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DIAGNOSTIC METHODS: Mentored Research: Reliability Study

How many balance task trials are needed to accurately assess postural control measures in older women?

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ABSTRACT

Summary: Taking the average of different trials is recommended for better balance assessment, but few studies have really proven this point under different balance conditions.
Objective: To assess the effects of averaging trials of five different balance tasks on postural control measures in older women.
Methods: A total of 90 older women (means: Age: 68 years; Weight: 67 kg; Height: 1.56 m; Body mass index, 27 kg/m^2) participated in this study. The participants completed five balance tasks with three performance trials for each task on a force platform in random order. The participants completed a total of three 30-s trials of tasks with 30 s of rest between trials. Repeated measure ANOVA and coefficient of variation were computed to compare differences for one trial vs. averaging across two or three trials on center of pressure (COP) sway values.
Results: There were no significant differences ($P > 0.05$) in COP sway values when comparing one vs. the average of two or three trials for all balance tasks. However, the coefficient of variation was higher for three trials (10–40%) than two (6–37%) or one trial (3–23%) for COP parameters.
Conclusions: Based on reduction of variability, the present study recommends the averaging of a minimum of two trials for balance assessment in older women.
The results of the current study have implications for balance assessment in older people in fall prevention programs.

1. Introduction

Several postural balance tests have been developed for both assessment and intervention of balance deficits (Howe et al., 2007). Stabilographic measures such as parameters of center of pressure (COP) sway calculated in time (velocity) and frequency (median or mean frequency) domains are commonly used for postural control assessment of older people (Bauer et al., 2008; Corriveau et al., 2001). In fact, COP sway measures are valid and reliable signs of balance impairment among older people (Pajala et al., 2008).

To overcome variability, various studies with different experimental balance protocols have documented the reliability of these variables for both healthy young adults and older subjects using the average of three to five repetitions (or trials) to increase the accuracy of data during a two-legged stance balance task (Corriveau et al., 2001; Lafond et al., 2004; Lin et al., 2008; Pinsault and Vuillerme, 2009; Ruhe et al., 2010) and in a few cases, during a one-legged stance task (Da Silva et al., 2013). Postural assessments

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under different challenging conditions (e.g. one-legged stance or semi-tandem with eyes open and closed) are also needed because they are essential for predicting performance in daily activities.

To date, only two studies have investigated the effect of averaging on postural control measures in older adults. A more recent study from 2004, reported by Lafond et al. (2004), suggested the use of the average of two and/or three trials during a two-legged stance task (bipedal condition) to obtain reliable data of COP parameters in older people. A previous study, reported by Corriveau et al. (2001), which used a similar balance task (bipedal condition), supported the use of an average of four trials to reach better data reliability. Additional studies that compare several trials and tasks are necessary for generalization of results in contributing to clinical decision-making during balance assessment, principally in older women who suffer major consequences from balance deficits (Galeet al 2016; Stel et al., 2004).

Therefore, the purpose of this study was to determine the effect of averaging postural control measures, comparing one trial vs. the averaging of two or three trials, for five different balance tasks in older women.We hypothesized that one trial should reproduce similar results in COP values when compared to the averaging of two or three trials.

2. Methods

2.1. Participants

A convenience sample of 90 older women was recruited from the community in the city of Londrina, PR, Brazil. Inclusion criteria were (1) age > 60 years; (2) no lower limb fractures, pain or disorders; (3) no cognitive impairment (Mini-Mental State Examination scores ≥23); (4) no use of medication that could significantly alter their balance (such as psychotropic drugs); and (5) no sensory or neurological disorders. The exclusion criterion was any inability to perform the tests proposed.

The sample size of the present study was defined by calculation of the mean and standard deviation (SD) of the results reported by Geurts et al. (1993). The significance level was 0.05 with the power of the sample estimated at 90%. The estimated sample size, using the mean and standard deviation (SD) value of the COPbalance parameter in quiet standing from one assessment (1.9, SD 0.6 mm) compared to two assessments (2.3, SD 0.6 mm), was 44 participants.

Participants were informed about the experimental protocol and gave written consent before their participation. The protocol and the consent form were approved by the local ethics committee (CEP/UEL:036/2012; CEP/EELO: PP0070/09). All participants were familiarized with the equipment and procedures before testing.

2.2. Assessments

Postural control measures were collected using a force platform (BIOMEC 400, EMG system do Brazil, SP, Ltda). The participants performed five balance tasks presented in random order: (1) two-legged stancewith eyes open; (2) two-legged stancewith eyes closed; (3) semi-tandem (heel of one foot alongside the hallux of the other foot) with eyes open; (4) semi-tandem with eyes closed, and (5) one-legged stance on the preferred leg (de Oliveira et al., 2014).

The participants completed the tasks barefoot with arms parallel to their trunk. During testing with eyes open, the participants looked at an eye level target 14.5 cm height x 14.5 cm wide x 4 cm thick on a wall 2 m away. All participants performed up to three 30s trials with 30s rest intervals between trials (Da Silva et al., 2013). To prevent falls during testing, an investigator stood close to the volunteers during all tasks. A mark on the force platform was used to standardize the position of the feet.

The vertical ground reaction force data from the force platform was sampled at 100 Hz, and filtered with a 35 Hz low-pass second-order Butterworth filter. The signals from the four force platform sensors were converted into COP data using computerized stabilography using MATLAB routines (The Mathworks, Natick, MA) to calculate the 95% confidence ellipse area of COP (A-COP in cm^2) (de Oliveira et al., 2014), and the mean COP velocity (VEL in cm/s) in the anteroposterior (A/P) and mediolateral (M/L) directions. These COP parameters are sensitive and reliable postural control measures (Bauer et al., 2008; Da Silva et al., 2013; Jonsson et al., 2004; Pinsault and Vuillerme, 2009).

The COP parameters were analyzed using one trial, the mean of two trials, and the mean of all three trials. Data collection on the force platform in one-legged stance was started after three seconds without having the contralateral foot touching the ground.

The physical activity level of the individuals was evaluated by the number of steps performed and measured by means of a pedometer (DIGI-WALKER model SW700, Yammax, Japan) for seven days, placing it to the right at the waist toward the midline of the knee (Tudor-Locke et al., 2011, 2012).

Finally, the participant answered a question about fear of falling: “do you have fear of falling?” and the answer had three options (always, sometimes and never). This procedure was used only to characterize whether our sample was afraid of falls mainly in the challenge condition (one-legged stance).

2.3. Statistical analysis

Means, standard deviations, and absolute and relative frequency are presented. TheShapiro-Wilk test was first used to evaluate the normality of the variables and determine which tests would be used.ANOVA with repeated measure was used to assess differences between the results of the averaging procedures (one trial vs. the averaging of two or three trials) for each balance task. To determine the magnitude of variability of data, the coefficient of variation (CV = (standard deviation/mean) × 100) was computed (Moghadam et al., 2011). In the single trial, the standard deviation used was the SD calculated across the mean of the distributions. All statistical analyses were performed with SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA) with a level of significance of 0.05.

3. Results

The characteristics of the participants are presented in Table 1. The participants were considered as normal weight by body mass index (BMI = 27; normal weight (23 < BMI < 28 kg/m2)) (World Health Organization, 2001) and for physical activity as low active (7.382 steps; low active = 5.000–7.499 steps/day) (Tudor-Locke et al., 2011). In relation to fear of falling, only 15% of the sample reported fear always.

Table 2 shows the results of the comparison between one trial

Table 1
Characteristics of the participants.

Variable	(n = 90)	Fear of falling	Absolute (%)
Age (years)	68 (5)	Always	13 (15)
Weight (kg)	67 (12)	Sometimes	30 (33)
Height (m)	1.56 (0.1)	Never	47 (52)
BMI (kg/m^2)	27 (5)		
Mini mental	25 (2)		
Steps (n)	7382 (3870)		

The data are presentedas mean and standard deviation. Body mass index – BMI.

Table 2
Mean (Standard Deviation) values of postural balance for five balance tasks: (1) two-legged stance with eyes open; (2) two-legged stance with eyes closed; (3) semi-tandem with eyes open; (4) semi-tandem with eyes closed, and (5) one-legged stance on the preferred leg with eyes open (n = 90).

		Balance Task				
Variable	Trials	1	2	3	4	5
A-COP (cm^2)	1	1.50 ± 0.96	1.40 ± 0.10	6.23 ± 3.92	8.72 ± 5.14	11 ± 5.45
	2	1.56 ± 0.98	1.48 ± 0.10	6.24 ± 3.10	8.92 ± 4.91	12 ± 4.09
	3	1.49 ± 0.87	1.49 ± 0.09	6.24 ± 2.80	9.09 ± 4.68	12 ± 4.00
	F (*P* value)	**0.96 (0.327)**	**1.89 (0.172)**	**0.01 (0.972)**	**1.81 (0.181)**	**2.95 (0.10)**
VEL A/P (cm/s)	1	0.84 ± 0.29	0.94 ± 0.34	1.66 ± 0.63	2.08 ± 0.77	3.43 ± 1.49
	2	0.85 ± 0.27	0.96 ± 0.35	1.65 ± 0.62	2.10 ± 0.76	3.45 ± 1.23
	3	0.84 ± 0.26	0.95 ± 0.34	1.62 ± 0.58	2.08 ± 0.75	3.50 ± 1.27
	F (*P* value)	**0.09 (0.764)**	**1.03 (0.312)**	**1.98 (0.162)**	**0.00 (0.986)**	**0.85 (0.357)**
VEL M/L (cm/s)	1	0.53 ± 0.13	0.54 ± 0.14	1.75 ± 0.69	2.33 ± 0.79	3.69 ± 1.28
	2	0.54 ± 0.12	0.56 ± 0.17	1.74 ± 0.58	2.34 ± 0.79	3.74 ± 1.09
	3	0.53 ± 0.12	0.55 ± 0.16	1.72 ± 0.56	2.32 ± 0.77	3.76 ± 1.02
	F (*P* value)	**0.09 (0.954)**	**1.16 (0.283)**	**1.10 (0.296)**	**0.03 (0.848)**	**1.08 (0.300)**

COP parameters: 95% confidence ellipse area of center of pressure (A-COP), COP velocity (VEL) in the anteroposterior (A/P) and mediolateral (M/L) directions. *P* value (>0.05) = No significant differences.

vs. averaging of two or three trials for all COP parameters and balance tasks. No significant differences ($P > 0.05$) were found for any comparison from the ANOVA with repeated results; one trial was similar to the averaging of two or three trials.

In general, higher variability was found for three trials (10–40%), except in one case where the third trials were lower (CV 3 = 7, and CV 1 = 8). In relation to the variability of balance tasks, the two-legged stance with eyes open showed a higher value for A-COP (CV 3 = 40%) and a lower value for VEL M/L (CV 1 = 3) than the other balance conditions (Table 3).

4. Discussion

The present study reported the effect of averaging on postural control measures for five different balance tasks in older women.-The conditions selected in this study are some of the main tasks used to evaluate postural balance in older people (Paillard and Noé, 2015). As expected, no significant differences between one trial vs. the averaging of two or three trials were found for all COP parameters and balance tasks investigated, which supported our hypothesis.

Considering the familiarization before testing (some quick trials of 30s), and the random order of tasks, apparently the learning effect across repeated balance trials was not significant, at least not within three repetitions, which is usually enough to evaluate balance in rehabilitation programs with patients of concern. On the other hand, very individual responses from each testing were observed, with variances between subjects and mainly between trials. The coefficient of variation in general was higher for three trials compared to the averaging of two or one single trial, as reported in Table 2. Thus, the clinical implication of these results would be to pay attention to reducing the variability, not only regarding time, during collection of data for clinical purposes.

In summary, the results of the present study are in agreement with previous work (Lafond et al., 2004), but some recommendations were based on intraclass correlation coefficient (ICC) (Corriveau et al., 2001; Lafond et al., 2004), not just using a statistical domain of variability such as CV. Lafond et al. (2004) reported that COP velocity was the most reliable for 2 trials of 2 min, obtaining an ICC over 0.90 in both AP and ML directions. On the other hand, Corriveau et al. (2001) reported that using the mean of 4 trials of 2 min stabilizes the COP-COM variable enough to potentially be used to evaluate postural balance (ICC >90).This was well recognized for two-legged standing balance task assessment, where previous studies recommended 2 or 4 trials at a minimum to obtain superior accuracy and reliability of data (Corriveau et al., 2001; Lafond et al., 2004).

Moghadam et al. demonstrated the reliability of a postural control assessment protocol using different levels of postural difficulty, under single and dual-task conditions in healthy older

Table 3
Mean coefficients of variation of five balance tasks: (1) two-legged stance with eyes open; (2) two-legged stance with eyes closed; (3) semi-tandem with eyes open; (4) semi-tandem with eyes closed, and (5) one-legged stance on the preferred leg with eyes open (n = 90).

		Balance Tasks				
Variables	Trials	1	2	3	4	5
A-COP (cm^2)	CV 1 (%)	23	22	14	15	20
	CV 2 (%)	37	30	24	25	26
	CV 3 (%)	40	37	27	28	34
VEL A/P (cm/s)	CV 1 (%)	5	5	5	6	9
	CV 2 (%)	8	9	10	12	15
	CV 3 (%)	11	10	12	13	18
VEL M/L (cm/s)	CV 1 (%)	3	8	5	5	7
	CV 2 (%)	6	7	9	11	12
	CV 3 (%)	7	7	11	12	16

COP parameters: 95% confidence ellipse area of center of pressure (A-COP); COP velocity (VEL) in the anteroposterior (A/P) and mediolateral (M/L) directions; Coefficient of variation (CV).

adults and showed the CV of these results (Moghadam et al., 2011).The results showed that the patterns of the CV values were greatly consistent with the intraclass correlation coefficient, so that for most conditions, mean velocity (M/L) had lower values relative to other measures (CV range, 3–13%) (Moghadam et al., 2011).These findings corroborate our results that demonstrated very similar values for the same variable (VEL M/L, CV range, 3–16%).

Another study that assessed intra-subject variability of selected force-platform parameters (amplitude, frequency and velocity of the COP sway) for ten postural control repetitions showed values of variability of 22–37% (Geurts et al., 1993). These values are close to those found in this study for A-COP (CV range, 14–40%) and different for both values found in VEL A/P and M/L directions. In fact, these differences can be explained by the characteristics of the samples: Geurts' study evaluated subjects with age between 22 and 65 years while the present study was with older women, as well as the type of task executed (Geurts' study used only an upright bipedal standing task while the present study used a variation of five tasks).

However, it is also suggested that the most accurate way to perform functional tests of balance is to take an average of two trials (Tyson, 2007). Tyson observed that this method approximately halved the error in comparison to using familiarization trials and that a mean of 2 trials was more accurate than a mean of 3 trials. In the present study, we demonstrated that the lower number of trials had lower variability, which was in agreement with the findings of Tyson. In addition, it must be remembered that fatigue, boredom, frustration, or loss of attention may become a problem with multiple repetitions (or trials) and could be the cause of the increased error for trials ≥ 3, as pointed out in Tyson's results.

4.1. Limitations

Finally, a limitation of the present study was that there was no comparison with older men. Therefore, the sample may not be generalizable to the general population of older and pathological patients.For strengths, this study analyzed 90 older women using different balance tasks.

5. Conclusion

The comparison between one single trial and the averaging of two or three trials on postural control measures during five balance tasks in older women did not show significant effects. However, three trials produced a higher coefficient of variation compared to other methods (principally in bipedal condition), which supports the use of the averaging of a minimum of two trials. The results of the current study have implications for balance assessment in older people in fall prevention programs.

5.1. Clinical relevance

- No significant difference was found in average of three trials for five postural balance conditions.
- The averaging of a minimum of two trials for balance assessment in older women is recommended.
- Reducing the number of trials can minimize the time spent assessing postural balance in older women.

Conflicts of interest

The authors declare no conflicts of interest.

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