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A New Approach to Measure Stability During Quiet Standing

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Abstract. stability during standing is achieved by a complex process which involves the performance of various systems. Using a force plate for analysing the stability for a period of one minute has been used exclusively by many investigators. However nobody analysed the stability during quiet standing for a prolonged standing (5 minutes). The main aim of this research study was to analyse the performance of the subjects regarding stability for a period of 5 minutes.A group of 40 normal subjects from the staff and students of Rehabilitation Faculty of Isfahan University of Medical Sciences were recruited in this research project. They were asked to stand on the force plate (Kistler) for a period of 5 minutes. They were instructed to look straight ahead and with their head erect and their arms at their sides in a comfortable position. The excursions of the COP sway in both planes were measured for all 20 seconds periods of data collection.The results showed that analysing the stability based on the sway of the COP, while the test was collected for one minute, is not a good representative of standing stability. There is a significant difference between the excursions of the COP during the first to fifth minutes. The stability of the subject was optimum in the third and fourth minutes of standing.

Keywords: Prolonged standing, Stability, COP sway

1. Introduction

Stability while standing is achieved by a complex process involving the function of musculoskeletal and neurological systems [1]. Various parameters based on the force plate output have been used to measure the stability during quiet standing and while undertaking various hand tasks [2-5]. The excursion of the Centre of pressure (COP) in the mediolateral and anteroposterior planes, speed of COP change, mean amplitude of COP change, standard deviation of the force applied on the force plate, the area of an ellipse for rejection, hip joint angle and its angular velocity, the magnitude of vertical ground reaction force, critical time interval, mean square critical displacement, sum of maximal direction time, and phase plane parameters have been used to measure the stability [1, 3-11]. In other side, the dynamic stability represents the ability of the subject to remain steady and upright while doing functional tasks [1, 12].

The static stability has been measured by the most of the investigators for one minute while the subject standing on the force plate [1, 4, 12-14]. However, only 20 seconds of the data has been selected for final analysis. It is clear that, in our every day life, we frequently stand for a prolonged period (more than a few minutes) when waiting in a line or standing in a work environment. There are some postural changes when

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the subjects standing for a prolonged time which are responses to avoid discomfort and fatigue [1, 15, 16]. To author' knowledge there is not enough evidence in literature to represent the behaviour of subjects with respect to time. Moreover, the difference between the performances of the subjects while standing for a short time (one minute) and for a long period is not cleared. Therefore the aim of this research study is to find the difference between the stability during quiet standing in a short and prolonged periods. Moreover, it was aimed to find the pattern of stability in both genders when standing for a long time.

2. Method

A Kistler force plate instrumented with piezoelectric force transducer was used to measure the centre of pressure (COP), which is recognized as a good approximation of sway of centre of gravity in a horizontal plane. The parameters which were investigated in this research project were the excursion of the COP sways in the mediolateral and anteroposterior directions.

2.1. Subjects

40 normal subjects were recruited from students and staff members of Rehabilitation Faculty of Isfahan University of Medical sciences. Table 1 shows the characteristics of the subjects participating in this research project. They had no musculoskeletal disorders or neurological illness and degenerative conditions based on the past medical records. An ethical approvalwas obtained from Isfahan University of Medical Sciences Ethical Committee. Every subject was asked to sign consent from before starting the test. All subjects used a dress shoe with heel height between 1 and 2 cm for men and 2 and 3 cm for women (the subjects asked to wear dress shoes as in the most daily prolonged standing the subjects wear shoes). They were asked to stand on the force plate for 5 minutes. They were instructed to look straight ahead to watch a target (a circle with 3 cm diameter), with their head erect and their arm at their sides in a comfortable position. The collected data were filtered with a cut off frequency of 10 Hz.

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

Parameter	Mass (kg)	Height (m)	Age (year)	Number
Male	73.4±12.53	1.77±0.051	21.5±3.54	20
Female	60.96±7.38	1.64±0.036	21.56±1.56	20

2.2. Parameters

The COP sways in both mediolateral and anteroposterior directions were split out into 20 seconds periods and were calculated according to the following equations [3, 6, 9, 17]:

$$\text{Excursion of CoP in AP plane} = \text{Cop}_{\max}^{\text{AP}} - \text{CoP}_{\min}^{\text{AP}} \quad \text{(Eq.1)}$$

$$\text{Excursion of CoP in ML plane} = \text{Cop}_{\max}^{\text{ML}} - \text{CoP}_{\min}^{\text{ML}} \quad \text{(Eq.2)}$$

The first 20 second of the data were deleted to remove the effects of movement of the subjects when are standing on the force plate [13, 18]. The normal distribution of the COP excursions were analysed by use of Shapiro-Wilk test. As the parameters had a normal distribution the parametric test was used for final analysis. The difference between the mean values of COP sways from various time periods was analysed by use of paired t test. The significant point was 0.05.

The most stable position was defined to be located where the COP excursion had a minimum value; it is presented in dark green colour in figures 4 and 5. The difference between the mean values of the COP excursions in other frames was evaluated with that of the most stable position by use of paired t test, with a significant point as 0.05. The unstable positions were determined if the p-value of the difference was less than 0.05 (it is presented in red colours in figures 4 and 5). The stable positions were defined as the places where the p-value of the difference between the mean value of the COP excursion in the most stable position and other frames was more than 0.05 (light green colour).

3. Results

The patterns of the COP sway in both planes for male and female subjects are shown in figures 1 and 2. The mean values of the COP excursion in the anteroposterior direction for all 20 seconds of data collection are shown in table 2. As can be seen the excursions of the COP varied with respect to time. The mean values of the COP excursion in the mediolateral direction with respect to the time for both female and male are shown in table 3.

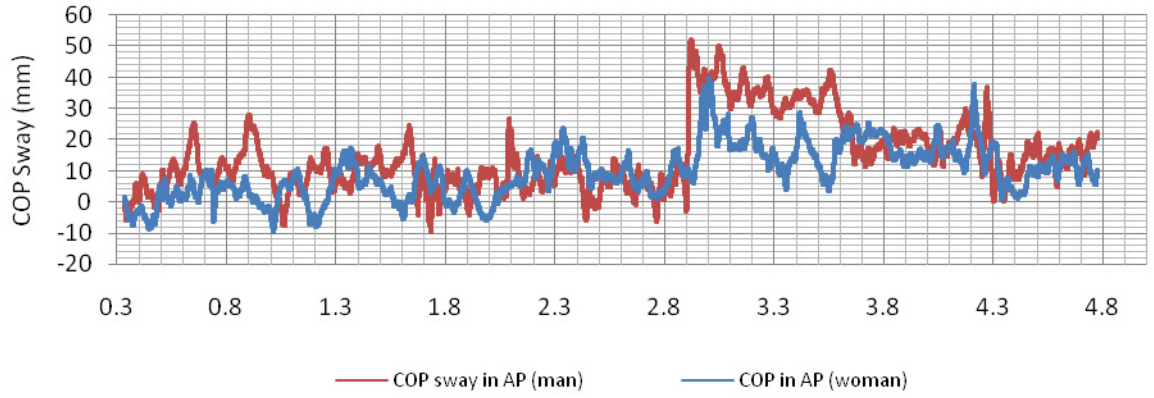

Fig. 1: The COP sways of both genders in the anteroposterior plane

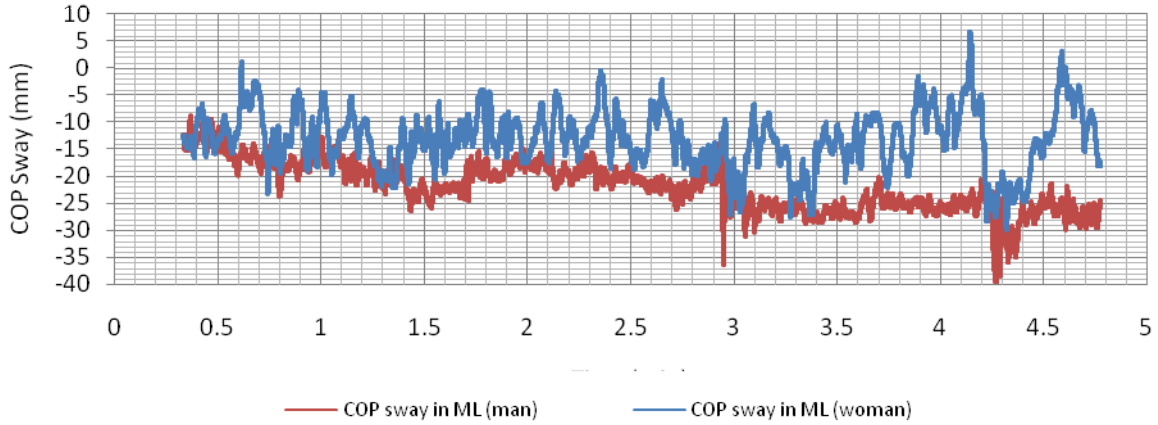

Fig. 2: The COP sways of both genders in the mediolateral plane

Table 2: The mean values of the COP excursions in the anteroposterior direction for both genders

parameters	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Mean value (men)	21.2 ±8.4	23.5 ±11	19.7 ±12	21.3 ±11	23.3 ±15	23.3 ±14	23.7 ±14	18.5 ±10	23.8 ±18	22.5 ±14	22.4 ±13	18.1 ±7.6	18.5 ±8.4	21.2 ±8.4
Mean value (women)	19.8 ±12	20.5 ±11	20.3 ±10	18.4 ±8	17.5 ±4.5	18.3 ±9.7	18.9 ±9.1	19.5 ±9.7	16.1 ±6.7	19.9 ±8.9	17.5 ±7.2	18.8 ±12	18.1 ±9.2	20.46 ±10.8

Table 3: The mean values of the COP excursions in the mediolateral direction for both genders

parameters	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Mean value (men)	14.5 ±7.8	13.6 ±10	13.2 ±12	10.6 ±6.7	15.1 ±12	16.4 ±12	14.9 ±14	13.1 ±8.5	14.3 ±12	13.1 ±8	11.2 ±8.3	11.8 ±8.5	11.2 ±8.9	10.7 ±7.7
Mean value (women)	15.6 ±8.7	13.7 ±7	13.1 ±6.4	13.2 ±6.6	12.9 ±7.3	11.7 ±5.1	16.6 ±13	13.4 ±7.2	12.3 ±5.8	12.9 ±7.2	13.5 ±6.8	13.7 ±9.5	12.6 ±6.8	12.9 ±8.5

The locations of the stable, unstable positions are presented in red and green colours respectively in figures 3 and 4.

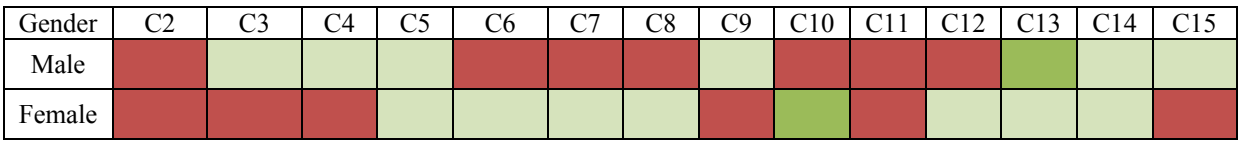

Fig. 3: The COP excursions in the anteroposterior plane, the red blocks represent the unstable position, the light green blocks represent the stable positions and the green block represents the most stable position, C represents the 20 seconds of data

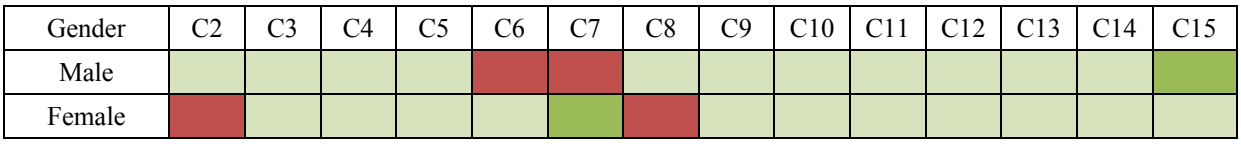

Fig. 4: The COP excursions in the mediolateral plane, the red blocks represent the unstable positions, the light green blocks represent the stable positions and the green block represents the most stable position

4. Discussion

The stability of normal and the subjects with various musculoskeletal disorders was measured during quiet standing by most of investigators. However they have collected the data only for a minute [14, 18-24]. A few researchers have tried to evaluate the stability conditions in patients suffering from low back pain during prolonged standing for half of an hour, which is too time consuming and difficult for most of patients [15, 16]. So it was aimed to evaluate the performance of the subjects while standing for a period of 5 minutes in this research study.

As can be seen from the figures 2 and 3, the pattern of COP sway in both the mediolateral and anteroposterior planes was the same in both genders. It means that in both genders a period or periods of stability (in which the p-value of the difference between COP sway of the most stable position and other positions was more than 0.05) was followed by a period or periods of instability (in which the p-value was less than 0.05). However, the main difference between the genders regarding stability is that men reach to a stable position later than women.

The results of paired t test showed that the stability of the subjects based on the second half of the first minute of data collection (as is used in most research study) is significantly more than that in the third minute (p-value of the difference was 0.04). It can be understood from figure 3 that males are more stable in the anteroposterior plane in the second and fifth minutes of data collection compared to women that are more stable in the third and fourth minutes. Both genders were more stable in the first and fourth minutes. The subjects were more stable in the ML plane than in the AP plane.

The main question posted here is that which frame of the collected data can represent the standing stability? It can be understood from the results of this research study that analysing the stability based on the performance of the subjects in the first minute of the test is not a good indicator of standing stability, as the subjects were more stable afterward. Moreover, it is not too practical to analyse the stability only based on the amplitude of the COP excursion (small excursion represents the more stability), which is happened during the third to fifth minutes of data collection. So another view regarding stability would be the ability of the subjects to return and stay in a more stable position from an unstable position. The number of stable positions to unstable positions could be reported as a new parameter to represent stability during quiet standing. The repeatability of these parameters needs to be analysed in another research study. Moreover it is suggested to check the influence of age, height, weight and sex on the aforementioned parameters. Last but not least, the difference between the stability of the subjects with a musculoskeletal disability can be analysed based on the mentioned parameters which will be a good indicator of the sensitivity of this method.

5. Conclusion

Most of the investigators often look at the performance of the subjects during quiet stance and consider sway characteristics, judging someone with increased sway to have poor balance. This has been done based on traditional method of standing stability analysis which based on collecting the data for one minute. However the results of this research study showed that analysing the stability based on this method is not a

good way to represent stability, as the performance of the subjects during a prolonged standing completely differs from that in the first minute. Some parameters such as the number of stable positions in contrast to unstable positions, and the ability of the subjects to return to a stable position from an unstable position are suggested in this regard.

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