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Standing balance test for fall prediction in older adults: a 6-month longitudinal study

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Abstract

Background A core component of older adult health care assessment includes identifying fall risk, which also includes identifying those with subtle balance deficits.

Objective To compare body displacement of the Center of Pressure (CoP) and time held during the balance test. Also, to examine whether balance tests at baseline can predict falls after 6 months.

Methods A longitudinal study with 153 community-dwelling older adults, between 60–89 years old. Anteroposterior (AP) and mediolateral (ML) amplitude and velocity CoP displacements were assessed in four upright positions using a force platform: double-leg, semi-tandem, tandem, and single-leg stances, with a maximum duration of 30 s each. Adjusted repeated measures ANOVA were used to compare the differences among the balance positions. Comparisons between males and females were also conducted. Logistic regression adjusted for confounders was performed to verify whether upright balance tests can predict future falls.

Results As the base of support narrows, body sway increases. A decrease in stance time was observed across the balance stages, i.e., double-leg/semi-tandem versus tandem versus single-leg stances. The mean duration held in the single-leg stance was 14.8 s and for tandem was 22.2 s. Similar stance durations were observed for double-leg and semi-tandem stances. Males were able to maintain balance positions longer than females even with greater CoP displacement. ML amplitude of CoP displacement and the time held during tandem and single-leg positions were able to predict falls after 6 months ($p < 0.05$).

Conclusion In clinical practice in which only stance time is recorded, it is possible to interchangeably use the double-leg or semi-tandem stance. To identify early signs of imbalance, we suggest setting a time limit for the balance test equal to or greater than 23 s, as 10 s appear to be insufficient to detect subtle balance deficits. The time maintenance on tandem and single-leg positions was able to predict future falls.

Keywords Aging, Body sway, Center of pressure, Force platform, Sex difference

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Introduction

To carry out daily activities safely, good postural balance is necessary, i.e., it is the state in which all forces acting on the body are balanced to maintain the desired position, whether the person is stationary or in motion [1]. With aging, physiological changes impair balance performance [2], leading to greater body oscillation [3], due to a decline in the interaction between neural and musculoskeletal components. Considering that approximately 30% of older adults over 65 years report having fallen at least once in the last 12 months [4], and that falls can lead to serious injuries, with social and psychological consequences for both the adults themselves and their families [5], identifying and treating individuals at risk of falling is an important health measure to prevent the occurrence of falls [6]. Therefore, evaluation for the older population must include balance assessment as a core component, providing an opportunity to identify older adults with varying levels of balance impairment.

Although a fall is a multifactorial event, it is expected that the greater the body sway, the worse one's balance is, and the higher the risk of falls [7–9]. Balance collapses when the center of mass falls out of the base of support. Stabilometry is a widely used method, primarily in laboratory settings, to evaluate balance since it quantifies the displacement of the Center of Pressure (CoP) over a force platform [10], with high sensitivity and accuracy [11]. It is presumed that the narrower the base of support, the greater the CoP displacement; however, it is not well established in the literature whether the body sway significantly increases between each balance position adopted within the test [12–15].

One important limitation of stabilometry is the fact that in many outpatient settings, the force platform is not available. Therefore, in clinical practice, a commonly used test to assess a patient's balance is the 4-Stage Balance. In this test, the patient is asked to maintain four different standing positions with varying bases of support, i.e., feet side by side, semi-tandem, tandem, and one-legged, each for 10 s, without using any assistive device [14, 16]. Maintaining less than 10 s in the stance has been associated with falls [11, 17, 18], the need for a walking aid related to the inability to keep the tandem stance [19], and risk of mortality related to single leg stance [20]. Maintenance of less than 6.5 s [18] in the single-leg stance is associated with a higher risk of falls.

On the other hand, older adults who can hold the single-leg position for 21 s or more are considered to have a good balance [21]. Therefore, setting the ceiling test period at 10 s may be useful for patients with evident balance impairment but may not be useful for identifying those with subtle imbalance, who should be targeted for early intervention approaches to avoid or mitigate future fall events. Therefore, this study aimed to compare the magnitude of body displacement and time maintenance among four stances of balance test in community-dwelling older adults, and to examine fall prediction after 6 months based on the performance of these balance tests.

Method

This was a prospective longitudinal observational study that included 153 older adults, between 60 and 89 years old, of both sexes. Participants were recruited through advertisements distributed in public places such as malls, parks, and street markets, as well as on social networks (WhatsApp groups, Instagram), newspapers and magazines with public circulation, community centers and events offered to older adults by the University of São Paulo, in Ribeirão Preto city (convenience sample) between 2015 and 2019. Older adults interested in participating in the study contacted our laboratory team by phone or email. Once the study criteria were met, an in-person assessment was scheduled at Laboratory of Equilibrum and Balance Evaluation (LA.R.E.), University of São Paulo. This study was approved by the local Human Research Ethics Committee and all participants signed an informed consent form on the assessment day, following Helsinki's declaration procedures for human research studies.

The exclusion criteria were as follow: cognitive impairment on the 10-point Cognitive Screener [22] according to the years of education, fractures in the last 12 months; neurological diseases; uncontrolled cardiovascular and metabolic diseases and complaints of dizziness. Thirty two older adults were excluded due to the exclusion criteria.

Subjects characteristics, i.e., sex, age, weight, height, and a history of falls in the last 12 months were obtained. Fall was defined as unintentional event that results in a change of older adult position to a lower level than the initial position [23]. All participants received an explanation of the concept of falls before we questioned then about the ocorrence of falls. We also provided examples to illustrate that falls include not only falling to the floor but also instances when they unintentionally sat down again while trying to stand up from a chair, sofa, bed or other surface. The physical activity level was assesses using The International Physical Activity Questionnaire (IPAQ), short version [24].

The upright balance was evaluated by measuring the body oscillation of the CoP using a force platform (EMG System do Brasil®). The CoP data were filtered with a low-pass 4th-order Butterworth digital filter with a cutoff frequency of 10 Hz and an acquisition frequency of 100 Hz [25]. The amplitude and velocity of anterior–posterior

(AP) and medial–lateral (ML) displacement of CoP were quantified.

Posturography test was carried out in four upright positions, with each position lasting 30 s, on a force platform. Participants were instructed to fix their gaze on a black target with a diameter of 5 cm, placed 1.5 m in front of them at eye level [25–27]. Each position was repeated twice, and the mean value was recorded. One minute interval was adopted between each trial. The dominant leg was characterized as the leg used to mobilization, i.e., to kick a ball [28]. Four positions were evaluated:

1) Double-leg stance with feet apart at shoulder width.
2) Semi-tandem stance with the dominant foot forward, i.e., one foot touches the big toe of the other foot.
3) Tandem stance with the dominant food forward, one foot placed in front of the other, heel touching toe.
4) Single leg stance, standing on the non-dominant leg while the knee of the dominant leg is flexed at 90° and the hip is in a neutral position.

The assessments took up to one hour to complete. The assessments were performed by four trained assessors, and the monthly calls were conducted by two other assessors. After the baseline assessment, participants were monitored by monthly telephone contact to obtain information on episodes of falls for 6 months. In every phone call, the concept of falling was reminded and the participants were asked whether a fall had happen within the last month. If the answer was 'yes,' additional information was collected, including the number of falls, the location of the fall, the activity the participant was engaged in at the time of the fall, whether there was an injury associated with the fall, whether an emergency room visit was required, and whether the participant needed assistance to stand up after the fall. All detailed information was recorded to ensure that participants did not report the same fall in subsequent months.

Statistical analysis

Measures of central tendency (i.e., means, standard deviation, and frequency) were calculated for sample characterization. Repeated measures ANOVA (Analysis of Variance), adjusted for age, sex, height, physical activity level, and retrospective number of falls, were used to compare the differences among the balance positions and the time held in each position. Sex differences were also investigated using repeated measures ANOVA, adjusted for age, height, physical activity level, and number of falls. False discovery rate (FDR) post hocs were applied to correct p-values in the ANOVA analysis [29]. After FDR, the alpha level for statistical significance was set at $p \leq 0.05$.

Differences between anteroposterior (AP) versus medio-lateral (ML) amplitude and velocity CoP displacements in each balance position were analysed using paired sample t-tests. Additionally, we divided the participants into groups based on the number of prospective falls over 6 months, and t-test statistical analysis was used to compare the CoP displacement between groups. The effect size for t-test comparisons was calculated using Hedges's G or Glass Delta, with the following thresholds: high ≥ 0.80; moderate between < 0.79 and ≥ 0.4; small between < 0.39 and ≥ 0.21 and by chance between < 0.2 and ≥ -0.2. Hedges's G was used when sample sizes differed between groups, and Glass Delta was used when standard deviations differed between comparisons [30]. To identify the ability of balance tests to predict prospective falls in 6 months, binary logistic regression was performed.

Due to the non-normal distribution, CoP displacements were transformed following the two-step method proposed by Templeton (2011) [31]. After data were transformed, Kolmogorov–Smirnov confirmed the normality of the distribution. Data analysis was carried out using the IBM SPSS 25.0 software (SPSS Inc.). The significance level was set at 0.05.

Results

The sample consisted predominately of females (78%), with a mean age of 73.9 years and a low physical activity level (Table 1). Of the 55 (36%) older adults who had prospective falls in 6 months, 87.27% were females and 12.73% were males. The most commonly reported conditions were arterial hypertension (93%), dyslipidemia (61%), hypothyroidism (35%), osteoarthritis (23%) and osteopenia or osteoporosis (16%).

Table 1 Sample characterization. Values are presented as means (standard deviations) and frequencies

	Older adults (60 – 89 years) *n*=153	
Age (Years), Mean (SD)		73.9 (7.80)
Sex n (%)	Females	120 (78.43)
	Males	33 (21.57)
Weight (kg), Mean(SD)		66.77 (11.07)
Height (m), Mean(SD)		1.56 (0.07)
Level of physical activity n (%)	Low	108 (69.2)
	Moderate	40 (25.6)
	High	5 (3.2)
Number of medications in use, Mean(SD)		9 (3.2)
Number of conditions, Mean(SD)		5 (2.1)
Retrospective falls history n (%)	Fallers	42 (27.5)
	Non-fallers	111 (72.5)

Anteroposterior CoP displacement

The results of adjusted repeated measures ANOVA showed that there is an increase in amplitude and velocity of body oscillation as the support base becomes narrower. The double leg position with the feet separated causes less body oscillation, whereas the single leg stance leads to greater body oscillation ($p<0.05$) (Table 2).

When participants were divided into sex, males had higher AP amplitude in double leg ($p=0.01$; Hedge's G = 0.51) and single leg stance positions compared to females ($p=0.002$; Hedge's G = 0.68). Regarding the AP velocity, there were differences in double leg ($p=0.01$, Hedge's G = 0.48), semi-tandem ($p=0.03$, Hedge's G = 0.43) and single leg positions ($p=0.001$, Hedge's G = 0.79) between males and females, with males having higher body sway.

Among the stance positions, there was no difference in AP amplitude between double leg and semi-tandem positions in males ($p=0.11$) (Table 2), and there was no difference in AP amplitude between tandem and single leg positions in females ($p = 0.17$).

Medio-lateral CoP displacement

The results of adjusted repeated measures ANOVA showed that, similar to what was observed in the anteroposterior direction, there is an increase in amplitude and velocity of body oscillation as the support base becomes narrower. Additionally, the double-leg position with the feet separated causes less body oscillation, while the single-leg stance causes greater body oscillation ($p<0.05$) (Table 2).

Table 2 Mean (SD) of transformed data of displacement of CoP

CoP parameters	Groups	Double leg	Semi-tandem	Tandem	Single leg	*p*-value among each position
		Mean (SD); 95%CI	**Mean (SD); 95%CI**	**Mean (SD); 95%CI**	**Mean (SD); 95%CI**	
AP Amplitude (cm)	Total sample	1.90 (0.67); 1.78-2.03$^{\#}$	2.52 (1.04); 2.32-2.71	4.04 (2.74); 3.55-4.54	4.92(1.72);4.61-5.24	≤ 0.01
	Females	1.82 (0.07); 1.67-1.97	2.48 (0.11); 2.25-2.71	3.99 (0.28); 3.43-4.55	4.62(0.18); 4.26-4.98	≤ 0.01 (except between tandem and single leg)
	Males	2.16 (0.11); 1.92-2.39	2.63 (0.20); 2.21-3.06	4.22 (0.57); 3.03-5.41	5.86 (0.33); 5.17-6.54	≤ 0.01 (except between double and semi-tandem)
ML Amplitude (cm)	Total sample	1.16 (0.55); 1.06-1.27	3.41 (1.01); 3.22-3.60$^{\#}$	4.34 (1.77); 4.01-4.68$^{\#}$	5.12 (2.37); 4.69-5.55	≤ 0.01
	Females	1.13 (0.06);1.01-1.26	3.37(0.10);3.16-3.58	4.31(0.19); 3.92-4.69	4.81(0.23); 4.34-5.27	≤ 0.01 (except between tandem and single leg)
	Males	1.25 (0.10);1.04-1.46	3.51 (0.22); 3.05-3.97	4.46 (0.32); 3.79-5.13	6.04 (0.47); 5.06-7.01	≤ 0.01 (except between semi-tandem and tandem)
AP velocity (cm/s)	Total sample	1.09 (0.27); 1.05-1.15*	1.74 (0.69); 1.62-1.87	2.72 (1.18); 2.51-2.93	3.90 (1.60);3.61-4.20	≤ 0.01
	Females	1.07(0.03); 1.00-1.13	1.65(0.07); 1.50-1.80	2.59(0.12); 2.36-2.84	3.59(0.17); 3.25-3.93	≤ 0.01
	Males	1.19(0.05); 1.09-1.29	2.03(0.11); 1.80-2.27	3.10(0.24); 2.61-3.59	4.84(0.29); 4.23-5.45	≤ 0.01
ML velocity (cm/s)	Total sample	0.93 (0.16); 0.89-0.96	1.94 (0.58); 1.84-2.05*	3.23 (0.97); 3.06-3.40*	4.35 (1.14); 4.14-4.56*	≤ 0.01
	Females	0.92 (0.02); 0.89-0.96	1.90 (0.06); 1.78-2.02	3.15 (0.10); 2.95-3.35	4.19 (0.11); 3.96-4.42	≤ 0.01
	Males	0.94 (0.03); 0.87-1.00	2.06 (0.08); 1.88-2.24	3.46 (0.15); 3.14-3.78	4.84 (0.21); 4.41-5.27	≤ 0.01
Mean time-limit (s)	Total sample	30 (0)	29.86 (1.11)$^{+}$	22.23 (10.96)$^{+}$	14.81 (11.87)	≤ 0.01 (except between double leg and semi-tandem)
	Females	30 (0)	29.88(0.10); 29.68-30	21.44 (0.83); 19.80-23.07	13.71(0.89); 11.94-15.47	≤ 0.01 (except between double leg and semi-tandem)
	Males	30 (0)	29.77(0,19); 29.37-30	25.11(1.35); 22.33-27.88	18.82(1.44); 15.85-21.78	≤ 0.01 (except between double leg and semi-tandem)

AP Antero-posterior, *ML* Medio-lateral, *SD* Standard deviation, *CI* Confidence interval

#$p<$ 0.05 between AP versus ML directions for amplitude of CoP displacement according to paired T-tests

*$p<$ 0.05 between AP versus ML directions for velocity of CoP displacement according to paired T-tests

$^{+}$ < 0.05 between semi-tandem and tandem position and between tandem and single leg

When participants were divided into sex, males had higher ML amplitude in single-leg stance positions compared to females ($p = 0.02$; Hedge's G = 0.50). Regarding the ML velocity, there was a difference in single leg position ($p = 0.01$; Hedge's G = 0.56) between males and females, with males having a higher velocity. Among the stance positions, there was no difference in ML amplitude between semi-tandem and tandem positions in males ($p = 0.06$); and there was no difference in ML amplitude between tandem and single leg positions in females ($p = 0.20$).

Amplitude of Body displacement

Regarding the amplitude of body displacement considering the total sample, in the comparison between AP and ML sway, the paired t-test showed that in the semi-tandem and tandem positions, the amplitude of displacement in the ML direction is significantly higher compared to the AP direction. In the double-leg position with separate feet, the AP amplitude is higher than the ML sway ($p < 0.001$) (Table 2). In the single-leg position, the amplitude of body sway was similar in both the AP and ML directions ($p = 0.4$).

Velocity of body displacement

Regarding the velocity of body displacement considering the total sample, in the comparison between AP and ML, the paired t-test showed that, except in the double-leg position, the amplitude of body sway in the ML direction is significantly higher compared to the AP direction ($p < 0.001$) for semi-tandem, tandem and single leg positions. In the double-leg position with separate feet, the AP velocity was higher than the ML velocity of body sway ($p < 0.001$) (Table 2).

Time-limit for balance position

There were no differences in time maintenance between double-leg and semi-tandem positions ($p = 0.1$). However, in the comparison between semi-tandem and tandem positions ($p < 0.001$; Glass Delta = 0.69), and between tandem and single leg ($p < 0.001$; Glass Delta = 0.67), the mean time that older adults were able to maintain the positions was different (Table 2), as the base of support became narrower, the time maintenance decreased.

When participants were divided into sex, there was a difference in the time maintenance during tandem ($p = 0.04$; Hedge's G = 0.33) and single leg stance between males and females ($p = 0.03$; Hedge's G = 0.43), with males being able to keep the test longer than females.

The FDR-adjusted p-values was calculated to correct the post-hocs test of ANOVA (supplementary material), and confirmed the significance of all results presented in Table 2.

CoP displacement between fallers versus non-fallers

Our results showed that older adults who reported any fall event after 6-month follow-up had greater body sway for AP amplitude ($p = 0.03$; Hedge's G = 0.41) and AP velocity in double-leg($p = 0.05$; Hedge's G = 0.32); greater body sway for AP ($p = 0.005$; Hedge's G = 0.45) and ML amplitude ($p = 0.006$; Hedge's G = 0.46) in semi-tandem; and greater body sway for ML amplitude in single-leg ($p = 0.01$; Hedge's G = 0.57) compared to non-fallers. Regarding the time held in balance positions, fallers held the tandem ($p < 0.001$; Hedge's G = 0.59) and single-leg stances ($p = 0.001$; Hedge's G = 0.60) for a shorter duration compared to non-fallers (Table 3).

Adjusted binary logistic regression revealed an association between prospective falls and the ML amplitude of body displacement between fallers and non-fallers [x^2 (8) = 25.287, $p = 0.001$; Nagelkerke $R^2 = 0.30$], correctly predicting 77.1% of all cases. Regarding the CoP displacement predictors, only the ML amplitude during single-leg stance was associated with fall prediction (Table 4), showing the increase of 1 cm in ML amplitude increases the likelihood of older adult falling in the next 6 months by 1.5 times.

Adjusted binary logistic regression revealed an association between prospective falls and the time held in each position [x^2 (7) = 36.131, $p < 0.001$; Nagelkerke $R^2 = 0.29$], correctly predicting 72.5% of all cases. Regarding the predictors, the time spent in tandem and single-leg stances was associated with fall prediction (Table 4). An increase of 1 s in the duration of these maintenance positions decreases the odds of an older adult falling in the next 6 months by 5%. The results showed that an increase in tandem and single-leg stance maintenance is a protective factor for fall prevention within 6 months.

Discussion

The aging process affects balance performance, increasing the risk of falls in older adults. Although the literature presents inconsistent results regarding the effectiveness of single-leg or tandem stances in accurately predicting future falls [18, 32–34], the 4-stage balance test has been incorporated into fall risk screening of older adults [35], along with mobility tests [6]. It is also recommended that the 4-stage balance test be administered to individuals with a positive fall risk screening. As presumed in the literature, our results showed that as the width of the base of support diminishes, i.e., from double-leg, semi-tandem, tandem, to single-leg stances, body oscillation increases. As expected, our results showed greater body oscillation in the single-leg stance, as it requires more control over the center of mass projection relative to the base of support, demanding greater effort from the hip and ankle muscles [36, 37]. Additionally, the single-leg

Table 3 Transformed CoP displacement data between those prospective fallers in the 6 months. Data expressed as mean ±standard deviation

Balance position	CoP displacement	Non-fallers (*n*=98)	Fallers (*n*=55)	*p*-value (eta^2)
Double leg	AP Amplitude (cm)	1.88 (0.70)	2.12 (0.58)	**0.03** (0.03)*
	ML Amplitude (cm)	1.18 (0.53)	1.25 (0.55)	0.43 (0.004)
	AP velocity (cm/s)	1.07 (0.31)	1.17 (0.31)	**0.05** (0.02)*
	ML velocity (cm/s)	0.91 (0.18)	0.96 (0.19)	0.09 (0.02)
	Time held (s)	30 (0)	30 (0)	-
Semi-tandem	AP Amplitude (cm)	2.53 (0.99)	3.01 (1.05)	**0.005** (0.05) *
	ML Amplitude (cm)	3.44 (1.03)	3.94 (1.09)	**0.006** (0.05)*
	AP velocity (cm/s)	1.83 (0.74)	2.05 (0.78)	0.09 (0.02)
	ML velocity (cm/s)	2.01 (0.60)	2.17 (0.66)	0.14 (0.01)
	Time held (s)	29.9 (0.10)	29.6 (1.82)	0.13 (0.03)
Tandem	AP Amplitude (cm)	4.18 (2.86)	4.55 (3.01)	0.49 (0.004)
	ML Amplitude (cm)	4.41 (1.72)	4.59 (2.06)	0.59 (0.002)
	AP velocity (cm/s)	2.79 (1.25)	2.99 (1.26)	0.40 (0.005)
	ML velocity (cm/s)	3.33 (1.02)	3.27 (0.96)	0.75 (0.001)
	Time held (s)	24.85 (9.19)	17.56 (12.32)	**<0.001** (0.10)*
Single leg	AP Amplitude (cm)	4.91 (1.78)	4.93 (1.59)	0.95 (<0.001)
	ML Amplitude (cm)	4.82 (2.37)	6.10 (2.23)	**0.01** (0.05)*
	AP velocity (cm/s)	3.93 (1.67)	3.77 (1.41)	0.52 (0.004)
	ML velocity (cm/s)	4.33 (1.19)	4.46 (1.06)	0.62 (0.002)
	Time held (s)	17.26 (11.55)	10.43 (11.25)	**0.001** (0.07)*

*$p < 0.05$ in the comparison between fallers vs non-fallers according to paired T-tests. Significant differences at $p < .05$ in bold

Table 4 Logistic regression of the association between CoP displacement and time held in each position and prospective falls

Variables	Balance test position	β	OR (95% CI)	*p*-value
AP amplitude	Double leg	0.79	2.20 (0.96 – 5.02)	0.06
	Semi-tandem	0.11	1.11 (0.60 – 2.05)	0.72
	Tandem	-0.06	0.94 (0.76 – 1.16)	0.56
	Single leg	0.06	1.07 (0.78 – 1.45)	0.67
ML amplitude	Double leg	0.93	2.53 (0.85 – 7.50)	0.09
	Semi-tandem	-0.006	0.99 (0.54 – 1.83)	0.98
	Tandem	-0.32	0.72 (0.51 – 1.02)	0.07
	Single leg	0.42	1.51 (1.14 – 2.00)	**0.003***
AP velocity	Double leg	-0.36	0.96 (0.11 – 8.02)	0.97
	Semi-tandem	0.14	1.15 (0.38 – 3.49)	0.80
	Tandem	0.19	1.21 (0.66 – 2.19)	0.52
	Single leg	-0.13	0.87 (0.58 – 1.32)	0.53
ML velocity	Double leg	0.93	2.54 (0.11 – 5.11)	0.55
	Semi-tandem	-0.37	0.68 (0.17 – 2.69)	0.59
	Tandem	-0.39	0.67 (0.29 – 1.54)	0.35
	Single leg	0.54	1.71 (0.913 – 3.23)	0.09
Time held	Semi-tandem	-0.85	0.43 (0.07 – 2.53)	0.35
	Tandem	-0.05	0.95 (0.91 – 0.99)	**0.04***
	Single leg	-0.05	0.95 (0.91 – 0.99)	**0.03***

OR Odds ratio, *95% CI* 95% confidence interval

Model adjusted for: sex, age, height and level of physical activity

Significant associations are indicated in bold and with an asterisk (*) for $p \leq .05$

stance relies more on supra-spinal control than spinal sensorimotor gain [38].

Our results showed that, in the double-leg stance, anteroposterior CoP displacement was greater than mediolateral displacement for both amplitude and velocity variables, unlike other positions. In contrast, in balance positions with a narrower base of support, such as semi-tandem, tandem, and single leg, mediolateral CoP displacement was greater than anteroposterior displacement. In the comparisons between sexes, overall male exhibited greater body sway than females. However, for tandem and single-leg positions males were able to maintain the stance longer than females, suggesting that males may be more efficient at controlling body displacement related to the base of support. Additionally, when comparing the four different balance positions, males showed no difference in AP amplitude between the double leg and semi-tandem positions, and no difference in ML amplitude between the semi-tandem and tandem positions. On the other hand, for females, there was no difference in AP amplitude between tandem and single leg positions, and no difference in ML amplitude between tandem and single-leg positions.

During narrow stances, older adults tend to exhibit higher electromyography activity in the hip and ankle compared to younger adults [39]. Additionally, older females with complaints of imbalance maintain the single-leg stance for a shorter duration than those without such complaints [26]. The ability to maintain a single-leg stance has practical applications, as it is necessary for performing daily activities like walking and climbing stairs, highlighting its importance for functional mobility. Positions that require a narrower base of support, particularly tandem and single-leg stances [40], challenge the mediolateral body stability. Consequently, hip muscle activation appears to play a role in maintaining balance [27, 41] due to its contribution to pelvic stability [39, 40, 42, 43].

Our results indicated that the minimum mean time limit held during the balance test was 14.8 s for single-leg stance and 22.2 s for tandem stance. For the single-leg stance, a longer duration indicates better balance. In the study by Bohannon et al., 1984 [44], older adults between 60–69 years ($n=30$) could hold the single-leg position for a mean of 22.5 s, while those aged 70–79 years ($n=31$) maintained it for a mean of 14.2 s. In our study, older adults aged 60 to 89 years held the single-leg position for a mean of 14.8 s. Our results differed from those of Bohannon et al. [44] due to the absence of separation of participants into distinct age groups.

When the sample was divided into fallers versus non-fallers, fallers were able to maintain the single-leg stance for a mean time of 10.4 s and the tandem stance for 17.5 s. In contrast, non-fallers maintained the single-leg stance for 17.2 s and the tandem stance for 24.8 s. Regardless of fall status, our results suggest that the time limit for the 4-stage balance test should be set to over 23 s. In our study, older adults were able to maintain the positions for a longer duration, particularly in the single-leg stance, compared to the study conducted by DePasquale e Toscano, 2009 [45], which included a sample of 58 community-dwelling older adults, reported that non-faller held the tandem and single-leg stances for a mean of 23.9 s and 10.3 s respectively, while fallers maintained the stances for a mean of 12.7 s and 3.2 s. It is important to note that in the study by DePasquale and Toscano, 2009 [45], the mean age of their sample, particularly among fallers, was higher than in our study. Additionally, their cross-sectional study included retrospective data on falls that occurred in the previous 2 years. In a comparison between fallers and non-fallers, Oliveira et al., 2018 [46] included 170 Brazilian older adults and found no difference in the duration of the single-leg stance between fallers and no-fallers (17 s and 18 s, respectively). However, they did observe differences in body displacement. Our results, in contrast, do not align with Oliveira et al., 2018 [46], as fallers in our study maintained the single-leg stance for a shorter duration and exhibited greater body sway compared to non-fallers. The main difference between our study and that of Oliveira et al.,2018 [46] is that they categorized participants into fallers and non-fallers based on retrospectively reported falls over the past 12 months. In contrast, we categorized participants based on prospectively reported falls over a 6-month period. The use of retrospective fall recall presents several challenges, including issues with memory recall, underreporting or overreporting of fall events, and variations in participants' understanding of the fall definition used by the research team. These challenges can hinder the accurate recording of fall events, especially if the definition of a fall extends beyond simply resting on the floor.

There are inconsistent results regarding the usefulness of single-leg test for predicting falls. Vellas et al., 1997 [15] observed that single-leg was not associated with future falls over a 3 years follow-up period; however, the required time to hold the position was only 5 s. In the systematic review conducted by Kozinc et al., 2020 [32], the single-leg test was recommended for assessing fall risk. In contrast, Omaña et al., 2021 [33] in their systematic review and Beck Jepsen et al., 2022 [34] in their umbrella review concluded that no single clinical test was able to reliably predict future falls in older adults. They emphasized the need for further studies to strengthen the evidence for instruments used in predicting future falls.

Previous studies have shown that greater mediolateral CoP displacement is associated with recurrent fallers, and with fall prediction in older adults [7, 9, 47–50]. Our results revealed that only the ML amplitude of body sway in a single leg stance was able to predict falls within 6 months. On the other hand, the time maintained in both tandem and single-leg stances also predicted falls within 6 months, highlighting the usefulness of upright balance tests in clinical practice for fall prevention. Our study has several strengths including a rigorous standardized protocol for assessing balance. This protocol involved a 30-s balance assessement with the participant's eyes fixed on a standard target. The distance between the participant and the target was precisely established, and the team received extensive training to ensure the consistency of the results. Additionally, falls were recorded prospectively through monthly phone calls over six months to minimize recall bias. Although we did not record the neighborhood and income of the recruited older adults, they came from various locations across the city, with different socioeconomic contexts; consequently, our results may reflect a heterogeneous sample rather than a biased one. We were able to control our analysis for several potential confounders. Additionally, our results showed a moderate effect size for the majority of comparisons, ranging from <0.79 to ≥ 0.4. The FDR-adjusted p-values further confirmed the results of the ANOVA. Our results suggest that, among the outcomes of our study, tandem and single-leg stance times are the most effective stance positions for fall risk stratification in community-dwelling older adults based on a prospective follow-up of six months.

However, this study is limited by the small sample size of male fallers, which prevented us from examining fall prediction by dividing the sample into males and females. Additionally, our sample included older adults up to 89 years of age, and we followed up with participants prospectively for 6 months. Therefore, future studies aiming to better understand standing balance performance and fall prediction should include the oldest-old adults and follow up with participants for at least 12 months.Due to the fact that neurological conditions such as Parkinson's disease, stroke, and cognitive impairment may affect balance performance through various mechanisms, we did not include these populations in our study.

Conclusion

Our results showed that the 4-stage balance test challenges the individual's balance, as the progressive reduction in the base of support leads to increased the body sway. Regarding the time limit, all participants were able to maintain the double-leg for 30 s, and most older adults could maintain the semi-tandem stance for 30 s as well. We suggest that balance positions should be assessed for at least 23 s, as a shorter time limit, such as 10 s, may not be sufficient to detect early stages of balance impairment. In predicting falls within six months, only the medial–lateral amplitude of center of pressure displacement and the time maintained in tandem and single-leg stances were associated with fall occurrence in community-dwelling older adults without any neurological conditions. In clinical practice, assessing the time an individual can maintain tandem and single-leg stances can help identify older adults at risk of falling within the next six months. These tests should be included in the set of assessments to grade the fall risk in community-dwelling older adults.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-024-05380-9.

Supplementary Material 1.

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Authors' contributions

DCCA and RMBB contributed to the study concept, analysis, supervision, and funding acquisition, writing, editing the final version of the manuscript. ACLB, PEM, DAOG, JRFJr, VRST, and VMF contributed to the data curation and assessments. ACLB and PEM contributed to the data analysis.

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Availability of data and materials

The data and materials presented in this study are available upon request from the corresponding authors.

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee at Clinical Hospital of Ribeirao Preto Medical School (CAAE: 50631615.9.0000.5440) and all participants signed the informed consent form to participate, following Helsinki's declaration procedures for human research studies.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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