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Leg and back muscle activity, heart rate, performance and comfort during sitting, standing, and using a sit-stand-support with different seat angles

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ABSTRACT

Long-lasting sitting and standing is related to several health risks and alternatives to these positions are needed. This study compared muscle activity, heart rate, performance, and comfort between sitting, standing, and using a stable sit-stand-support with four different seat angles. Twenty-one subjects fulfilled three tasks (typing, a tweezing task and a task simulating ironing) in every position for five minutes. The heart rate was higher using a sit-stand-support and standing compared to sitting. The activity of the m. erector spinae was similar or lower using a sit-stand-support compared to sitting or standing. The activity of the m. gastrocnemius was in between the levels of sitting or standing. No significant differences were observed for the performance. The sit-stand-support most often was preferred to sitting. A stable sit-stand-support may be a solution for short interruptions of sitting or standing.

Relevance to industry: A stable sit-stand-support may be an option for short interruptions of sitting and standing and may reduce the consequences of these static positions.

1. Introduction

At many work places during the whole day, the employees are required to remain in a standing or a sitting position. Graf et al. (2015) showed that in 2010 in Europe 46% of all employees stand for more than three quarter of their working time. A study from Canada reported that 61% of men and 48% of women usually stand at work and 39% of men and 52% of women usually sit at work (Tissot et al., 2009). Prolonged standing as well as prolonged sitting work is known to lead to health problems. Well-known health problems of long-lasting sitting are musculoskeletal problems like back, neck and shoulder problems (Grandjean and Hunting, 1977). Furthermore cardiovascular disorders (Gardiner et al., 2011; Saidj et al., 2013), obesity (Owen et al., 2010; Zeng et al., 2014), and cancer (Matthews et al., 2012) were found to be related to prolonged sitting. Recent studies additionally reported a direct augmentation of the mortality due to prolonged sitting (Chau et al., 2013; Dunstan et al., 2011; Katzmarzyk et al., 2009; Owen et al., 2010). Katzmarzyk et al. (2009) showed a dose-response relation between sitting and mortality. Furthermore, several authors show no or only a weak positive influence of physical activity that is done beside the sitting time (Chau et al., 2013; Katzmarzyk et al., 2009; Matthews et al., 2012). On the other side, prolonged standing is associated with health risks, too. Reported health risks of prolonged standing are low back pain (Andersen et al., 2007), pain in the lower limbs (Graf et al., 2015), chronic venous disorders (Sudol-Szopinska et al., 2011) and plantar fasciitis (Werner et al., 2010). These results show that prolonged sitting as well as prolonged standing should be reduced.

Different options are discussed to reduce sitting time. An often discussed possibility to reduce sitting time is a sit-stand table (Chau et al., 2014; Gao et al., 2016). Studies showed that sit-stand-tables were well accepted but the reduction of sitting time was only moderate. Further options are active breaks (Bailey and Locke, 2015), treadmill desks (Koepp et al., 2013), or cycling workstations (Elmer and Martin, 2014). Finally, a sit-stand-support could be a possibility to reduce sitting time as well as standing time. A big variety of sit-stand-supports are on the market, but only little research analyzing their effect on the working subject exist. Furthermore, all studies analyzed the effect of one sit-stand-support against sitting and/or standing. To our knowledge, no study exist comparing different stable sit-stand-support systems and analyzing their influence on the user. Especially no study comparing different seat angles or guidelines that give literature-based recommendation of the best seat angle of a stable sit-stand-support could be found. Only five studies were located that analyzed sit-stand-support systems that are at least partly comparable to the system

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analyzed in this study. One of these studies analyzed a saddle chair with a backrest (Bendix et al., 1985) and found better subjective ratings and lower peak levels of trapezius muscle activity for the saddle chair, compared to standing and sitting without legroom. Irving (1992) compared a sit-stand-support, distributing the pressure between the buttocks, the shins and the feed, to standing and found positive subjective ratings in surgeons. Three studies (Antle et al., 2015; Chester et al., 2002; Seo et al., 1996) analyzed a stable, forward-bended sit-stand-support and found mixed results for the comfort, muscle activity and leg swelling compared to sitting and standing. Thus, considering literature, further research about the possible use of stable sit-stand-support is needed.

Therefore, the aim of this study was to measure muscle activity, heart rate, performance, and comfort in subjects using a sit-stand-support with different seat angles and to compare these parameters with those while sitting or standing. This study should help to understand if a sit-stand-support is a reasonable alternative to sitting and standing and to determine which seat angle is the best for which kind of a work task.

2. Material and methods

2.1. Subjects

Twenty-one subjects (eleven females, age 24.2 ± 3.3; ten males, age 26.8 ± 8.2) participated in this study. Subjects fulfilling one of the following criteria were excluded: skin disease, chronic pain (more than 30 days in the last 12 months), leg or lower back injuries, or a BMI > 30. The study was approved by the ethical committee of ETH Zurich (Switzerland) and all subjects gave their written informed consent. Subjects were instructed according to the Helsinki declaration, participated voluntarily and were free to discontinue their participation at any time without explanation.

2.2. Procedure

After the subjects were introduced to the study and gave their informed consent, the electrodes for the electromyography (EMG) were attached bilaterally to the m. gastrocnemius, m. vastus lateralis and m. erector spinae according to the recommendations of SENIAM (2015). For the electrocardiogram (ECG) a two electrodes lead was used. One electrode was placed on the left side of the chest wall below the breast, the other one below the clavicle. To reduce movement artifacts, the cables were taped to the skin. The measurements were done in six positions (sitting, standing, using a sit-stand-support prototype (s. Fig. 1) with a seat angle of 0°/25°/50°/65° against the horizontal axis) and with three different tasks in every position (Fig. 2). The order of the positions and of the tasks was randomized. Before the start of the experiment, the subjects had time to find the best height of the chair and the sit-stand-support in every angle as well as the according height of the table. For the sit-stand-support with a horizontal seat, the subjects were instructed, that the height has to be clearly higher than the height of the chair. The height the subject chose was accepted if the knee angle was at least 115°. A fine adjustment of the height of the table to every task was done directly before the start of the task. Subjects were allowed to work with their arms supported on the table. The experiment consisted of computer work (typing; Fig. 2a), a tweezing task (arranging electrical resistors, SMD (surface-mounted device) components, in an array using a tweezer; Fig. 2b), and a task using gross motor skills (following a line using an unplugged iron; Fig. 2c). Every task was done in every position for five minutes with a five minutes break in between. The subjects spent the break sitting on an office chair. The measured muscle activity was normalized to a reference voluntary contraction (RVE). All the normalizations were done three times for 20 s with a break of 40 s. To normalize the m. gastrocnemius the subject had to stand on tiptoe with one leg. The distance between the floor and the heel was given. To normalize the activity of the m. vastus lateralis, the subject had to lie on the back and lift one leg with a 90° angle in the hip and the knee. A weight of 500 g was added to the foot. To normalize the activity of the m. erector spinae, the subject had to lie prone and lift the upper body.

During the work tasks the performance and the comfort were assessed. The performance was assessed by counting the tipped signs (typing task), the arranged SMD components (tweezing task) and the number of times following the line with the iron (ironing task). The comfort was assessed with questions, asking "how comfortable is your position in general/for your neck/back/arms/buttocks and upper legs/lower legs and feet" on a scale from 0 "highly comfortable" until 10 "highly uncomfortable" (adapted from Nordic questionnaire (Kuorinka et al., 1987);). At the end of the experiment we asked the subjects about the most comfortable position for every of the three tasks.

2.3. Apparatus

The muscle activities were measured with bipolar surface EMG (PS11-UD, THUMEDI GmbH & Co. KG, Thum-Jahnsbach, Germany) at a sampling rate of 4096 Hz. Pre-gelled Ag/AgCl electrodes (35 × 26 mm, Kendall Arbo, Covidien, England) were used and the subjects' skin was prepared with abrasive paste (Nuprep, Weaver and Company, Aurora, CO, USA). Data was filtered with an analogue 3rd order high pass filter with a cut off frequency of 4 Hz (−3 dB) and a 10th order anti-aliasing

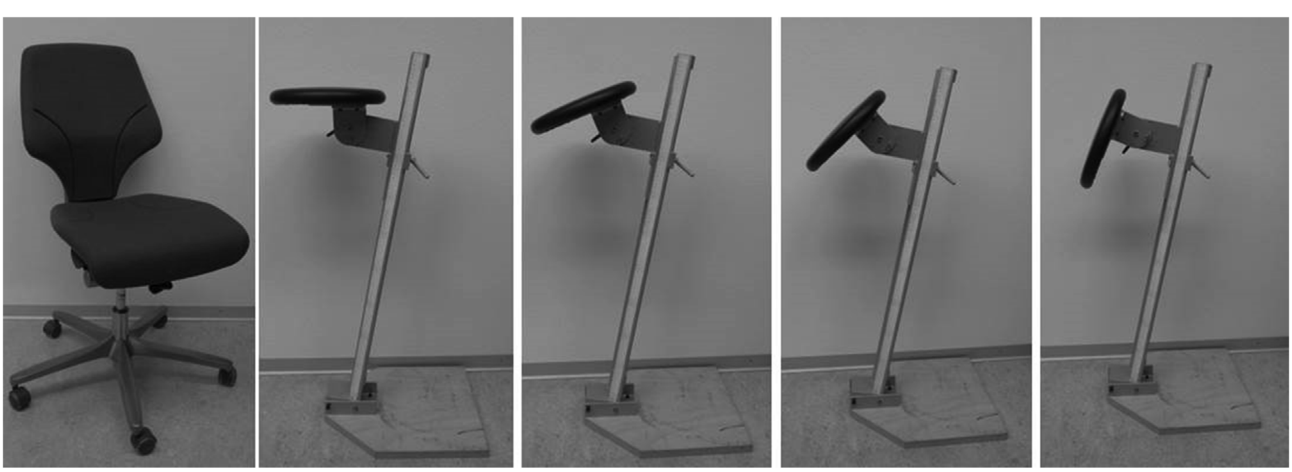

Fig. 1. The office chair and the prototype of the sit-stand-support with the angles 0° to the horizontal axis, 25°, 50° and 65°. The height of the devices that was chosen by the subjects was 21.0% ± 1.4% body height, 40.0% ± 1.4% body height, 43.0% ± 1.6% body height, 46.2% ± 1.4% body height and 50.1% ± 1.5% body height from the left to the right.