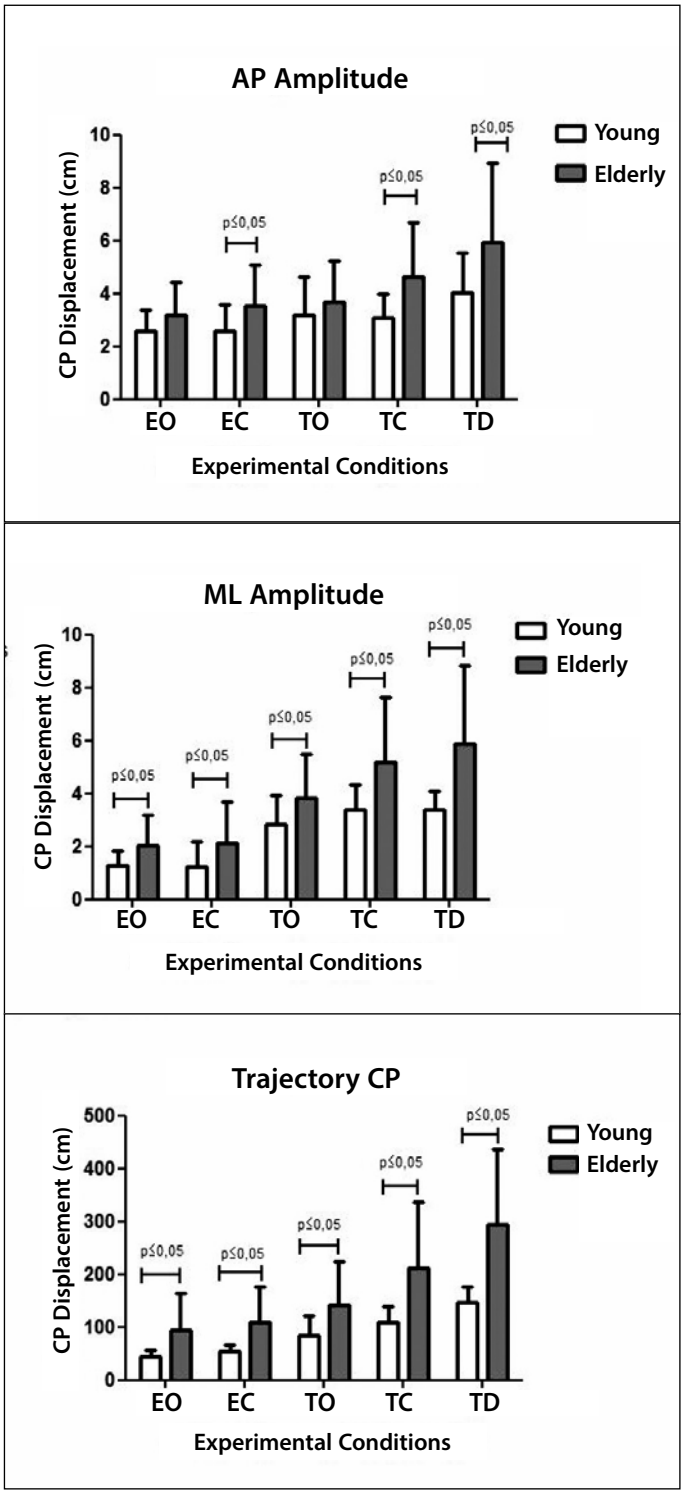

Figure 2. Comparison between groups for AMP-AP, AMP-ML and TRAJ-CP at the five experimental conditions: EO: feet apart and eyes open; EC: feet apart and eyes closed; TO: feet together and eyes open; TC: feet together and eyes closed; TD: tandem position and eyes open. Significant differences between the young and elderly groups ($p \leq 0.05$).

Table 1. Correlation between the field tests.

	BBS	POMA	FR	TUGT
BBS		0.77 *	0.50 *	-0.57 *
POMA	0.77 *		0.31	-0.55 *
FR	0.50 *	0.31		-0.67 *
TUGT	-0.57 *	-0.55 *	-0.67 *	

* ($p \leq 0.05$) statistically significant difference.

Table 2. Correlation between the field tests and the force platform tests.

		BBS	POMA	FR	TUGT
EO	AMP-AP	-0.28	-0.24	-0.05	0.16
	AMP-ML	-0.24	-0.33 *	-0.12	0.31
	TRAJ-CP	-0.40 *	-0.46 *	-0.28	0.46 *
EC	AMP-AP	-0.41 *	-0.36 *	-0.21	0.29
	AMP-ML	-0.37 *	-0.25	-0.18	0.19
	TRAJ-CP	-0.47 *	-0.39 *	-0.43 *	0.45 *
TO	AMP-AP	-0.21	-0.15	-0.21	0.13
	AMP-ML	-0.42 *	-0.33 *	-0.20	0.25
	TRAJ-CP	-0.51 *	-0.43 *	-0.25	0.36 *
TC	AMP-AP	-0.45 *	-0.22	-0.41 *	0.27
	AMP-ML	-0.29	-0.09	-0.38 *	0.32 *
	TRAJ-CP	-0.47 *	-0.31	-0.56 *	0.47 *
TD	AMP-AP	-0.05	-0.04	-0.13	0.23
	AMP-ML	-0.08	-0.13	-0.21	0.47 *
	TRAJ-CP	-0.22	-0.28	-0.37 *	0.65 *

* ($p \leq 0.05$) EO = feet apart and open eyes. EC = feet apart and closed eyes. TO = feet united and open eyes. TC = feet united and closed eyes. TD = feet at tandem and open eyes.

DISCUSSION

Although the results of the BBS test were able to differentiate the young and elderly subjects, they presented scores above 50 points, that is to say, young and elderly were detected as having "optimum independence condition", which indicates remarkable "ceiling effect" in this test. Further studies have detected similar results and state that there is low specificity of the scale to evaluate elderly subjects with better functional capacity[6,16]. Thus, it seems that the BBS does not detect discreet differences as those consequent of physical activity programs[17,18]. However, it is a test which presents good sensitivity and specificity for expectation of falls in elderly subjects[14,19].

The advantage of the BBS and POMA scales is that both evaluate many balance aspects in a single test; however, similarly to the BBS, the POMA test was able to discriminate the two evaluated groups, but also presented ceiling effect. The POMA test has been criticized for its limitations in detecting individual variations and for its low sensitivity in discriminating elderly with different level of ability[9].

The results in the FR test demonstrated that it is possible to discriminate young and elderly subjects (figure 1). Although it evaluates the movement in a single direction, anterior stability limit, this test is described as strongly associated with the risk of falls in elderly and has been used as prediction for falls in that population[12].

The TUGT test also presented significant difference between groups (figure 1), which may indicate that individuals with reduced balance may feel less confident during a task and perform it more slowly to avoid falls, as occurs in the elderly. This test has been considered valid for monitoring both of the level of functional mobility and risk of falls of the elderly[3].

The evaluations on a force platform are described as quantitative evaluations of body oscillation, being more reliable with better accuracy and potential to detect slight balance disturbs[15,20]. In this study, the tests on the force platform were able to discriminate younger from elderly subjects in the expressive majority of the tested variables. The AMP-AP at the feet apart and eyes open (EO) and feet together and eyes open (TO) conditions were variables which did not differ between young and elderly subjects. Melzer et al.[21] did not find differences in the oscillation of the center of pressure in the AP direction when comparing elderly subjects with and without history of falls in the test of force platform at the same conditions either. However, the CP velocity in the AP direction was correlated with age at the foot apart and eyes open condition[22]. It can be observed in the results of the present study that when the same conditions are performed, feet apart and feet together with eyes closed, the differences between young and elderly subjects occurred; observing hence that the task becomes more challenging and greater control of the posture system is demanded, especially from the somatossensory system. Thus, the elderly can present more difficulty in keeping suitable posture control when there is reduction of sensory information[4,23].

The AMP-ML and TRAJ-COP variables distinguished young and elderly subjects at all conditions. Differences in lateral stability were also found in the elderly with and without history of falls, suggesting this variable with good sensitivity for prediction of risk of falls in this population[23,24].

The tandem condition is considered a condition which demands high posture control, especially in the mediolateral direction. Difficulty in this task was observed both in young (trajectory = 147.2 ± 123.6cm) and elderly subjects (trajectory = 294.1 ± 143.4cm), among which, three elderly subjects could not perform the task in 60 seconds. Era *et al.*[20] show that in some populations (> 80 years) there are difficulties in completing the test, in an opposite effect to the "ceiling effect", in which many participants could not maintain the tandem position for longer than 10s. The feet position in tandem is not a condition naturally kept on daily routine and, therefore, a certain level of difficulty was imposed. The challenge imposed by this task seems to be attractive for balance maintenance and restoration tests.

The highest value of correlation coefficient among the field tests occurred between the BBS and the POMA. The high correlation found between these tests may have occurred due to the great similarity between their protocols, in which many tasks preserve high similarity between each other, as in seated balance, standing balance, from sitting to standing position and vice versa, standing balance with eyes closed, turning head to the back, turning 360º, picking an object from the ground and balance with unipodal support. Thus, in practice, the choice of both tests for balance assessment seems to be fairly redundant and little recommended.

Within the BBS scale there is a task of anterior reach which is similar to the FR test. In this study correlation between these two tests was also found. However, Bennie et al.[25] did not find significant correlation between these two tests.

The associations between the field and force platform tests indicated two field tests which correlated with a higher number of variables on the force platform, the BBS scale and the TUGT. The study by Oliveira et al.[26] showed association between performance of the elderly institutionalized in the TUGT test with

the performance of bathing, dressing and Katz index transferring activities. These findings indicate that the TUGT presents good relation with functional capacity of the elderly as well as performance of activities of daily living. Good discrimination of the TUGT test is noticed in the functional evaluation of the elderly. Thus, this test seems to be more sensitive and specific to measure the probability of falls among the elderly[27], since lower ability to keep balance is one of the main factors associated to the risk of falls in the elderly.

Assuming that the tests on the force platform present high discrimination power and constitute the most sensitive test for balance assessment, the BBS and TUGT tests are the most recommended for balance determination.

The results on the force platform also indicated that the ML oscillations seem to be the ones which discriminate the most young subjects from elderly subjects at the majority of conditions. However, with the removal of the visual information and with the reduction of the base of support (which decreases the tactile sensitivity of the subject), the dependence on visual information of the elderly becomes clear. Probably, the deterioration of the proprioceptive and vestibular systems which may occur by the natural aging process[4] may have induced the elderly to depend and rely more on the vision sense for posture control and balance.

The results found in the present study evidence the capacity the field tests have to discriminate subjects with great differences in the capacity to maintain posture. However, the doubt concerning their capacity to identify subtle differences as the ones which supposedly derive from physical activity programs and or clinical rehabilitation interventions with the goal to restore such function remains. Additionally, a relatively high correlation between field tests and the test considered gold standard for balance assessment (force platform) was verified. Thus, the use of simple and low cost tests for evaluation of capacity and balance is possible, where the BBS and TUGT tests are the preferred, since they more strongly associated to the results found on the force platform.

All authors have declared there is not any potential conflict of interests concerning this article.

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