Cognitive and biomechanical effects of postural changes in office environments

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Abstract: The aim of the study is to investigate the physical and mental effects caused by postural changes between sitting and standing in office environments. Cognitive function, movement pattern, salivary cortisol level, cardiac rhythm, physical activity and workload were measured in laboratory conditions. Up to now, 18 office workers (36.7 ± 10.0 yrs.) have undergone a measuring routine in alternating (sitting and standing) postures twice. Until the end of the study each subject will take part in 4 measurement days. In order to investigate long-term effects, subjects have been provided with traditional or active workspaces (Sit-to-Stand workstations) in either the first or the second half of the study. To investigate short term effects, 38 out of 45 students (22.2 ± 1.9 yrs.) completed the aforementioned measurement setup twice in either sitting or alternating postures at a 1-week interval. Preliminary long-term-study and short-term-study results show significant changes in self-reported sedentary time ($p=0.018$) and performance perception ($p=0.003$, $\eta^2=0.283$). Additional findings will be analyzed after completion of both studies.

Keywords: Sedentary work, office environment, postural changes, height-adjustable desks, mental fatigue, cardiovascular health

1. Introduction

The continuous increase in sedentary work over the last years, especially in countries with higher degrees of computerization and industrialization (Ng & Popkin 2012), resulted in a higher risk of hypertension, overweight, obesity and diabetes (Owen et al. 2009, Proper et al. 2007).

There are many efforts to stop this progress, reaching from small worksite interventions for physical activity, e.g. taking the steps instead of the elevator, to the implementation of dynamic workstations like recumbent bicycle or treadmill desks (Rovniak et al. 2014, Gilson et al. 2009). Some researchers show decreasing cognitive performance when using dynamic workstations caused by an increased load on mental processing and motor control triggered by the additional body movements (Commissaris et al. 2014, John et al. 2009). A promising possibility how to avoid this loss of performance is the implementation of height-adjustable desks. As there are no additional simultaneous body movements, cognitive skills should not be affected.

In comparison to many other studies which have already investigated the effects of either prolonged sitting or standing (Claus et al. 2008; Leivseth & Drerup 1997, Rohlmann et al. 1999, Bennett et al. 1989) also by means of height-adjustable desks we decided to focus on the physiological and cognitive effects caused by postural changes between sitting and standing. Therefore we started two different studies focusing on long-term and short-term effects. With regard to short-term-study (STS) results we hypothesize, that postural changes:

(1) do not effect short-term performance on computer tasks;
(2) increase performance perception.

With regard to long-term-study (LTS) results we hypothesize, that postural change

increase short-term performance on computer tasks;
(1) increase performance perception;
(2) decrease occupational sedentary time;
(3) increase cardio vascular parameters;
(4) reduce salivary cortisol level.

2. Methods

2.1 Subjects

Thirty-eight (18 male, 20 female) healthy Caucasian participants (age 22.2 ± 1.9 years, weight 67.5 ± 10.0 kg, height 173.2 ± 9.8 cm, body mass index (BMI) 22.3 ± 1.9 kg/m^2, mean ± SD) and eighteen (nine male, nine female) healthy Caucasian participants (age 36.7 ± 10.0 years, weight 73 ± 11.4 kg, height 177 ± 11 cm, BMI 23.1 ± 1.8 kg/m^2, mean ± SD) without former experience in laboratory experiments participated in the short-term and long-term-study, respectively. All participants had a high school diploma and gave informed consent. The local ethical committee approved the study.

2.2 Experimental Design

For both studies a randomized repeated measures design was used. Additionally, an independent control group was added. Baseline adaptive randomization was used for group assignments. To avoid inequality between groups STS and LTS subjects were split by sex and company, respectively.

2.3 Workstation and Conditions

All measurements were carried out in the same room under laboratory conditions. The experimental setup consisted out of 2 height-adjustable desks (Aluforce pro 100 HC, Actiforce Europe GmbH) equipped with standard 24 inch height-adjustable computer screens (Dell Professional U2412M, Dell Inc.), keyboards and wired mice (Dell products). The left desk adjusted for sitting was additionally equipped with an ergonomic office chair (Kastel Kolor, Kastel s.r.l.). Both desks were placed next to each other in the middle of the room. Light conditions, room temperature, humidity, air flow and noise level were the same for every workstation and measuring day. For the intervention period of the LTS, subjects have been provided with the aforementioned height-adjustable desks in either the first or the second half of the study to allow them to change postures for a longer time period. Moreover, a logging tool was developed to measure daily sedentary time and postural changes.

2.4 Procedures

The complete protocol, including preparatory activities, rest breaks and filling out questionnaires, took 4 - 4.5 hours and was always started in the afternoon between 1:30 p.m. and 3:00 pm. Participants were asked to refrain from high-intensity physical activity, alcohol and recreational drugs on the test day and the day before. On the test day itself, they were asked to avoid caffeine-containing beverages and stressful situations. First, the IPAQ-questionnaire was carried out to investigate physical activity and sedentary time. Second, electrodes were placed on the subjects and standardized test instructions were given. In order to get information about the cardiovascular baseline parameters, participants watched different documentary films in sitting position for 30 minutes. After that, participants started the test battery. Next, a NASA-TLX questionnaire was used to determine workload perception. Finally, the subjects underwent another 30 minute break while watching a documentary film. To avoid differences in test explanations and questionnaires all measurements were supervised by the same study leader.

2.5 Test Battery

The test battery contained five similar test blocks. Each block consisted of one text editing task, one Stroop-test and one “d2R-test of attention” followed by a five minute break and was repeated five times. In the STS these blocks were executed in either alternating postures (sitting – standing – sitting – standing - sitting) or sitting postures. In the LTS these blocks were realized in alternating postures only. The order of tasks within the block remained constant. The duration of each block was approximately 25 minutes. To simulate typical office work a text editing task was realized. In this task the subjects were encouraged to fill in spaces in an ergonomic guideline text where all spaces were missing for 10 minutes. After this participants had to complete two psychological tests to assess selective attention, processing speed and cognitive function. The digital Stroop-Color-Word-Conflict Test containing congruent, incongruent and neutral tasks was used to measure selective attention and processing speed (Mead et al 2001). In each Stroop-test 190 tasks had to be answered correctly. This took approximately 10 minutes. The “d2R-test of attention” was used to determine concentration performance. Both tests are characterized by a high test-retest reliability ($r = 0.77 - 0.95$) and do not require any specific previous knowledge except of rudimentary language skills (Brickenkamp et al. 2010, Franzen et al. 1987).

2.6 Physiological Parameters

Heart rate variability (HRV) and salivary cortisol level were used to determine the physiological state of the participants. HRV was used to determine correlations between HRV and cognitive parameters which have been rarely shown in the past (Hansen et al. 2003, Johnson et al. 2012). The salivary cortisol was used to quantify long-term-effects on the level of stress caused by postural changes. In order to detect the „cortisol awakening response“ (CAR), cortisol measurements were carried out on the measuring day as well as 20 minutes after waking up on the following day.

2.7 Questionnaires

Self-report questionnaires were used to quantify physical activity behavior and workload perception. The long version of the International Physical Activity Questionnaire (IPAQ) was used to measure physical activity and sedentary time (Hagströmer et al. 2005). Since the "usual week" and the "last 7 days" reference periods performed similarly (Craig et al. 2003) we decided to ask subjects about their last week before measurement. To avoid missing IPAQ values the questions were posed by the study leader. To determine the workload perception the NASA-TLX questionnaire was used (Hart & Staveland 1988). For simplicity and clarity reasons we used the Raw TLX (RTLX) only. It performs similarly to the full version but does not contain any weighting factors (Hart 2006).

2.8 Statistical Analysis

Statistical analyses were conducted using SPSS version 21 for windows (SPSS, Chicago, IL). Standard statistical methods were used for calculations for means and standard deviations. ANOVA with repeated measures was used to test whether the different conditions had any effects on the outcome parameters assessed. When appropriate, post-hoc analyses were conducted using the Tukey test. The effects of time, group and interaction between both effects were evaluated for sedentary time, reaction time, concentration performance and performance perception. In addition, paired t-tests were used to show differences between the two test sessions when the normality condition was satisfied. To test for normality, a Shapiro-Wilk test was used.

3. Results

3.1 Reaction time and concentration performance

There are differences in concentration performance ($p=0.000$, $\eta^2=0.886$) and reaction time ($p=0.006$, $\eta^2=0.195$) regarding time for STS subjects, without any effect regarding group ($p>0.05$). Furthermore, paired tests showed influence of time on reaction time values for one group (IVG 2) only.

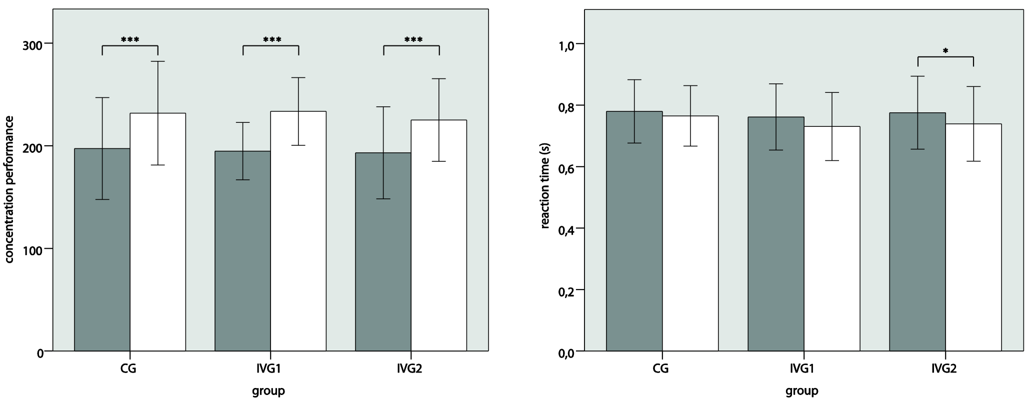

Figure 1: *Concentration performance (left) and reaction time (right) for STS subjects for the first (grey bars) and second (white bars) day of measurement for control group (CG, sitting only), intervention group 1 (IVG1, alternating postures on day 1) and intervention group 2 (IVG 2, alternating postures on day 2) *p < 0.05 ***p < 0.001*

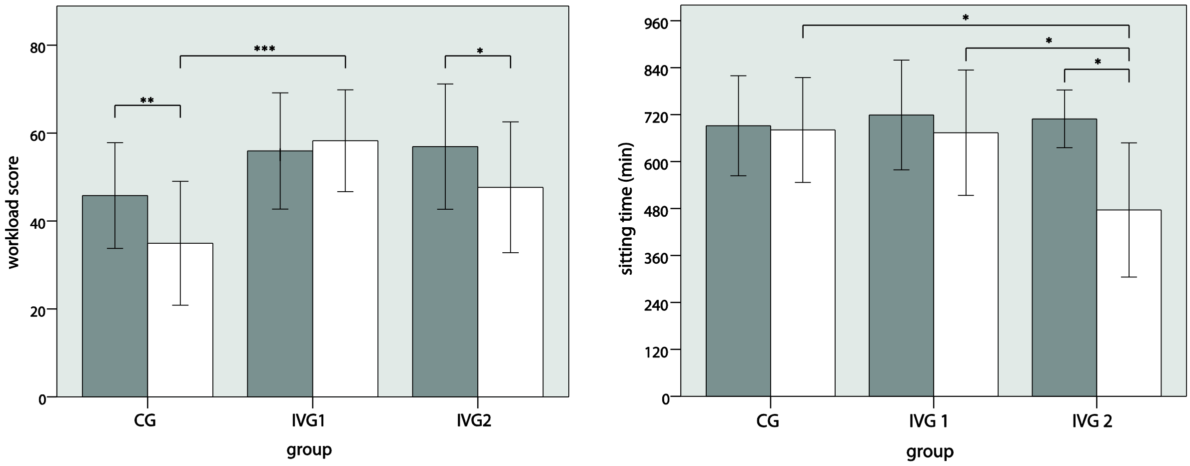

***Figure 2**: Workload perception for STS subjects (left, n=38) and daily sitting time for LTS subjects (right, n=18) for the first (grey bars) and second (white bars) day of measurement for three different groups (CG, IVG1, IVG2). *p < 0.05 **p < 0.01 ***p < 0.001*

3.2 Sitting time and workload perception

There are differences in workload perception regarding time ($p=0.006$, $\eta^2=0.197$), group ($p=0.003$, $\eta^2=0.283$) and the combination of both ($p=0.022$, $\eta^2=0.196$) for STS subjects. For LTS subjects differences were found in working day sitting time regarding time ($p=0.016$, $\eta^2=0.331$) and the combination of time and group ($p=0.025$, $\eta^2=0.388$), without any effect regarding group only ($p>0.05$). This effect occurs only for subjects equipped with novel workspaces (LTS - IVG2).

4. Discussion

The present study evaluated physiological and cognitive parameters of subjects working in either sitting or alternating working postures for a shorter and longer period, respectively. Preliminary results show significant changes in self-reported sedentary time for people using two height-adjustable desks at their daily workspace. Since this effect is much stronger than illustrated in previous studies (Neuhaus et al. 2014) we believe that using two small height-adjustable desks can be used to reduce daily sedentary time more efficiently. Furthermore, there was no influence on cognitive tasks for subjects with alternating working postures. These results are consistent with findings of Commissaris et al. 2014 who found no influence for subjects working in standing postures. Another effect described by Commissaris et al. 2014, the influence on workload perception for subjects using active or dynamic workstations, was confirmed in the present study. Subjects who alternated posture on the first test day estimated higher workload scores on the second day. We believe that returning to a standard “old” working environment after having worked in a novel one demotivates people and therefore results in a higher workload perception.

5. Literature

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