Intersession reliability of center of pressure measurement during bipedal standing with different count-back orders

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Abstract

Introduction

Dual-task assessments can identify changes in postural control during balance assessments. Static standing with backward counting is frequently used to evaluate postural control while dual-tasking. The most reliable countdown method for standing postural stability has not yet been defined.

Research objective

to investigate postural stability's intra- and inter-day reliability while backward counting in different steps.

Method

Thirty-nine healthy adults (20 females, 26.94 ± 7.55 years) completed 70 s trials of stability tests with no dual-task, counting backward under five conditions (in ones, tows, threes, fours, and fives) while standing on a force-plate in three sessions: two sessions were on the same day, and the third session was one-week apart. The repeatability of measurements was tested using repeated-measure analysis of variance, interclass correlation, and standard error of measurements.

Results

The interclass correlation scores ranged from 0.67 to 0.92, and the standard error of measurements ranged from 2.9% to 13.4%. No significant systematic changes ($p < 0.05$) occurred between the testing sessions for any backward counting.

Discussion

The backward counting showed higher reliability when performed in condition 5 (counting backward in five's). The inter-day reliability scores were greater than intera-day reliability.

Conclusions

Dual-tasking with most backward counting (in ones to fives) is reliable, and a quantitative assessment of the center of pressure could be used to monitor the changes in postural stability between sessions.

1. Introduction

The postural control system integrates sensory inputs from the somatosensory, vestibular, and visual systems to maintain upright standing (Ivanenko and Gurfinkel, 2018). Center of pressure (CoP) measurement with force-plate during quiet standing is the norm for the assessment of postural control (Prieto et al., 1996). The CoP signal consists of a two-dimensional displacement of the CoP over the force-plate along antro-posterior (AP) and medio-lateral (ML) directions. It has been stated that CoP velocity is a relevant parameter for evaluating postural control during quiet standing (Lafond et al., 2004; Ruhe et al., 2010). Evaluating balance control and stability, especially in older adults, is often done using the mediolateral CoP velocity (Hilliard et al., 2008). Variations in the CoP velocity could be a sign of postural instability following musculoskeletal injuries, neurological disorders, or aging-related changes, all of which can lead to impaired postural control (Nashner, 2014). Researchers and healthcare practitioners assess postural control to quantify neuromuscular control capabilities, identify individuals at higher than average risk for balance disability, improve balance performance as a marker for rehabilitation interventions, and return to independent living (Paillard and Noé, 2015). Standing balance is a complicated motor activity that needs a sufficient processing capacity to control coordinated body movements in the brain (Woollacott and Shumway-Cook, 2002). The capacity to carry out muscular and cognitive activities simultaneously is necessary for securely standing in real life (Yogev-Seligmann et al., 2008).

Important aspects of human movements, like balance, gait, turns, and transitions (e.g., sit-to-stand), have all been linked to the capacity of cognitive processing (Sunderaraman et al., 2019). People who have a slower processing rate walk more slowly, with reduced rhythm in their steps (Morris et al., 2016) and increased risk of falls (Chu et al., 2013). Hence, cognitive dual-task techniques have gained popularity in recent studies as a helpful clinical marker for postural stability assessment. (Mancioppi et al., 2021). Therefore, inhibiting the brain from using all of its attention resources for balance through the use of a cognitive dual-task may make this test more sensitive than quiet standing for determining a patient's ability to maintain balance in everyday activities (Zijlstra et al., 2008). The dual-task procedure generally consists of a core motor function (such as a balance test) and a secondary attention-demanding task (like a cognitive task) (Ghai et al., 2017). In addition to keeping their upright balance in real-life activities, people frequently need the ability to undertake secondary tasks (Shumway-Cook and Woollacott, 2000). Postural instability is more likely to occur when performing tasks requiring splitting one's attention between two things (Stins et al., 2009). Attention is the basis of processing capacity during a dual-task and is driven by the interaction between sensory and cognitive elements (Corbetta and Shulman, 2002). Attention's main function during data processing includes focusing, selecting, or blocking the available stimuli (Woollacott and Shumway-Cook, 2002). Several types of dual-task scenarios include secondary manual tasks, reaction time, decision-making, mental tracking, verbal fluency, and working memory activities (Petrigna et al., 2020). Static standing with mental tracking is frequently used to evaluate postural control while performing two tasks (Yang et al., 2015). Postural control has been shown to give more weight to the sensory channel, which is crucial for both posture and secondary tasks (Redfern et al., 2017). Thus, certain concurrent tasks (e.g., secondary manual tasks or reaction times that depend on visual cues) enhance postural instability and raise the risk of falls during testing procedures, especially in people with balance disorders (Bayot et al., 2018). Backward counting methods do not rely on visual cues and are one of the most widely used mental tracking approaches for dual-tasking in the clinical setting (Bayot et al., 2018; Petrigna et al., 2020). Moreover, doing this whilst subtracting in a variety of sequences has been found to present a varied amount of cognitive resource challenges (Petrigna et al., 2020). The use of particular orderings for counting backward makes this mental tracking activity more challenging and may raise the demand on cognitive ability and deplete the central processing reserve (Bayot et al., 2018). It has been reported that attention-demanding tasks could make changes in the consistency of CoP trajectory (Drozdova-Statkevičiene et al, 2018), affecting the reliability of the force-plate measures of postural stability parameters.

Evaluating balance control and stability, especially in older adults, is often done using the mediolateral CoP velocity. When assessing postural stability, it is essential to ensure that any variation in the CoP measures between testing sessions reflects a change in the systems that control posture rather than systematic or random measurement error (Hadian et al., 2008). Reliability is defined as the consistency of the outcomes over trials and is often measured using the intraclass correlation coefficient. (ICC) (Weir, 2005). The ICC defines the ratio of subject variance to total variance however, it does not account for additional variation sources that could affect measurement precision. The identification of the measurement error warrants reliability studies. Standard error of measurement (SEM), which is given along with ICC value in reliability studies, is the parameter that can quantify an estimate of measurement precision. Several studies have reported the reliability of CoP parameters during standing postural control and counting backward. However, no prior study has focused on determining the most reliable method for counting backward in standing postural stability. A study on a healthy population with a less challenging secondary task is part of the preliminary stage of these clinical investigations to ensure safety evaluation, establish baseline data, and assess the feasibility and design of the study—all of which are essential for ethical approval of future studies involving people with specific health conditions (Shen et al., 2019). The objective of this study was to investigate the intra- and inter-day reliability of a cognitive dual task postural control that counted backward under five conditions (in 1s–5s).

2. Method

2.1. Study design

A repeated-measures reliability design was used in this study. The independent variables included the time (time 1: T1, time 2: T2, and time 3: T3). Participants were given a three-digit number (500) and were asked to subtract it under five conditions (i.e., by ones in condition 1, twos in condition 2, threes in condition 3, fours in condition 4, and fives in condition 5) while standing on a force-plate. The mean velocity of the CoP parameter, as detailed in the following, was the dependent variable. The institutional review board and ethics committee of Isfahan University of Medical Sciences approved this study.

2.2. Participants

Thirty-nine participants (20 female and 19 male) took part in the study. They aged 26.94 ± 7.55 (M±SD) years, had height from 154 to 187 (M±SD: 170.15 ± 9.25) cm, and in weight from 43 to 103 (M±SD: 70.89 ± 13.83) Kg. Healthy volunteers from the University's personnel and students served as a convenience sample for recruiting participants. At the time of the data collection, participants affirmed that their health was good and that they had no problems with their balance. None had vertigo, orthopedic, or neurological disease that had been medically diagnosed. Each participant provided their informed consent before the study began.

2.3. Testing procedure

Each participant went through three testing sessions. T1 was at 8:30 a.m., T2 was at 1:30 p.m., and T3 was at 8:30 a.m. on the same weekday seven days later (Fig. 1). The participants stood barefoot over a Kistler® force-plate (Model: 9260AA6, Kistler instrument AG, Sweden) with a sampling rate of 100 Hz, and the postural sway was recorded for 70 s. The force-plate had a 600×500 mm metal sandwich cover and the four 3-dimensional piezoelectric force sensors were installed underneath the legs (Fig. 2). The force-plate was recessed into a walkway so that the Y-axis was oriented towards the forward stance. (Fig. 3A). Participants were instructed to maintain their arms at their sides, place their heels together with a 45-degree angle between their forefeet (Fereshtenejad et al., 2024), and stare straight ahead at a fixed spot in a quiet environment (Fig. 3B). A foot placement pattern had been drawn on the paperboard and adhered to the force-plate (Fig. 3A) to prevent the base of support from changing between testing sessions. Participants' postural stability was examined under six different conditions. The testing conditions were backward counting aloud from 500 b y different orders from 1 to 5 and not counting at all. The participants randomly determined the testing sequence by drawing concealed envelopes from a hat. A typical value for the postural sway for each condition was generated by repeating three tests for each condition and averaging the results. The test was conducted in a laboratory setting to control the environmental conditions throughout all testing sessions with a temperature of around 22 °C, 15% relative humidity, 120 lux of illumination, and 40 dB of noise. A light lunch was permitted for the participants at 11 a.m., but caffeine use (coffee or tea) between T1 and T2 was not allowed. The participants were allowed a 1-min pause between every trial to avoid getting tired. The same rater repeated the whole testing session in the second and third sessions in order to assess the test-retest reliability.

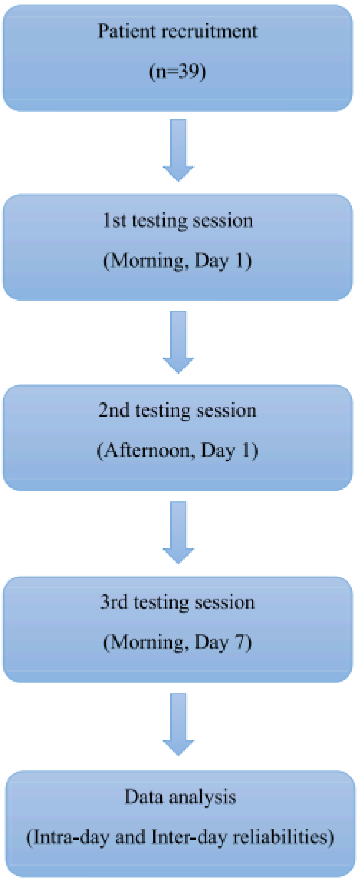

Fig. 1. The study flowchart.

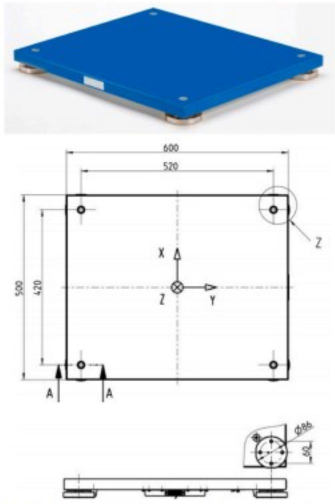

Fig. 2. The structure, assembley, and dimentions of the force-plate was used in the study (units are in mm).

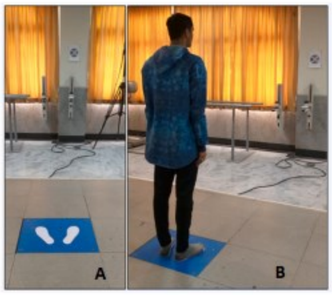

Fig. 3. A: the foot placement pattern was defined on the mounted foreplate; B: the evaluation of postural stability in upright standing.

2.4. Data processing

Six voltage outputs—Fx, Fy, Fz, Mx, My, and Mz—represent the mechanical input into the force-plate and its corresponding piezoelectric force sensors. Fx, Fy, and Fz stand for the anterior-posterior, medio-lateral, and vertical components of the applied forces, respectively, while Mx, My, and Mz are the three components of the moment of force (or torque) operating on the force-plate. In a coordinated system, the recorded CoP time series had two components: anteroposterior (AP) and mediolateral (ML). The following formulae were used to calculate the position of the CoP, where 0.057 is the thickness of the force plate (Challis, 2021):$CoPAP=(0.057Fz+Mx)FyCoPML=(0.057Fx+Mz)Fy$ Signals from the force-plate transformed from analogue to digital using the Qualysis Track Manager software (V.2.48-QTM, Qualysis AB, Sweden). The CoP signals were run through a Butter-Worth filter with a 10 Hz cut-off frequency. Each trial's beginning and last 10 s were trimmed (remaining 50s). This approach was designed to lessen the influence of possible fluctuations that participants could have made to obtain a comfortable posture over the force-plate at the start of testing or while predicting the completion of the recording duration. The study outcomes were processed by computing the digital time series data using MATLAB (V.14, Matwork, Natick, USA). The mean velocity, or average speed of the CoP, was determined by dividing the entire excursion of the CoP by the remaining time (50 s) using the following equations (Prieto et al., 1996):$MeanVelovityAP=\sum nn-1(APi+1-APi)250MeanVelovityML=\sum nn-1(MLi+1-MLi)250$

2.5. Statistical analysis

Based on sample size calculation for reliability studies (Bonett, 2002), thirty-six participants were required for this study. A significance level of 0.05, power of 0.8, expected reliability (ICC) of 0.8 based on similar previous studies (Moghadam et al., 2011; Swanenburg et al., 2008), and minimum acceptable reliability (ICC) of 0.6 were all taken into consideration for this calculation.

The reliability of the COP measures was estimated using the generalizability theory (G theory). Two sections make up this theory: the decision (D-) research and the generalizability (G-) investigation. The G-study estimates the different sources of measurement error that impact the variability of participants' values. In this study, analysis of variance (ANOVA) with repeated measurements was used to investigate the repeatability of CoP parameters and assess the impact of study time on the dependent variable. The normality (Shapiro–Wilk's test), equality of variances (Levene's test), and sphericity (Mauchly's test) of the data were confirmed before conducting inferential testing to ensure that parametric assumptions had been satisfied. If an ANOVA test revealed a statistically significant difference, post-hoc comparisons were conducted for pairwise comparisons using the Sidak approach to control for Type 1 error. The two-way mixed-effects model with consistency testing for the mean values was used to compute the interclass correlation coefficients (ICCs) and their 95% confidence intervals (CIs) to quantify relative variability. The following criteria were used to evaluate ICC values: reliability was poor if less than 0.5, moderate if between 0.51 and 0.75, good if between 0.75 and 0.9, and excellent if higher than 0.9 (Koo and Li, 2016). The information needed to decide on the measuring methodology is supplied by the D-study. It calculates the reliability of the observed values that match any study design other than which is used in the G-study. The standard error of measurement was determined as the absolute reliability parameter to verify the precision of the measurements (SEM = standard deviation of measurements × 1−ICC) (Denegar and Ball, 1993). The relative SEM values were calculated and presented as a percentage of the mean (Relative SEM= (SEM/mean) × 100) (Denegar and Ball, 1993). The statistical analyses were conducted using SPSS software (V.18; IBM, Armonk, NY, USA), and the significance level was set at 0.05.

3. Results

Data from 39 participants were used to determine the intra-day (T1 versus T2), between-session (T1 versus T2 and T3), and inter-day (weekly - T1 versus T3) reliability. The participants' demographic characteristics are presented in Table 1. Participants demonstrated greater postural sway velocity in standing while counting backward. The collected results did not indicate any significant differences across sessions, and the repeated measures of ANOVA did not show any impact of intra- and inter-day testing on the mean velocity of CoP. The mean and standard deviation for the test (T1) and retest (T2 and T3) sessions are shown in Table 2. In all testing conditions, there was no statistically significant difference between the mean scores for T1, T2, and T3 for any CoP measures ($p > 0.05$), indicating no systematic bias exists.

Table 1. Demographic and clinical characteristics of participants.

Table 1: Demographic and clinical characteristics of participants.			Empty Cell
Characteristics		**Values**[a]	**Range**[b]
Gender, n (%)	Female	20 (51%)	–
	Male	19 (49%)	–
Age, y	–	26.94 (7.55)	18–52
Height, cm	–	170.15 ± 9.25	154–187
Weight, kg	–	70.89 ± 13.83	43–103

a

Values are mean (SD) unless others indicated; Patient-Rated Tennis Elbow Evaluation Patient-Rated Tennis Elbow Evaluation.

b

Range: Minimum-Maximum.

Table 2. Mean, standard deviation, and repeated measures ANOVAs 0f the CoP variable in different study conditions.

CoP Parameter	Counting Back	Session 1 (M±SD)	Session 2 (M±SD)	Session 3 (M±SD)	1-way repeated measures ANOVA
Mean Velocity-AP (mm/s)	C0	6.13 ± 1.67	6.1 ± 1.47	5.74 ± 1.63	f = 2.02; p = 0.15; η2 = 0.11
	C1	7.16 ± 2.14	6.8 ± 1.8	6.81 ± 1.74	f = 0.65; p = 0.53; η2 = 0.04
	C2	7.9 ± 2.87	7.35 ± 2.47	6.97 ± 1.62	f = 0.86; p = 0.07; η2 = 0.14
	C3	7.48 ± 2.82	7.23 ± 2.16	6.95 ± 1.75	f = 1.15; p = 0.33; η2 = 0.06
	C4	7.4 ± 2.59	7.17 ± 1.95	6.98 ± 1.89	f = 1.98; p = 0.15; η2 = 0.11
	C5	7.08 ± 2.11	6.69 ± 1.98	6.89 ± 1.82	f = 1.7; p = 0.2; η2 = 0.09
Mean Velocity-ML (mm/s)	C0	4.01 ± 1.39	3.79 ± 1.34	3.62 ± 1.46	f = 1.03; p = 0.37; η2 = 0.06

CoP Parameter	Counting Back	Session 1 (M±SD)	Session 2 (M±SD)	Session 3 (M±SD)	1-way repeated measures ANOVA
	C1	4.43 ± 1.41	4.25 ± 1.48	4.4 ± 1.55	f = 0.4; p = 0.67; η2 = 0.02
	C2	4.51 ± 1.33	4.24 ± 1.61	4.13 ± 1.63	f = 1.9; p = 0.17; η2 = 0.11
	C3	4.44 ± 1.42	4.35 ± 1.58	4.56 ± 1.79	f = 0.76; p = 0.48; η2 = 0.04
	C4	4.72 ± 1.83	4.56 ± 1.77	4.57 ± 1.73	f = 0.15; p = 0.86; η2 = 0.01
	C5	4.65 ± 1.83	4.24 ± 1.73	4.51 ± 1.5	f = 1.75; p = 0.9; η2 = 0.09
Mean Velocity-R (mm/s)	C0	8.13 ± 2.22	8.02 ± 2.26	7.6 ± 2.51	f = 1.12; p = 0.32; η2 = 0.07
	C1	9.91 ± 3.65	9.22 ± 2.92	9.29 ± 2.97	f = 0.93; p = 0.4; η2 = 0.05
	C2	10.21 ± 3.8	9.47 ± 3.29	9.15 ± 2.54	f = 1.95; p = 0.16; η2 = 0.11
	C3	10 ± 3.42	9.47 ± 3.25	9.2 ± 2.6	f = 1.77; p = 0.17; η2 = 0.1
	C4	10.06 ± 3.84	9.48 ± 2.79	9.7 ± 4.02	f = 0.75; p = 0.48; η2 = 0.04
	C5	9.66 ± 3.37	8.79 ± 2.82	9.06 ± 2.43	f = 2.17; p = 0.13; η2 = 0.11

M: mean; SD: standard deviation; AP: anteroposterior; ML: mediolateral; R: resultant; C0: no counting; C1-5: backward counting from ones to fives.

According to the ICC values, which varied from 0.67 to 0.92, and the relative SEM from 2.9% to 13.4%, all parameters demonstrated moderate-to-excellent reliability under most testing conditions. Compared to other orders, counting backward in fives demonstrated greater ICCs. Counting backward could increase the between-session ICCs compared to standing with no counting. There was a slight rise in the between-session reliability values for counting backward from 1 to 5. Inter-day (weekly) ICC values were higher than intra-day (periodic) ICC values. The SEM% values show similar results; the between-session SEM values decreased while the order of count back increased from 1 to 5. Table 3 displays the ICC, 95% CI, and the relative SEM for intra-day, inter-day, and between-session reliability.

Table 3. The reliability analyses of the CoP variable in study conditions.

Sway Parameter	Testing Condition	Between Session Comparison			Intra-day Comparison			Inter-day Comparison		
		ICC	95% CI	SEM%	ICC	95% CI	SEM%	ICC	95% CI	SEM%
Mean Velocity-AP (mm/s)	C0	0.86	0.76–0.93	5.55	0.82	0.64–0.83	6.06	0.85	0.71–0.93	5.41
	C1	0.8	0.64–0.89	7.82	0.68	0.38–0.84	11.32	0.9	0.8–0.95	4.84
	C2	0.84	0.73–0.91	7.21	0.82	0.64–0.91	8.57	0.88	0.76–0.94	4.73
	C3	0.87	0.77–0.93	6.15	0.85	0.71–0.92	6.78	0.88	0.77–0.94	4.46
	C4	0.89	0.8–0.94	5.13	0.79	0.58–0.89	8.92	0.86	0.73–0.93	5.01
	C5	0.92	0.86–0.96	3.53	0.88	0.76–0.94	4.93	0.92	0.84–0.96	2.9
Mean Velocity-ML (mm/s)	C0	0.76	0.58–0.87	11.72	0.77	0.55–0.88	11.34	0.74	0.48–0.87	12.98
	C1	0.81	0.66–0.9	9.48	0.67	0.32–0.8	13.4	0.88	0.77–0.94	5.68
	C2	0.86	0.75–0.93	6.65	0.82	0.64–0.91	8.73	0.84	0.67–0.92	7.26
	C3	0.85	0.73–0.92	8.33	0.71	0.42–0.86	12.41	0.89	0.78–0.94	5.29
	C4	0.81	0.66–0.9	10.59	0.77	0.56–0.88	11.84	0.83	0.67–0.91	8.53
	C5	0.85	0.73–0.92	9.68	0.77	0.55–0.88	11.75	0.89	0.78–0.94	5.54
Mean Velocity-R (mm/s)	C0	0.82	0.67–0.9	7.62	0.75	0.52–0.87	9.48	0.85	0.72–0.93	8.29
	C1	0.85	0.74–0.92	7.37	0.75	0.51–0.87	8.24	0.91	0.82–0.95	3.87
	C2	0.84	0.73–0.92	7.54	0.78	0.56–0.89	10.35	0.92	0.84–0.96	3.5
	C3	0.86	0.76–0.91	4.9	0.88	0.78–0.93	4.22	0.88	0.78–0.94	5.22
	C4	0.87	0.78–0.93	6.66	0.79	0.6–0.89	9.7	0.77	0.55–0.89	10.31
	C5	0.88	0.78–0.93	5.9	0.8	0.6–0.9	9.21	0.91	0.83–0.95	3.42

ICC: interclass correlation; CI: confidence intervals; SEM: standard error of measurement; AP: anteroposterior; ML: mediolateral; R: resultant; C0: no counting; C1-5: backward counting from ones to fives.

4. Discussion

This result supports the hypothesis that variation in the backward counting order could affect the reliability values of postural stability measurements using a force plate. However, there were no major differences in postural stability reliability between different backward counting orders. Results showed good to excellent reliability under most backward counting conditions. Inter-day reliability showed slightly better values than intra-day reliability under most test conditions.

Mean CoP velocity was chosen in this study because it has been reported as the most sensitive and reliable parameter commonly used to assess postural stability (Lafond et al., 2004; Ruhe et al., 2010). Previous research showed that the relative and absolute reliability values of mean CoP velocity were higher than other parameters of postural stability in people during a counting backward dual task (Swanenburg et al., 2008). The mean velocity of CoP in counting backward tended to be more reliable than no counting. This finding was expected since adding a cognitive task could draw attention to an external focus (backward counting) while keeping the body balanced (Resch et al., 2011). The external focus makes it possible for motor control to work more automatically, resulting in more effective performance (Wulf et al., 2001). The reliability results were relatively better in the AP direction compared to the ML direction. The reason for this phenomenon is not entirely apparent but may be related to the degree of range of motion in the ankle and hip joints. The hip strategy offers a greater range of motion at higher speeds than the ankle strategy (Nashner, 2014). From a clinical point of view, this result could be relevant as postural sway in the ML direction has been reported to discriminate between fallers and non-fallers (Maki et al., 1994; Swanenburg et al., 2010). The cognitive task performed while dual-tasking in this investigation could impact balance performance and reduce the reliability scores in the ML direction.

The underlying factors that generated the variability in postural sway during the assessment are difficult to identify. It is possible that the results' variability was influenced by the fact that counting backward was performed aloud. Backward counting aloud was undertaken so that the assessor could verify that the dual tasking was accurate in this investigation. As opposed to repeating phrases silently, it has been shown that speaking aloud could have a higher impact on postural stability (27). Counting backward aloud could make the secondary task verbal fluency in combination with the mental tracking task (Petrigna et al., 2020).
In comparison to inter-day values, intra-day reliability levels were lower. The participants could become exhausted if they undergo too many trials in one day. Although the cognitive task allowed for external attention focus and shifting to manage postural stability automatically, it was not possible to gauge how much attention was being directed toward the secondary task. The backward counting was a relatively simple task for the participants in this experiment. A high level of accuracy for backward counting was observed in this trial. The issue with a simple secondary task is that it could not present a sufficient challenge for central processing to transfer postural control to a more automated procedure.

Despite some differences, the reliability values were still within the acceptable range compared to previous studies. With regard to counting backward aloud, our results agree with the results of Swanenburg et al. (2008), who reported an ICC of 0.8 for the mean velocity of

CoP when counting down in 7s increments. In addition, Moghadam et al. (2011) showed an ICC of 0.89 for the mean CoP velocity in healthy people when counting backward in 3s or 7s. A similar pattern as that described for relative reliability was seen for absolute reliability (SEM%). This can suggest that a small measurement error was made during the measurements.

Several limitations of this study should be noted. This study investigated the reliability of dual-tasking conditions in healthy participants. The university personnel and students with educational backgrounds were the study's participants. There may be a greater cognitive capacity for dual-tasking in the participants of this study compared with the general population. The reliability values obtained in this study might not apply to other populations. Not all balance confounders were taken into account in the study methodology. For example, participants were free to roam about and work between intra-day sessions (T1 and T2), which might lead to individual tiredness. Numerous CoP-based parameters, such as the frequency or shape of the CoP excursion, could be employed in the trials. However, these were not examined in this investigation. The verbalization of backward counting during static balance may influence postural sway due to respiratory function and movements of the temporomandibular joint (Madeleine et al., 2011). It should be noted that participants in this study were speakers of the Persian language.

This study showed that the sequence of backward counting in the young, healthy volunteers had an impact on the intersession reliability of the CoP assessment. Thus, more research into the test-retest reliability of CoP measurement while counting backward in populations of elderly or diseased subject groups may be possible. The implication of our findings for the research and clinical practice is that backward counting, and its order determine the reliability of postural stability and should be controlled between different assessments.

5. Conclusion

This study demonstrated the absolute and relative reliability of the mean velocity of CoP under different backward counting orders in a group of healthy individuals. This study showed that counting backward increased postural sway. More accurate assessments of the CoP were made while standing and counting backward in increments of 5.

Ethics committee approval

The work completed here was a research project approved by the Isfahan University of Medical Sciences Ethics Committee (Registration No: IR. MUI.REC.1395.2.272).

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