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Using a psychophysical approach to identify a user's self selected thermal comfort on a task chair

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ABSTRACT

It is understood that posture and support affect discomfort and consequently have received widespread attention from researchers. Another factor that could contribute to comfort is the thermal influence due to interaction between the human and the seating surface for which literature is limited. The primary focus of this research was to identify a user's self-selected thermal comfort on a traditional foam-based seat pan while performing a typing/mousing/reading task. A psychophysical approach was applied to evaluate the thermal influence of a task chair with the seat pan temperature as the objective variable. The method of adjustments protocol used two testing sessions with different initial settings. Results of the preliminary study with 10 female participants between 30 and 45 years indicated that the psychophysical methodology is applicable for the purpose. Results also indicate that users' self-selected comfort was achieved when the average temperature of the seat-pan interface was lower than the participant's oral body temperature.

Relevance to industry: Properties of seat pan materials should be considered by chair designers, which could help alleviate the thermal discomfort experienced by chair users.

1. Introduction

Sedentary jobs are common in today's workplace. Workers in occupations such as banking, insurance, transportation, call center operations, office administration, drafting, and software applications can be seated for more than four hours of their normal shift (Amick et al., 2003). Branton (1969) implied that while performing sedentary tasks, the worker should not feel any discomfort due to improper seating, that is, the worker should be in a state of non-awareness of the seat. From a manufacturer's perspective, the design objective is to optimize comfort and support for a user with minimal increase in the cost of the chair. Hence, comfort has become a major aspect which chair manufacturers use to distinguish their products from competitors. Promoting "good" posture and minimizing discomfort is of paramount importance for chair manufacturers.

When a person sits on a chair, a fraction of the body weight is transferred to the supporting surfaces such as the seat pan which supports the buttocks and the thigh areas. A common observation is that after a certain duration of sitting, the person starts to feel uncomfortable and tends to make small movements in the chair (i.e. in-chair movements) often referred to as "fidgeting" (Vergara and Page, 2000; Branton, 1969). Previous research indicates that while infrequent in-chair movements over prolonged time duration could be considered a primary risk factor in the development of work related musculoskeletal disorders (Bhatnager et al., 1985), frequent movement could imply discomfort (Fenety and Walker, 2002). Other studies suggest that large changes in postures can be good indicators for discomfort (Vergara and Page, 2000; 2002) while the frequency and/or magnitude of the small movements are influenced by seating duration and level of discomfort (Fenety et al., 2000; Telfer et al., 2009; Jensen and Bendix, 1992; Michel and Helander, 1994). Some researchers have also evaluated the in-chair movement from a "settling down time (SDT)" following initial contact with different seating surface and reported that testing for SDTs may be useful in the indirect objective assessment of wheelchair cushions (Cascioli et al., 2011). These in-chair movements are also important for the people who are independently not able to reposition themselves from a pressure–relief perspective since frequent weight shifting could prevent pressure sores (Seymour and Lacefield, 1985). In physically capable humans, these movements could be the human body's response to either

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relieve pressure at the ischial tuberosities (ITs) or a thermoregulatory response (i.e. the body is trying to dissipate heat that was built up at the skin or clothing interface temperature and the environment) or both. In this case, the immediate environment would be the seating interface. Hence the cushioning material combined with the external fabric, could have an impact on the thermal comfort of a user.

Few studies (Brooks and Parsons, 1999; Bartels, 2003; Brattgard and Severinsson, 1978; Cengiz and Babalk, 2007; Habboub, 2003; Hedge et al., 2005; Fisher et al., 1978; Finestone et al., 1991; Stewart et al., 1980; Stockton and Rithalia, 2007; Liu et al., 2011) have investigated this aspect of seating comfort. While studies related to interaction of the seat and seated human using temperature as an objective measure are available for the automotive seating (Brooks and Parsons, 1999; Cengiz and Babalk, 2007; Oi et al., 2012), aircraft seating (Bartels, 2003) and wheelchairs (Brattgard and Severinsson, 1978; Fisher et al., 1978; Finestone et al., 1991; Stewart et al., 1980; Stockton and Rithalia, 2007; Liu et al., 2011), to the author's knowledge, limited research inquiry has be conducted to study the interaction of the seat cushion and the seated human for task chairs over prolonged duration of uninterrupted sitting using temperature as an objective measure. Habboub (2003) used a thermister based acquisition system to collect data on different seat cushion types for a maximum uninterrupted seating duration of 60 min, while Hedge et al. (2005) used a subjective measure (thermal comfort sensation votes) to identify the effects on different seat pan configurations. Liu et al. (2011) used a 20 min sitting period to evaluate seat interface temperature for three types of seat material (foam, gel mold and solid wood). Thus, there is a need to increase the body of knowledge in seating with regards to the thermal properties and their effect on user comfort. The intent of this research is to identify a user's perceived thermal comfort on a traditional foam-based seat pan while performing a typing/mousing/reading task using a psychophysical protocol.

Ratts et al. (2003) defined thermal comfort as the freedom from thermal pain or thermal interactions which are undesirable by the person. Another widely used definition is “the condition of the mind that expresses satisfaction with the thermal environment” (ASHRAE 55–2010). Keeping in mind that researchers have interpreted comfort and discomfort in multiple ways (Barkla, 1964; Branton, 1969; Helander and Zhang, 1997; Lee et al., 1991; Lueder, 1983; Shackel et al., 1969; Shen and Vértiz, 1997; Slater, 1985; Zhang et al., 1996), comfort in this study should be interpreted as the minimization of factors that may lead to discomfort.

2. Methods and procedures

2.1. Participants

Participants for this study included 10 female volunteers between the ages of 30–45 years. The participants were pre-screened for any history of back injury or illness. The study received approval from the University's Human Subjects Board. The participants gave informed written consent prior to participation and were compensated for their time. Since the skin temperature measured around the thigh was the objective parameter in this study, selecting a population that was sensitive to thermal variations was critical. In terms of gender, previous research studies identified females to be more sensitive to temperature changes when compared with males (Hedge et al., 2005; Rohles, 1971). Females are also predisposed to have more adipose tissue deposited around their thighs and buttocks when compared to males (Nielson et al., 2004). The subcutaneous adipose tissue forms an insulating barrier around the shell of the body and therefore plays a major role in body temperature regulation (It is to be noted that the thighs and the buttocks are the primary contact surfaces while a human is seated). Additionally, it has been reported that poor ventilation due to sitting increases the scrotal temperature of males (Koskelo et al., 2005), which could potentially influence the seat-interface temperature and thereby the thermal comfort perception. Hence, females were selected for this study.

Age was another factor which was identified to affect thermal comfort, hence this factor was also considered during the experimental design. Task chairs are typically used in administrative offices and call center operations offices. Batt et al. (2005) and Rafaeli et al. (2008) reported that the women constituted 66 percent and 69 percent of the workforce, respectively in the call centers and the average age of the workers was 30 years (range 22–50) and 35.6 years, respectively. Hence, a lower age limit of 30 was used in the study. This age (30 years) may possibly provide people with more sedentary lifestyle which would be more appropriate to the study. Since menopause may have an effect on the temperature sensitivity and core body temperature of a female, the upper limit for age was set at 45 years. (Note: average age for the onset of menopause ranges from 48 to 55 (McKinlay and McKinlay, 1986)).

2.2. Apparatus

A workstation, test chair and a temperature data acquisition system were developed and used in this study. The workstation (adjustable in height to accommodate 5th percentile female up to 95th percentile male) with a computer monitor, a document holder, an adjustable keyboard holder, and a footrest was set up in the testing room (Fig. 1). A traditional foam-based seat pan with a heating and cooling source, upholstered with a non vapor permeable upholstery fabric (100% vinyl) was mounted on the test chair.

The test chair used in this study was a commercially available (Haworth, Inc, Holland,USA) height adjustable task chair with adjustable armrests (height, pivot and lateral movement) and a mesh fabric back. The adjustable lumbar support was removed from the task chair. The chair height and arm rest height (adjustable in height to accommodate 5th percentile female up to 95th percentile male) were adjusted to the user's anthropometric dimensions prior to a testing session. Aaras et al. (2001) reported lower incidence of discomfort due to use of armrests. Previous research studies also indicate that users prefer backrest support (Dainoff, 1994). Researchers also indicated that unsupported postures could impact the lumbar curve (Keegan, 1953), increase lumbar discomfort (Vergara and Page, 2002), and disc pressure and muscle activity in the lower back (Nachemson and Morris, 1964).

Fig. 1. Illustration of adjustable workstation.