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Can a smart chair improve the sitting behavior of office workers?

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ABSTRACT

Prolonged sitting can cause health problems and musculoskeletal discomfort. There is a need for objective and non-obstructive means of measuring sitting behavior. A ‘smart’ office chair can monitor sitting behavior and provide tactile feedback, aiming to improve sitting behavior. This study aimed to investigate the effect of the feedback signal on sitting behavior and musculoskeletal discomfort. In a 12-week prospective cohort study (ABCB design) among office workers ($n = 45$) was measured sitting duration and posture, feedback signals and musculoskeletal discomfort. Between the study phases, small changes were observed in mean sitting duration, posture and discomfort. After turning off the feedback signal, a slight increase in sitting duration was observed (10 min, $p = 0.04$), a slight decrease in optimally supported posture (2.8%, $p < 0.01$), and musculoskeletal discomfort (0.8, $p < 0.01$) was observed. We conclude that the ‘smart’ chair is able to monitor the sitting behavior, the feedback signal, however, led to small or insignificant changes.

1. Introduction

Office workers sit for long periods during their working hours (Thorp et al., 2012). Workers usually exceed recommendations regarding maximum time working in a sitting position (Netten et al., 2011; Goossens et al., 2012; Ryan et al., 2011). Prolonged sitting results in an increased risk of developing health problems (Healy et al., 2013; Chau et al., 2010) and musculoskeletal discomfort (Mathiassen, 2006; Hallman et al., 2016; Zemp et al., 2017). Due to the static character of sitting, the level of muscular tension may cause fatigue and, with insufficient recovery, can result in long-term health problems (Hamburg-van Reenen et al., 2008). To prevent these health problems, the sitting behavior of office workers must be improved (Thorp et al., 2012; Robertson et al., 2009; Straker et al., 2013).

To gain a more comprehensive insight into the sitting behavior of office workers, there is a need for objective and non-obstructive means of measuring sitting behavior (Thorp et al., 2012; van Uffelen et al., 2010; Netten et al., 2011; Wells et al., 2007). Sitting behavior can be measured with questionnaires and activity trackers (Robertson et al., 2008, 2009; Amick et al., 2012; Straker et al., 2013). Multiple studies have investigated the reliability of questionnaires for measuring sedentary behavior and have shown that self-reported measures are a valid way of assessing sedentary behavior (Clemes et al., 2012; Craig et al., 2003; Healy et al., 2011). However, questionnaires are based on self-reporting and therefore reflect the individual's own perceptions (Harvey et al., 2013; Clark et al., 2011), and do not provide detailed information about the actual sitting behavior (Cleland et al., 2014; Healy et al., 2011; Clemes et al., 2012). Activity trackers can be used to objectively measure sitting and standing duration (Robertson et al., 2009; Straker et al., 2013), but they cannot measure sitting postures (Netten et al., 2011; Healy et al., 2011). A measuring tool to provide more detailed patterns of sitting throughout the day is needed. (Zemp et al., 2016).

With a ‘smart’ office chair (*Axia Smart Chair*, BMA Ergonomics, Zwolle, the Netherlands) equipped with sensors located in the seat

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surface (4 sensors) and backrest (2 sensors), see Fig. 1, sitting behavior can be objectively monitored. Additionally, a tactile feedback signal (vibration) can be provided to the user if a set duration limit is reached. Application of this intervention in an eight-week pilot study appeared to shorten sitting duration and improve posture (van der Doelen et al., 2011; Netten et al., 2011), but the initial effects decreased over time (Goossens et al., 2012). None of these studies, however, tested for longer durations or controlled for the sitting duration, amount of activity away from the smart chair during working hours, or the effects of tactile feedback. Additionally, it is unknown if improved sitting behavior reduces health problems and musculoskeletal discomfort (Cascioli et al., 2016; Netten et al., 2011). These shortcomings were addressed in the present study.

In this study the smart chair and its feedback signal were further investigated and its effect on sitting behavior and musculoskeletal discomfort was explored. The aims of this study were to: (1) investigate the effect of the feedback signal on the sitting behavior, defined as sitting duration (30 and 60 min), posture and the dynamic (alternation between sitting and non-sitting and postures) and static components (sitting blocks and blocks of sitting in one posture) of sitting; (2) investigate the effect of the feedback signal on the perceived local musculoskeletal discomfort related to working while seated for a prolonged time; (3) investigate the difference between the measured sitting duration with the smart chair and behavior measured both in and out of the chair with an activity tracker (sitting duration and amount of steps).

2. Methods

2.1. Design

In this 20-week prospective cohort study, sitting behavior was monitored among the office workers of five companies. Based on the availability of materials, this study was performed in two cohorts of 24 and 25 subjects, respectively, between 2015 and 2016. For this study, the first 12 weeks were divided into four phases (ABCB design). Phase 1 (week 1; acclimatization): the Axia Smart Chair and the subject's workplace were adjusted according to ergonomic guidelines in dynamic interrelation, followed by one week of acclimatization (Goossens et al., 2012). Phase 2 (weeks 2–3; monitoring I): the subject's sitting behavior was monitored while the feedback signal was deactivated. Phase 3 (weeks 4–9; intervention): the feedback signal was activated and the subject's sitting behavior was monitored. Phase 4 (weeks 10–12; monitoring II): the feedback signal was deactivated and the subject's sitting behavior was monitored. In weeks 2 (begin monitoring phase I), 4 (begin intervention phase), 9 (end intervention phase) and 12 (end monitoring phase II), the subjects wore an activity tracker (Actigraph GT3X+, ActiGraph LLC, Fort Walton Beach, FL, United States) throughout the whole working week. On one specific day in weeks 2, 3, 9 and 12, the subjects received questionnaires by mail (at the beginning and end of their working day) about their experienced local musculoskeletal discomfort (LMD questionnaire of van der Grinten and Smitt, 1992), and the second cohort received two additional questionnaires in weeks 5 and 7 to gain further insight into the discomfort experienced during the intervention phase. The measurement scheme is presented in Table 1. Except for the additional questionnaire, all subjects followed the same protocol and received the same intervention.

Fig. 1. BMA Axia Smart Chair with label with sensor location. (BMA Ergonomics, 2017)
Single column fitting image.

2.2. Subjects

The subjects were office workers recruited by distributing flyers within the selected companies, followed by an oral presentation to inform participants about the contents of the study. The companies were active in medical care, technical services, civil engineering, industrial cleaning and the petro chemistry industry. Inclusion criteria: the subjects worked at least three days a week, 5 h a day (37.5% of a working week), and had a personal workplace. Pregnant women were excluded due to the shift of their center of gravity (Casagrande et al., 2015). The Medical Ethics Committee of the University Medical Center Groningen, the Netherlands, issued a waiver for this study, stating that it does not involve medical research under Dutch law (M15.175675).

2.3. Material

2.3.1. Office chair

This study used the Axia Smart Chair developed by BMA Ergonomics (Zwolle, the Netherlands). This chair is a 'regular' office chair equipped with pressure sensors located in the seat surface (4 sensors) and backrest (2 sensors). The measuring interval was 1 s and the data, logged once per minute, included the most dominant posture and the related score for this time span. The data were collected using Axia Insight software (BMA Ergonomics, Zwolle, the Netherlands). In the output, eight postures were defined as follows: (1) optimal support (van der Doelen et al., 2011), (2) poor upper back contact, (3) poor lower back contact, (4) too much to the left, (5) too much to the right, (6) slouching, (7) edge of the chair and (8) not sitting. Feedback was provided based on an algorithm (BMA Ergonomics, Zwolle, the Netherlands) that accounted for sitting posture, duration and alternation between postures. Based on this score, a feedback signal was provided to the subject; a (vibration) feedback signal was given when the user demonstrated prolonged periods (30 or 60 min, standard 60 min) in unfavorable sitting postures and a low number of alternations ($\leq$3 alternations in posture per 60 min) (Goossens, 2009) for more than a preset amount of time during the preceding hour (van der Doelen et al., 2011; Netten et al., 2011). The tactile feedback signal was located in the seat surface and consisted of four short pulses over 4 s. The subjects received the feedback signal and information about their sitting behavior was also available from a fixed tab attached to the seat of the chair. The user could activate this fixed tab themselves whenever they wanted. This fixed tab on the chair showed the current sitting posture, the most dominant sitting posture over the preceding half hour and the average score (between 1 and 5, with higher scores indicating more optimal sitting behaviors).