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Disparity of a Seat Cushion and Its Influence on Postural Control

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Properties of supporting surfaces of a seat have an influence on postural control. Centre of pressure (COP) displacement parameters reflect both the balance controlling process and movements of the centre of a mass of entire body. The subjects of the study were 9 healthy men. A seat cushion was examined with a 2-force platform setup. Force exertion at a seat pan and feet and COP displacement at a seat pan were measured to analyse postural control. Analysis of variance determined the differences in postural control depending on a cushion type among the subjects. Significant differences in COP displacement parameters were in COP trajectory length, medio-lateral COP displacement and COP velocity. The results of the study showed that foam cushion ensures better postural control.

cushion foam cotton centre of pressure measurements postural control

1. INTRODUCTION

Office work is performed mostly in a sitting posture. Rules of ergonomics should be applied in an office to ensure safe work environment and to support performance of workers. Tasks, work behaviours and activities of office workers should be considered. An improved sitting comfort is a factor that most seat manufacturers use to distinguish their products from those of their competitors. Identifying proper chair for an individual, especially if it has to be low cost and nonmotorized, is a difficult task for furniture industry.

Deformable work surfaces affect balance negatively and cause fatigue and pain [1]. Differences in comfort and stability have been reported in situations when the subjects sit on surfaces with different firmness and texture [2]. A soft foam mat in comparison with a wooden mat decreases general fatigue, leg fatigue and discomfort ratings [1]. Postural activity is lower when standing on a soft surface, but the activity is sufficient to prevent swelling of legs. Softer materials cause less perceived tiredness but extremely soft floor and hard flooring surfaces result in higher ratings of tiredness [3]. Anterio-posterior and lateral torque variances are

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higher when standing on a firm foam than on a medium and soft foam [4]. Materials used in production of supporting surfaces can influence human postural control and comfort.

Seat discomfort is influenced by both static (e.g., seat stiffness) and dynamic seat characteristics (e.g., vibration magnitude) [5]. Materials used in production of seat cushions can induce users' discomfort [6]. The influence of seat cushions on postural control has been studied in patients in wheelchairs with paraplegia and spinal cord injuries [7], and in healthy patients sitting on automobile seats [8] and agricultural machinery seats [9]. Relative comfort of cushions has been obtained by performing pressure measurements at human–seat interface [10] and pressure sores [11]. The properties of supporting surfaces of seats have an influence on postural control and centre of pressure (COP) displacement parameters [12]. Therefore, designing a more comfortable seat requires evaluation of seat cushion materials which might provide better postural control and less discomfort.

The parameters of COP such as medio-lateral COP displacement (defined as an average position of COP in medio-lateral direction) and anterio-posterior COP displacement (defined as an average position of COP in anterio-posterior direction) are indicators of postural stability [13]. Radius of a stabilogram, derived from the area contained within the closed irregular curve including all recorded COPs [14], provides an indirect estimate of the area, which indicates measurement of postural stability. A range of medio-lateral and anterio-posterior COP excursion, defined as a range of COP displacement, indicates a maximal deviation of COP in any direction, i.e., it makes it possible to estimate overall postural performance [15, 16]. Trajectory length of COP is a sum of COP trace on a platform and it gives qualitative distribution of postural sway [15, 16]. The speed of COP displacement, defined as mean speed of COP displacement, is a sum of displacement scalars, i.e., cumulated distance over sampling period divided by sampling time. It represents amount of activity required to regulate postural sway and provides functional measure of postural control [17]. Force platforms have been used to understand balance control in poststroke individuals while standing [18] and unsupported sitting [19] by analysing the trajectory and oscillations of a COP location. When a sample group has significantly larger COP displacement sway area, maximum displacement or average velocity compared to another sample group, the former is thought to be less stable [19]. Thus, COP displacement parameters can be used to evaluate the relative postural stability depending on different seat cushions.

There are studies suggesting that standing on different materials influences COP displacement parameters and postural control. However, there are no studies on the influence of materials used in production of seat cushions on postural control among healthy subjects while sitting. This study analysed postural control parameters depending on different seat cushions: cotton, foam and wooden. The study's assumption was that the subjects would demonstrate better postural balance and control in a form of directions and magnitude of postural sway while sitting on a relatively comfortable seat cushion.

2. METHODS

2.1. Subjects

The subjects of the study were 9 right-handed, healthy and young men. They did not have any history of motor problems, neurological diseases or vestibular impairment. The subjects were informed about the experimental setup and the procedure before they gave their written consent [20].

2.2. Experiment Setup

A rig test of a simulated seat system was used in the experiment. The setup included two multi-component piezoelectric force platforms sized 40 × 60 cm (Kistler, Switzerland); one placed on the ground served as a footrest (P1), the other placed 42 cm above the ground served as a seat pan (P2). The platforms were vertically adjusted and stabilized with a heavy duty mechanical jacking mechanism (Figures 1–2). Backrest and armrest were excluded from the simulated seat system. This study tested the three square seat cushions: (a) cotton, (b) foam (filled with polyurethane foam and covered with rexine) and (c) wooden. Each cushion was 6.5-cm-high and 40-cm-long to allow every subject to place his feet comfortably on the ground. During each trial, the cushion was placed on the seat. The subjects had to sit quietly with eyes open, arms on their lap and with feet on the force platform. They also had to look at a point marked at a distance of 3 m. The subjects used the seat system for ~10 min only; longer tests could cause fatigue.

2.3. Force Platform Measurement and COP Displacement Parameter

Ground reaction forces reflecting stabilometric dimensions were measured with a piezoelectric force platform. The platform was connected to amplifier control units (Kistler, Switzerland) and a data logger (BTS Bioengineering, Italy). The initial body weight was recorded when the volunteers were standing barefoot on the platform with their eyes open, when sensory inputs (visual, vestibular and somato-sensory) were unaltered for possible postural control. Standing or sitting on the multicomponent piezoelectric force platforms provided dynamic and quasi-static measurements of three forces along three orthogonal axes f_x, f_y and f_z, and three moments around the three axes m_x, m_y and m_z.

The acquisition of platform signals was repeated thrice for 60 s at a sampling frequency of 100 Hz. The stabilometric dimensions, e.g., COP displacement, were derived from the analysis of platform signals using SMART and SWAY software (BTS Bioengineering, Italy). The force platforms were calibrated before experiments. The subjects attended a laboratory in the morning to ensure that the sitting trials were performed in nonfatigue condition. The force platforms connected to the amplifier control units and the data logger provided the ground reaction forces corresponding to the fractions of the body weight transferred to P1 and P2. The force platform signals analysed with SMART measured three orthogonal components of force (f_x, f_y and f_z acting from x, y and z directions) and three moments around the three axes (m_x, m_y and m_z). Analysis of weight of the reaction forces at P1 and P2 provided an extent of the body load transferred to the seat pan and the feet.

The weighted force distributions when a person was standing or sitting on the platform were derived as a square root of a sum of squares of the three forces at x, y and z. The weight of f_y represented 98% of the total weight distribution. The platform signals from P2 were further analysed with SWAY. Medio-lateral and anterio-posterior directions of COP displacement were also calculated [15, 16].

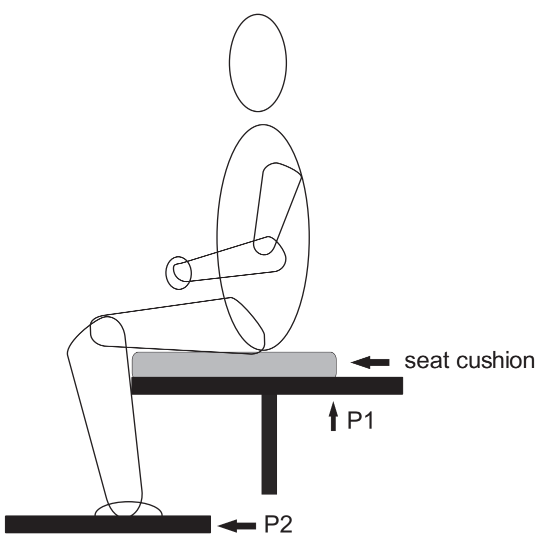

Figure 1. Experimental setup. *Notes.* P1 = footrest, P2 = seat pan.

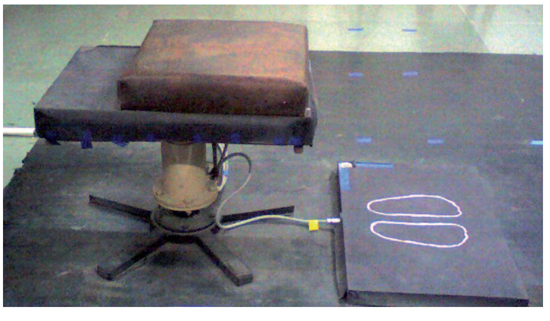

Figure 2. Schematic diagram of subject sitting on experimental setup.

2.4. Statistical Analysis

SPSS version 15 was used for data analysis. Levene's test for homogeneity of variance was used to understand variations in COP displacement with respect to the time and postural modes. The study used the null hypothesis. To reveal the influence of postures on COP parameters, one-way (sitting modes) repeated measures analysis of variance (ANOVA) was used with time blocks as a covariate. The least significant difference test was applied to obtain post hoc multiple comparisons of the test measures, with respect to variations in the seat cushions.

3. RESULTS

The subjects of the study were male, their mean (*SD*) age was 28.8 (4.4) years. Their mean (*SD*) body height and standing body weight were 155.3 (5.3) cm and 59.3 (7.4) kg, respectively. The subjects' mean (*SD*) body mass index was 21.7 (3.2) and lower leg length was 52.4 (2.8) cm.

In the simulated sitting system, upper body and part of upper leg were supported by the force platform, which served as a seat pan, and lower leg and part of upper leg were supported by the floor surface. Table 1 presents the relative values of the force distribution at a seat pan and feet for the different seat cushions. Pressure beneath sitting bones reflects comfort factor; the bottoming feeling due to the cushion hardness [5]. The subjects exhibited relatively less force exertion at the seat pan and the feet while sitting on the cotton cushion than while sitting on the wooden or the foam cushion.

Different COP displacement parameters such as medio-lateral COP displacement, COP trajectory length, speed of COP displacement, deviation of medio-lateral COP displacement and deviation of speed (millimeters/second) showed significant variance with respect to the different cushion surfaces (Table 2, Figures 3 a–c).

Table 3 presents pair wise comparison of the influence of the different types of cushion materials on COP displacement parameters at the seat pan. The subjects sitting on the foam cushion showed higher medio-lateral COP displacement than when sitting on the cotton cushion ($p < .05$) or the wooden cushion ($p < .001$) (Figure 3 a). Speed of COP displacement ($p < .001$), COP trajectory length ($p < .001$), speed deviation ($p < .001$) and deviation of medio-lateral COP ($p < .05$) were higher when the subject was sitting on the foam

TABLE 1. Force Distribution at Seat Pan and Footrest

		P1		P2	
Condition	**Cushion Type**	***M***	***SD***	***M***	***SD***
1	cotton	11.8	1.6	46.0	7.3
2	foam	11.5	2.2	46.7	6.7
3	wooden	12.4	1.7	46.6	7.9

Notes. P1 = seat pan, P2 = footrest.

TABLE 2. Centre of Pressure (COP) Displacement Parameters at Seat Pan

	Cushion Type ($M \pm SD$)			
Parameter	**Cotton**	**Foam**	**Wooden**	f^a
Anterio-posterior COP displacement (mm)	191.3 ± 27.3	192.8 ± 28.4	196.1 ± 33.2	0.2
Radius (mm)	1.1 ± 0.8	1.2 ± 0.8	1.0 ± 0.5	0.3
Medio-lateral COP range (mm)	4.4 ± 2.0	4.7 ± 3.9	4.5 ± 2.4	0.3
Anterio-posterior COP range (mm)	6.4 ± 6.1	6.0 ± 5.2	5.3 ± 3.5	0.1
Medio-lateral COP displacement deviation (mm)	0.7 ± 0.4	0.8 ± 0.6	0.7 ± 0.3	2.9*
Anterio-posterior COP displacement deviation (mm)	1.1 ± 1.1	1.0 ± 0.9	0.9 ± 0.7	0.002
Radius deviation (mm)	0.7 ± 0.7	0.7 ± 0.7	0.6 ± 0.5	0.004
Speed deviation (mm/s)	12.6 ± 2.1	12.1 ± 2.1	12.8 ± 2.0	9.1**

Notes. * $p < .01$, ** $p < .001$; a = ANOVA.

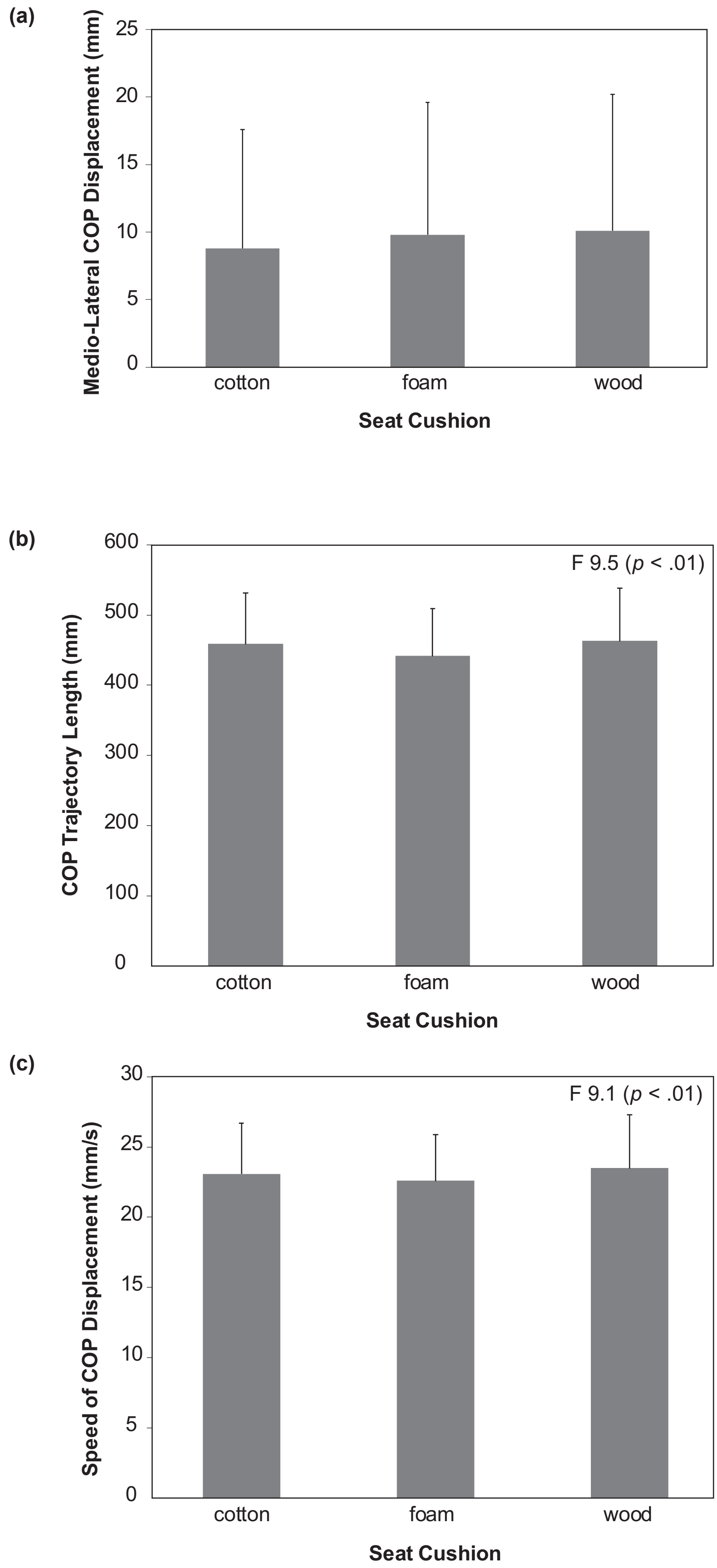

Figure 3. Centre of pressure (COP) displacement of subjects sitting on different surfaces: (a) medio-lateral COP displacement, (b) trajectory length and (c) speed of COP displacement.
Notes: Error bars denote *SD*.

TABLE 3. Multiple Comparisons of Analysis of Variance (ANOVA) With Different Sitting Cushions and Centre of Preassure (COP) Parameters at Seat Pan

Condition	Condition	Medio-Lateral COP	Trajectory Length of COP Displacement	Speed of COP Displacement	Deviation of Medio-Lateral COP Displacement	Speed Deviation
1	2	*	***	***	*	***
	3	*ns*	*ns*	*ns*	*ns*	*ns*
2	3	***	***	***	**	***

Notes. * $p < .05$; ** $p < .01$; *** $p < .001$.

cushion than on a cotton cushion. COP trajectory length, speed of COP displacement, speed deviation ($p < .001$) and deviation of medio-lateral COP ($p < .01$) were higher when the subject was sitting on the wooden cushion than on the foam cushion.

4. DISCUSSION

Sitting dynamics depends on personal modes, sitting circumstances and a type of seating system [21]. Studies on postural stability emphasize the significance of optimization of the combination of sitting modes, comfort, ergo-design and aesthetic features of a seat [22, 23]. Studies on sitting and seat systems focus on anthropometric, biomechanical and electromyographic analyses [24], and on comfort rating [25]. However, stabilometric analysis of seat dynamics is scanty [26, 27, 28].

Properties of a cushion have an influence on perceived feeling of subjects and their discomfort [29]. The contact surface area and changes in the human–seat interface serve as an effective indicator in measuring static seating discomfort [9, 30]. Relative variations in seat cushion materials can influence fatigue and discomfort of subjects [3]. There is a need to evaluate seat cushion materials and identify a material which might provide subjects with a relatively improved posture, balance and less discomfort [31].

Maintaining straight sitting postures involve visual, vestibular, proprioceptive and auditory systems. Significant shifts in COP displacement occur when subjects become fatigued and exhibit poor postural control [17]. Subjects sway more in fatigue condition than in nonfatigue; this is caused by an increase in COP range, mean speed and dispersion of COP displacements with fatigue [15, 16]. COP measurements underline significance of measuring postural imbalance which results from interaction between somatosensory, vestibular and visual inputs [32]. Thus, stabilometric dimensions can be useful to evaluate sitting and seat components [26, 33].

An increase in COP measures, e.g., COP trajectory length and speed, reflects postural imbalance [34]. Increase in sway velocity is correlated with the risk of falling in multitask test conditions (during the balance task, the subject is given an additional task such as a mathematical problem to resolve). In the present study, COP trajectory length and speed were significantly lower when the subjects were sitting on the foam cushion than on the wooden or the cotton cushion. The postural control was relatively better when the subjects were sitting on the foam cushion.

An increase in medio-lateral COP displacement is an indicator of higher postural sway and fatigue while standing [35]. Søndergaard, Olesen and Søndergaard performed correlation analysis to determine correlation between COP parameter and discomfort while sitting [36]. They could not find any correlations between discomfort and mean values of medio-latreal and anterio-posterior COP displacement parameters. According to Vuillerme, Forestier and Nougier's study, there is no relationship between fatigue and increase in medio-lateral COP displacement while sitting. In the present study, when the subjects were sitting on the foam cushion there was a significant increase in medio-lateral COP. An increase in medio-lateral COP displacement while sitting cannot suggest postural imbalance and discomfort while sitting. Thus, an increase in mean medio-lateral COP displacement cannot be an indicator of postural imbalance and discomfort while sitting on a foam cushion. According to

Chung and Lee, anterio-posterior COP displacement is a sensitive parameter used to differentiate the postural balance and relatively higher anterio-posterior COP displacement is an indicator of postural imbalance [37]. In the present study, there are no statistically significant variations in anterio-posterior COP displacements with reference to different seat cushions. Anterio-posterior COP displacement was relatively higher for the subjects sitting on a wooden cushion, although it is not statistically significant.

The deviation in the direction of COP displacement is an indicator of variability of COP from its centre indicating the overall postural performance [38]. Madeline, Voigt and Arendt-Nielsen studied unconstrained standing for 105 min. They reported an increase in the variability of COP displacement when the subjects were standing on a hard surface; in comparison to standing on an antifatigue mat [39]. Zhang, Drury and Wooley did not find any difference in COP deviation during unconstrained standing on a hard or soft surface with soft sole shoes [40]; these findings are congruent with the findings of the present study.

The range of COP displacements indicated maximal excursion of COP in any direction. It is a global measure that makes it possible to estimate the overall postural performance, i.e., stability. Laughton, Salvin, Katdare et al. reported significantly higher anterio-posterior COP range in elderly fallers in comparison with elderly nonfallers and young subjects [41]. In the present study, there were no statistically significant differences in medio-lateral or anterio-posterior COP ranges for the three different cushions. Sway radius represents the overall neuromuscular function of spinal muscles for the performance of muscular system due to the average postural stability. Radius of COP displacement did not show statistically significant difference among the three studied cushions.

The occurrence of postural changes measured by the range, radius and anterio-posterior COP displacements was remarkably invariant with respect to the tested seat cushions. Differences in the seat cushions influenced COP dimensions such as COP trajectory length and speed of COP displacement; they showed an increase in deviation when the subjects were sitting on the wooden cushion. This study suggests higher postural stability of subjects on cotton and foam cushions.

4.1. Limitations

Only one force plate at the seat pan was used during this study. The use of two force plates, at the seat pan and at the feet, could help to record changes in postural control measurements in relation to the feet. The force platform measurements were quick and performed during breaks between tasks. However, further study might demonstrate variations for different tasks and longer recordings. A further evaluation of postural control of subjects sitting on different cushions and performing tasks could aid to explore the underlying mechanisms of postural control. The present study did not directly identify how any specific physiological mechanism, e.g., visual versus vestibular, helps to regulate postural control. A comparative evaluation with respect to gender, BMI and age could provide more information on postural control.

5. CONCLUSION

Subjects make subtle postural orientation and adjustments depending on the circumstances of sitting and a seat type. Analysis of sitting dynamics focuses on significance of assessing characteristics of a design of a seat system and its consequences to subjects. This study demonstrated that materials used for seat cushions influence postural stability. Variations of the cushion materials significantly influenced medio-lateral COP displacement, COP trajectory length, speed of COP displacement, deviation of medio-lateral COP and speed deviation. The findings of this study showed that a seat cushion has an influence on postural balance and control.

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