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Characterization of the dynamics of sitting during a sustained and mentally demanding computer task

Pascal Madeleine*[1][0000-0002-2164-234X], Ramtin Zargari Marandi[1,2][0000-0001-9233-1656], Kristoffer Larsen Norheim[1,3][0000-0001-9727-4646], Nicolas Vuillerme[1,2][0000-0002-5202-4173] and Afshin Samani[1][0000-0001-6119-8231]

[1] Sports Sciences, Department of Health Science and Technology, Faculty of Medicine, Aalborg University, Aalborg, Denmark
[2] University Grenoble-Alpes, AGEIS, Grenoble, France
[3] Clinic of Occupational Medicine, Aalborg University Hospital, Aalborg, Denmark
*pm@hst.aau.dk

Abstract. This laboratory study studied the dynamics of sitting during a sustained and mentally demanding computer task. Mental fatigue ratings, overall performance and kinetic were recorded in 20 asymptomatic computer users performing computer work for 40 minutes divided in 12 time epochs. The displacement of the center of pressure (COP) in anterior-posterior (AP) and medial-lateral (ML) directions was calculated. The average, standard deviation, and sample entropy values were computed from the COP time series to assess respectively, the magnitude, size and complexity of sitting dynamics. Fatigue ratings significantly increased from before to after the computer task while the overall performance did not change significantly over time. Likewise, the direction of displacement of the COP did not affect significantly the AVG but resulted in larger SD and SaEn values in the ML direction compared with AP direction. Time did not play a significant role on any of the outcome measures. The present study demonstrated that the sitting dynamics can be assessed in an ecological environment, e.g. in office chairs. Further, we found that 40 minutes seated computer work did not changed the dynamics of sitting. On the contrary, we observed increased size and structure of variability in the ML than the AP direction. This latter finding can be used to design office chairs or interventions aiming at preventing discomfort due to long time sitting.

Keywords: Nonlinear Dynamics, Sitting Control, Variability

1 Introduction

Sedentary behavior and sitting are interlinked to such an extent that sitting is now considered as the new smoking of our generation! [1]. This may sound particularly peculiar but sitting at a desk every day can actually lead to musculoskeletal disorders, heart disease, type-2 diabetes, and, cancer [2-5]. For instance, sitting for >6 hours compared with <3 hours results in a 40% higher all-cause death rate [5].

The latest European working conditions survey has recently underlined the following health problems: backache (reported by 43%), neck or upper limbs pain (42%), headache/eyestrain, and overall fatigue (both 35%), muscular pains in the hip or lower limbs (29%) [6]. Interestingly, these problems can all be linked to computer work performed seated or standing, e.g. [7]. Moreover, prolonged seating results in discomfort as well as changes in the biomechanics of seated posture [8]. Actually, discomfort and fatigue have also been suggested as a predictor of work-related musculoskeletal disorders and pain [9].

The relationship between seat pressure and discomfort has been underlined at several occasions [10;11] Discomfort is reported to increase if the pressure between the front of the seat and the portion of the thigh above the knees is higher or lower than 6% of the total weight on the seat [12]. Especially, the changes in size and structure of variability of the seated posture appear to be related to the increase in discomfort [8]. However, our knowledge of the dynamics of sitting posture during computer in ecological conditions is still limited [13;14].

The aim of this study was to characterize the dynamics of sitting during a sustained and mentally demanding computer task. We hypothesized that the size of variability will increased while its structure will decrease during a prolonged computer task.

2 Methods

2.1 Subjects

Twenty asymptomatic young computer users (nine females, 11 males) participated in the study. The volunteers were 23±3 years, 1.74±0.08, and weighted 71±11 kg. All computer users were right-handed and had normal or corrected-to-normal vision. The volunteers signed an informed consent prior to entering the study. The study was approved by The North Denmark Region Committee on Health Research Ethics (N-20160023) and conducted in accordance with the Declaration of Helsinki.

2.2 Computer Task

The computer task was performed for 40 minutes divided in 12 times 20 cycles. MATLAB R2015b (The Mathworks, Natick, MA, USA) was used to implement a graphical user interface displayed on a 19-in screen located approx. 57 cm in front of the computer user. The computer task was designed to be mentally demanding and consisted of a sequence of cyclic computer operations including memorization, wash-out and replication [15]. The pattern to be memorized and duplicated consisted of five randomly-positioned points (e.g., circle, square, and triangle) connected to each other by lines. A distracting point appearing on the replication panel was used to rend that task more challenging. After five seconds, a new cycle with a different pattern appeared. The intensity of mental fatigue was assessed before and after the task completion. The overall performance was computed based on the number of correct and incorrect clicks as well as speed [15]. The overall performance was averaged for each 20 consecutive cycles.

Fig. 1. Illustration of the designed instrumented office chair enabling the recording of sitting postural control characteristics.

2.3 Instrumented Office Chair

A force and torque 3D transducer (AMTI MC5, Watertown, MA, USA) was mounted on an office chair specially adapted for the purpose of recording sitting postural control. The chair ensured the possibility to maintain an upright sitting posture and a natural curvature of the lower back (Fig. 1). The adjustment of seat height, seat depth, arm rest, back height, backward tilt tension and lockable tilt are some of the chair features. In the present study, the settings were kept similar for all participants. Special care was put on the positioning of the instrumented chair with respect to the computer screen and table, i.e., the frontal plane was parallel to the computer screen. Foot rest was provided in a way that kinetic recordings were not affected.

The recorded force and moments data were low pass filtered ($F_{cut\text{-}off}$: 6 Hz, Butterworth order 4). Then, the displacement of the center of pressure (COP) in anterior-posterior (AP) and medial-lateral (ML) directions was calculated based on the recorded moments in the AP and ML direction and force measured in the vertical direction. The average displacement (AVG), standard deviation (SD) and sample entropy (SaEn) values were extracted from the COP signals in the AP and ML directions. The SD was extracted to delineate changes in the absolute size of variability while the SaEn represent changes in the complexity of the sitting dynamics [8;13]. The embedding dimension was set to 2 and the tolerance distance to 20% of the SD of the COP displacement in agreement with previous studies [8;13]. SaEn is a unit less, non-negative number describing the structural complexity of time series [16]. The mean AVG, SD and SaEn values were extracted over 20 consecutive cycles.

2.4 Statistics

A one way repeated measure of analysis of variance (RM-ANOVA) was used to address changes in fatigue and overall performance over time. A two way RM-ANOVA was applied to the AVG, SD and SaEn of the COP with direction (AP, ML) and time (1-12 epochs) as independent factors. In case of significant main effect or interaction, the Hom-Sidak test was used for pairwise multiple comparisons. Mean +/- SD are reported. The statistical significance was set to $p < .05$.

3 Results

3.1 Fatigue and Performance Metrics

The level of mental fatigue ratings increased significantly from before to after the completion of the task ($F(1,19) = 76.87$; $p < .001$). The level of overall performance tended to increase over time ($F(1,11) = 1.81$; $p = .054$).

3.2 Dynamics of Sitting

There were no significant effects of direction ($F(1,19) = .34$; $p = .569$) or time ($F(1,11) = .42$; $p = .945$) and no significant direction × time interaction ($F(11,209) = 1.39$; $p = .180$) for the AVG of the COP (Fig. 2).

There was a significant effect of direction ($F(1,19) = 56.64$; $p < .001$) but not of time ($F(1,11) = .77$; $p = .670$) for the SD of the COP. SD was larger in the ML direction than in the AP direction ($p < .001$). There was no significant direction × time interaction ($F(11,209) = 1.33$; $p = .209$) for the SD of the COP (Fig. 3).

Similar to SD, there was a significant effect of direction ($F(1,19) = 8.21$; $p < .001$) but not of time ($F(1,11) = .48$; $p = .915$) for the SaEn of the COP. SaEn was larger in the ML direction than in the AP direction ($p = .010$). There was no significant direction × time interaction ($F(11,209) = .42$; $p = .947$) for the SaEn of the COP (Fig. 2).

4 Discussion

The present study showed that the designed computer task elicited fatigue among young asymptomatic adults. The overall performance level and the dynamics of sitting did not significantly change over time. Contrary to our hypothesis, the size of variability and the complexity of sitting dynamics did not change over time. On the other hand, we found larger size of variability and complexity of the COP time series in the ML direction compared with the AP direction. This finding provides novel and important information for chair designs or ergonomic interventions aiming at preventing discomfort due to long time sitting.

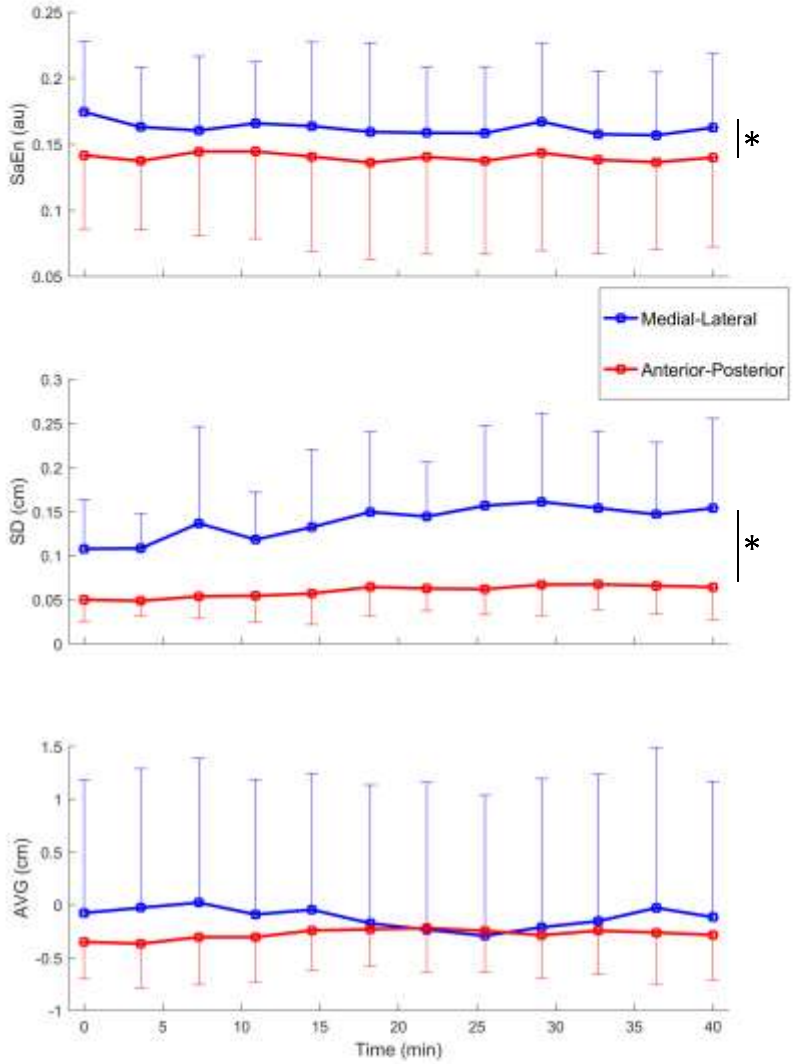

Fig. 2. Mean +/- SD of the average displacement (AVG), standard deviation (SD) and sample entropy ((AP)SaEn) values of the center of pressure in the medial-lateral (blue) and anterior-posterior (red) direction. * indicates $P \leq .01$.

The changes in the level of mental fatigue confirmed that the designed computer was mentally demanding even if no changes in performances (tendency towards increased performance) were seen contrary to our recent study [15]. The inherent component of the computer task consisted of memorization, washout and replication. Contrary to a previous version of simulated mouse work e.g. [17], the patterns to be reproduced were selected from an inventory of randomly generated patterns. In the present case, the points were arranged in such a way that the length of the connecting lines was limited within four to eight degrees of visual angle and the pattern was displayed around the center of the panel to avoid additional postural adjustments [15]. Further, the number of points to be connected was set to five plus one distraction point. The setting corresponded to a medium load [15], and the overall performance was higher than the results we have recently reported during short duration task in asymptomatic young participants. This can mostly be explained by a learning effect (trend towards improved overall performance) towards the computer task to be performed.

Sedentary behavior and sitting constitute a real societal challenge. Some of the deleterious effects of sitting cannot be reversed through healthier habits like e.g., training [4]. Thus, it is important to promote changes in sitting postures and combat sedentary behaviors [18]. However, our knowledge of sitting dynamics is still very limited [13;14]. In this study, we have characterized the dynamics of sitting during a sustained and mentally demanding computer task. For that purpose, an instrumented chair was designed and built using a commercial office chair. The chair features were maintained to enable realistic seating conditions. In contradiction to our hypothesis based on [8;13], the size of variability did not increased during the prolonged computer task. Likewise, the complexity did not decrease. Interestingly, the size of variability and the complexity of the COP time series were larger in the ML direction compared with the AP direction. This is contrary to what is generally observed during standing confirming that the attentional demands influence postural strategies [14]. The sitting dynamics were also characterized by similar average displacement in the ML and AP direction. The reported differences in the size and structure of variability open for new perspectives for office chairs design. Future office chair could promote more variability in the ML direction than in the AP direction as this may help in preventing discomfort and improving health [19].

In summary, the dynamics of sitting did not changed during prolonged seated computer work. The present study showed for the first time increased size and structure of variability in the ML than the AP direction. This aspect of sitting dynamics should be taken in consideration when designing office chairs or workplace interventions.

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