

Research Article

The Effect of Visual Input on Postural Stability in Healthy Subject Based on New Method of Measurement

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Abstract | Clinically, the Romberg test has been used for evaluating stability in patients with various neurological defects. This test evaluates patients in 1 minute standing, but studies have shown that any stability test performed for less than five minutes is not clinically valuable. This study has evaluated stability with open and close eyes in normal subjects during five minutes standing in twenty healthy subjects. The subjects were asked to stand on a force plate for one and then five minutes, respectively. Their stability parameters were evaluated based on the old and new methods. Paired sample t-test was used for comparison between two methods and different conditions (eyes open and eyes closed). Traditional method for stability analysis showed no difference between two conditions in one minute standing ($p \geq 0.05$). However, the new method confirmed that stability parameters significantly decreased in five minutes standing ($p < 0.001$). Moreover, patients were unstable in standing during the fourth and fifth minute. Taken together, diagnosis based on five minute standing using the Romberg test appear to be sensitive and accurate than one minute.

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Introduction

Ability to stand and walk independently is based on the performance of neuromuscular system. Moreover, three important systems contributing to postural control include the visual, vestibular, and somatosensory systems (Collins and De Luca, 1995; Nashner et al., 1982; Hu and Woollacott, 1994). Vestibular inputs were produced by linear and angular accelerations of the head. Somatosensory inputs (e.g. proprioceptive and cutaneous sensation) are being simulated by contact forces and motions of the extremities. Visual inputs are resultant of linear and angular motions of the visual field. The role of each

of these physiological systems (vision, somatosensory and vestibular inputs) is examined by removing one of these modalities in laboratory settings and then the subject's postural control is evaluated.

The most popular protocol for assessing visual contribution in maintenance of balance is Romberg test (Black et al., 1982; Dichgans et al., 1976; Paulus et al., 1984; Paulus et al., 1989; Ring et al., 1989). In this test, subjects are examined in quiet standing in two conditions include open and close eyes and postural sway is calculated by a force platform. Various parameters used to measure stability including excursion of centre of pressure (COP), velocity of COP sways and

path length sways in Anterior-Posterior (A-P) and Medial-Lateral (M-L) planes.

Clinically, the Romberg test has been used for evaluating stability in patients with various neurological defects such as spinal cord injury (SCI) and multiple sclerosis (MS) (Njiokiktjien and De Rijke, 1972; Collins and De Luca, 1995). Removing one of these inputs (visual, vestibular, and somatosensory systems) decreases standing stability significantly (1, 6). From a motor control viewpoint, postural sway increases when a subject closes his or her eyes (Collins and De Luca, 1995; Paulus et al., 1984) and this is an indication of instability. Standing stability has been evaluated using force plate based on Romberg test (the duration of the test is one minute) (Khasnis and Gokula, 2003).

However, it has been shown that sensitivity and accuracy of stability analysis in five minutes is a more effective approach than traditional method (one minute stability test) to analysis standing stability of patients (Tagi Karimi et al., 2014; Karimi and Esrafilian, 2013). Duarte and Zatsiorsky showed that after 5 minutes COP shift in A-P about 17 millimeters and after 3 minutes and 30 seconds shift M-L about 22 millimeters (Duarte and Zatsiorsky, 1999). Although Karimi and Esrafilian in their study demonstrated that foundation on the traditional method (1 minute standing), the SCI and Perthes patients were more stable than normal subjects but based on the new method (5 minute standing) these groups were unstable than normal adults (Karimi and Esrafilian, 2013). In other studies, significant differences between stability parameters in the first and fifth minutes (Tagi Karimi et al., 2014; Taghi Karimi et al., 2013). It has been demonstrated that the unstable position occurred in the third and fifth minutes (Esrafilian et al., 2013; Karimi and Esrafilian, 2013).

Romberg test (as a standard test) by open and close eyes has been used for assessing stability in less than 1 minute but recent studies reported instability is demonstrated in third and fifth minute. Since there is no study evaluating the influence of vision in prolonged standing, the aim of this study was to evaluate the stability with open and close eyes in normal subjects during prolonged standing. This study will contribute the effect of vision input in stability and balance in prolonged standing.

Method

Subjects

Twenty healthy adult subjects participated in the study. Table 1 shows the characteristics of the subjects participated in this study. Exclusion criteria included any known history of musculoskeletal or neurologic disorders or any other medical condition that would affect their stability such as visual or hearing impairments. Ethical approval was obtained from Isfahan University of Medical Sciences, Ethical Committee. Informed written consent was obtained from each subject before data collection.

Table 1: The characteristics of the subjects participated in this research project

Participants	Number	Age	Mass	Height
Healthy subjects	20	22±5	63±7.5	1.65±0.12

Equipment

A Kistler force platform with piezoelectric force transducer was used to measure ground reaction forces (GRF) from which COP data were calculated in horizontal plane. Data were collected at 100 Hz for conditions of quiet one and five minutes standing. Stability was evaluated by calculating some parameters such as COP excursions in mediolateral and anteroposterior directions, velocity of COP sways in mediolateral and anteroposterior directions, and path length of COP in these planes based on the following equations:

$$COPEAP (mm) = X_{max} - X_{min} \dots \dots \dots (1)$$

$$COPEML (mm) = Y_{max} - Y_{min} \dots \dots \dots (2)$$

$$PLAM (mm) = \sum^{n-1} \sqrt{(x_{i+1} - x_i)^2} \dots \dots \dots (3)$$

$$PLML (mm) = \sum^{n-1} \sqrt{(y_{i+1} - y_i)^2} \dots \dots \dots (4)$$

$$VAP \left(\frac{mm}{min} \right) = \frac{\sum^{n-1} \sqrt{(x_{i+1} - x_i)^2}}{t} \dots \dots \dots (5)$$

$$VML \left(\frac{mm}{min} \right) = \frac{\sum^{n-1} \sqrt{(y_{i+1} - y_i)^2}}{t} \dots \dots \dots (6)$$

Where, COPEAP, COPEML, PLAP, PLML, VAP, and VML are the excursion of the center of pressure in the anteroposterior direction, excursion of the center of pressure in the mediolateral direction, path length in the anteroposterior direction, path length in the mediolateral direction, velocity of the COP in the

Table 2: COP in A-P and M-L direction with and without input

Mean COP excursion in anteroposterior plane (closed eyes)	29.2± 23	27.9± 17	29.4± 18	27.1± 17	31.2± 22	26.5± 15	28.4± 19	29.5± 17	27.3± 18	27.7± 19	25.4± 14	28.0± 14	26.5± 14	29.7± 18
Mean COP excursion in anteroposterior plane (opened eyes)	30.2 ± 28	32.8 ± 31	25.9 ± 11	26.1 ± 17	24.6 ± 12	25.4 ± 14	25.7 ± 16	22.2 ± 9	26.1 ± 19	27.6 ± 19	24.2 ± 13	27.7 ± 15	30.4 ± 22	28.0 ± 17
Mean COP excursion in mediolateral plane (closed eyes)	14.1± 7	15.8± 7	18.7± 13	15.1 ± 10	15.8 ± 10	19.6 ± 17	18.7 ± 16	17.4 ± 10	17.6 ± 12	19.0 ± 27	20.5 ± 27	15.8 ± 10	15.0± 9	18.2± 12
Mean COP excursion in mediolateral plane (opened eyes)	13.9 ± 7	16.4 ± 6	17.0 ± 12	13.2 ± 10	14.4 ± 9	13.3 ± 17	13.1 ± 15	14.1 ± 10	16.0 ± 12	17.5 ± 27	16.7 ± 27	17.0 ± 10	17.0 ± 9	17.1 ± 12

Table 3: Path of length COP in A-P and M-L direction with and without vision input

Path length of COP in anteroposterior direction (closed eyes)	484.1 ± 219	451.4 ± 195	481.8 ± 208	452.9 ± 178	451.2 ± 196	467.8 ± 202	469.8 ± 177	443.1 ± 158	467.9 ± 178	448.7 ± 166	468.5 ± 178	459.6 ± 179	441.2 ± 172	453.4 ± 170
Path length of COP in anteroposterior direction (opened eyes)	435.1 ± 172	422.5 ± 111	410.8 ± 71	399.2 ± 107	396.1 ± 78	402.8 ± 93	425.6 ± 142	409.7 ± 129	402.4 ± 105	401.7 ± 88	408.2 ± 89	400.2 ± 96	408.6 ± 98	412.8 ± 95
Path length of COP in mediolateral direction (closed eyes)	582.0 ± 354	562.1 ± 363	612.6 ± 394	558.2 ± 346	568.8 ± 401	586.6 ± 430	595.1 ± 355	541.0 ± 312	591.8 ± 362	561.0 ± 367	597.5 ± 369	580.9 ± 353	553.3 ± 355	553.3 ± 344
Path length of COP in mediolateral direction (opened eyes)	485.4 ± 355	488.3 ± 363	491.0 ± 392	465.5 ± 347	475.8 ± 400	478.6 ± 430	500.1 ± 356	495.6 ± 311	480.9 ± 362	481.3 ± 368	496.2 ± 366	478.6 ± 354	474.6 ± 356	492.2 ± 345

anteroposterior direction, and velocity of the COP in the mediolateral direction, respectively (12).

Procedure

Prior data collection, the subjects were allowed to get a balanced standing position on the force platform. Then they were asked to stand quietly on the force plate for five minutes in anatomical comfortable position (looking straight ahead with their head erect and their arm at their sides). Subjects were instructed not to touch their lower extremities with their hands to prevent stabilization of extended physiologic proprioception caused by fingers sensory feedback and they analyzed with open and close eyes by random.

Randomization minimizes risk of possible fatigue as a confounding variable. Butterworth low pass filter with 10 Hz frequency was used to minimize errors in sway path calculation due to high frequency noise. Data were divided each 20 second periods (Karimi and Esrafilian, 2013). The first 20 seconds of the data were eliminated to avoid the effect of undesirable initial movement of standing. Subjects were also asked to stand on the force plate for a minute (based on traditional method). The second third of the data (between 20 and 40 seconds) were used for final analysis.

Statistical analysis

Shapiro-Wilk test revealed that the data was normally distributed. The minimum value of COP, velocity and

sum of path were selected as most stable frame. Other frame was evaluated by paired T-test with significance level set at $p=0.05$. The frame is near to unstable if difference was significant by considering alpha 0.05 that is shown by red colour and is unstable by considering alpha 0.05 that is shown by dark red. The frame is stable if it was not significant. Differences between eyes open and eyes close based on new (regardless of frame time) and traditional method was evaluated using paired T test. The differences between stability parameters under the two test conditions for traditional based test were evaluated by paired t test.

Results

The mean and standard deviation values of stability parameters for these conditions (eyes open and eyes closed) are shown in Tables 2 to 4. Tables 2, 3 and 4 display variations between mean values of stability

parameters in different frames time. Stability pattern in five minute quiet standing is shown by dark and light green color representative unstable and stable position, respectively.

There are significant differences in COP M-L ($p = 0.01$), and A-P, M-L and M-L and A-P direction (both $p < 0.001$) in eyes closed and eyes open conditions. However, there was no significant difference in COP A-P ($p = 0.195$). Table 4 shows the mean and values of stability parameters under both conditions (eyes closed and eyes open).

Stability of the subjects was also evaluated based on the traditional method. The mean values of COP excursions in the mediolateral and anteroposterior directions were 32.86 ± 31.7 mm and 16.43 ± 9.3 mm during opened eyes, respectively compare to 27.98 ± 17.3 and 15.44 ± 7.56 mm during closed eyes

Table 4: Velocity in A-P and M-L direction with and without vision input

Velocity of COP in anteroposterior direction (closed eyes)	968.3 ± 438	902.9 ± 390	963.7 ± 416	905.8 ± 356	902.4 ± 392	935.6 ± 404	939.7 ± 355	886.3 ± 316	935.8 ± 356	897.5 ± 333	937.0 ± 357	919.3 ± 359	882.4 ± 344	906.8 ± 340
Velocity of COP in anteroposterior direction (opened eyes)	870.2 ± 444	845.0 ± 400	821.6 ± 427	798.4 ± 373	792.3 ± 404	805.7 ± 416	851.2 ± 369	819.4 ± 325	804.8 ± 371	803.5 ± 353	816.4 ± 370	800.4 ± 376	817.3 ± 361	825.6 ± 358
Velocity of COP in mediolateral direction (closed eyes)	1164.1 ± 708	1124.3 ± 726	1225.3 ± 788	1116.5 ± 693	1137.7 ± 803	1173.3 ± 861	1190.2 ± 710	1082.0 ± 624	1183.6 ± 725	1122.0 ± 734	1195.0 ± 738	1161.9 ± 707	1106.6 ± 710	1106.7 ± 688
Velocity of COP in mediolateral direction (opened eyes)	971.6 ± 242	970.6 ± 223	977.9 ± 195	925.5 ± 232	939.2 ± 201	952.5 ± 230	1005.3 ± 378	980.2 ± 347	948.7 ± 227	951.2 ± 204	983.5 ± 232	956.9 ± 231	949.4 ± 219	990.8 ± 225

Table 5: Comparison stability parameters between open and close eyes with new and traditional method

Conditions	COPX	COPY	Velocity X	Velocity Y	Path length X	Path length Y
Opened Eyes based on traditional method	32.86 ± 31.7	16.43 ± 9.3	422.5 ± 111.5	488.4 ± 112.6	854 ± 223	970.7 ± 223
Closed Eyes based on traditional method	27.98 ± 17.3	15.44 ± 7.56	451.4 ± 195.3	562.1 ± 363	902.96 ± 390.7	1124 ± 726
P-value	0.157	0.34	0.27	0.198	0.27	0.189
Opened Eyes based on new method	26.96 ± 18.6	15.52 ± 11.13	819.46 ± 213.77	964.577 ± 242.91	409.73 ± 106.88	484.63 ± 122.531
Closed Eyes based on new method	28.17 ± 17.81	17.25 ± 14.98	920.31 ± 362.56	1149.27 ± 716.04	460.15 ± 181.28	574.63 ± 358.022
P-value	0.195	0.000	0.000	0.000	0.000	0.000

($p=0.15$ and 0.34 , respectively). The velocities of COP sways in anteroposterior direction were 422.5 ± 111.5 mm/min and 451.4 ± 195.3 mm/min during eyes open and eyes closed, respectively ($p=0.27$). Table 5 shows the mean values of stability parameters under both opened and closed eyes conditions, based on the traditional approach. As it can be seen from the table there were no differences between the test conditions.

Discussion

This study investigated the effects of time of standing with open and close eyes on the stability parameters during five minute standing to evaluate the hypothesis that Romberg test in five minute is more accurate than just 1 minute. Most patients with neurological and musculoskeletal disorders with balance impairment show stable posture in 1 minute while they cannot control their stability in five minute (11, 12). However, the most of activity daily living such as talking, washing the dishes, waiting for a taxi or standing in a work environment need prolonged period of standing.

Long quiet standing for five minutes was chosen for this study not only to mimic real daily living situation but also to challenge stability in different temporal frame to magnify balance proceeding in normal healthy subjects. Although muscle fatigue is a normal response to prolonged standing but an early, excessive and chronic fatigue is abnormal and is indicator of a neuromuscular disorder (Neumann, 2002).

A previous study in this field showed three COP relocation pattern during long standing (Duarte and Zatsiorsky, 1999). Movement in body segment specially arm, head and trunk, also weight transfer from one leg to another result decrease influence of fatigue and control of stability cause COP movement. But the important matter is the ability of subjects to move from unstable position to stable position (Karimi and Esrafilian). Another study confirmed that using one-minute stability test did not show instability in patients with musculoskeletal disorders (Karimi and Esrafilian., (2013)). Tagi Karimi et al. (2014) reported a theory, during 1 minute standing children with Perthes and subjects with spinal cord injury were more stable than healthy subjects, while in five minutes standing there is not accurate. That study also reported that the most unstable position was in third and fifth minutes (Karimi and Esrafilian). The present study also showed that the most stable position was

in the second and most unstable position was in the fourth and fifth minutes. These results are in accordance with Duarte and Zatsiorskysudy (Duarte and Zatsiorsky, 1999) and support karimi and Esrafilian theory (Karimi and Esrafilian, 2013)). These researchers demonstrated that five minutes stability test is more accurate for balance evaluation in patients with musculoskeletal disorders. Prolonged standing in five minute describes balance details.

The present study also showed that visual inputs play an important role within equilibrium control especially in sum of path and velocity. This study demonstrated that there were significant differences between in all of stability parameters under the eyes open and eyes closed, conditions except for the COP in anteroposterior direction. There are different mechanisms for control of postural stability in M-L and A-P direction. Hip motion strategy by activation in adductor and abductor muscles control M-L stability while ankle motion strategy by dorsiflexor and plantarflexor muscles control A-P stability (Winter et al., 1993). Weight transfer from one leg to another migrate COP more distances during eyes closed than eyes open. This result is shown by evaluation of progressing the data. Decreased postural stability was observed in subjects with vision loss compared with their healthy counterparts (Ray et al., 2008), while this instability is not shown in first 1 minute in most of patients. Traditional method shows no significant differences during eyes open and eyes closed while standing in five minutes confirms a decrease in stability, which may be due to visual input. Prolonged standing test demonstrates instability in these situations.

The present study highlights areas for future clinical research to better understand standing postural control and stability for persons with musculoskeletal and neurological disorders with stability problem. This study was done only in one trial with limited sample size. A study with a larger sample size may help to understand in more details the different frame times without evaluating repeatability of parameters. Comparison stability parameters between normal and amputee subject or people with different disorder is recommended in following studies for evaluation of stability.

CONCLUSIONS

The present study showed the most unstable time in five minute standing is fourth and fifth, that is better

test for description instability details. Romberg test in five minutes is more accurate and sensitive than just 1 minute standing test because close eyes causes instability in minute fifth standing.

Conflict of interest

The authors report no conflicts of interest.

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