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Effects of backrest design on biomechanics and comfort during seated work

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Abstract

The purpose of this study was to examine the effects of backrest configuration on seatpan and backrest pressure, spinal posture, and comfort. Thirty volunteers (15 male, 15 female) typed a standardized text passage while seated at a computer workstation in five backrest configurations: chair only, chair with a supplementary backrest, and with each of three lumbar pad thicknesses. Pressure, lumbar and cervical angles were collected during 15-min trials. Subjective data were collected during each trial and at the end of the entire protocol. The addition of a supplementary backrest to a standard chair reduced peak and average pressure on the back by 35% and 20%, respectively ($P<0.02$). Lumbar lordosis was observed only when lumbar pads were used, being greatest with the large pad. Participants preferred backrest configurations that had lower pressure on the back and less lordotic lumbar posture (backrest only or 3 cm lumbar pad), regardless of anthropometrics. Comfort was rated highest in conditions that would not necessarily be considered biomechanically ideal. Further delineation between specific comfort and objective seating variables is required to effectively reduce and prevent low back pain.

Keywords: Seating; Backrest; Pressure; Comfort; Spine; Posture

1. Introduction

Over the past century, there has been an increase in the proportion of seated occupations (van Dieen et al., 2001) and although these jobs are generally less physically demanding, seated work is a risk factor in the development of low back pain (Cartas et al., 1993; Lengsfeld et al., 2000; Videman et al., 1990). Substantial health costs and the increase in sedentary occupations have led to a considerable amount of attention directed toward office seating, as the chair industry represents 25% of a $10 billion a year office furniture industry in the United States (Freeland, 1998). Amongst other aspects in seating and chair design, the backrest has become a focal point.

The role of a chair backrest is to attenuate the stresses exerted on the vertebral column by relaxing the erector spinae musculature, while maintaining lumbar lordosis and increasing comfort (Corlett and Eklund, 1984). Backrests have been evaluated using spine posture (Andersson et al., 1979; Bendix et al., 1996; Bishu et al., 1991; Dolan et al., 1988; Lord et al., 1997; Makhsous et al., 2003; Vergara and Page, 2000b), pressure measures (Dunk and Callaghan, 2005), electromyography (EMG) (Andersson et al., 1974; Andersson and Ortengren, 1974; Dolan et al., 1988; Makhsous et al., 2003; van Dieen et al., 2001), and subjective measures, such as discomfort scales and questionnaires (Bishu et al., 1991; Coleman et al., 1998; Corlett and Bishop, 1976; Shackel et al., 1969; van Dieen et al., 2001; Vergara and Page, 2000a, 2002).

While comfort is an important criterion to the user, there has been little research to relate comfort to biomechanical variables, such as pressure or low back posture in office seating. Seatpan and backrest pressures have been used in

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the evaluation of car seats (Andreoni et al., 2002; Gyi and Porter, 1999; Porter et al., 2003) and wheelchairs (Houle, 1969; Parent et al., 2000; Sprigle et al., 1990; Takechi and Tokuhiro, 1998), for which comfort and function are very important. Lumbar spine posture has been linked to low back pain in seating (Dolan et al., 1988; Wilder and Pope, 1996). However, posture measurements when seated typically require alterations of the backrest and used cumbersome equipment, both of which likely alter natural behaviour (Bendix et al., 1996; Bishu et al., 1991; Parent et al., 2000). Vergara and Page (2000a, b) developed two simple devices which did not require alteration of the backrest or interfere with the user. Most interestingly, they proposed a "fidgeting" index, which assessed small movements using lumbar and pelvic angle amplitudes and frequencies (Vergara and Page, 2002). Overall, the relationships between comfort and objective measures are not clearly defined. Pressure distribution appears to be related to comfort in car seats, but has not been shown in office applications, while posture and muscle activity are even less clear (de Looze et al., 2003).

With the large selection of consumer products available, there is a need to establish backrest design and selection criteria based on relationships between comfort, pressure, posture, and anthropometrics. The purpose of this paper was to examine the effects of backrest configuration on backrest and seatpan interface pressures, lumbar and cervical spine posture, and comfort.

2. Methods

2.1. Participants

Thirty adult volunteers (15 male, 15 female) with no history of low back pain were recruited from the University community. Participation required the ability to type continuously at a minimum rate of 20 words/min. Anthropometric data including, height, weight, hip girth, waist girth, leg length (greater trochanter to lateral malleolus), torso length (greater trochanter to C7), and shoulder (biacromial) breadth measurements were collected. These data were used to calculate body mass index (BMI), waist–hip ratio (WHR), and leg–torso ratio (LTR).

2.2. Protocol

Participants typed a standardized text passage at a computer workstation using a non-adjustable chair without armrests or wheels, in five randomized backrest conditions: (i) chair only (CO); (ii) chair and supplementary backrest only (BO); (iii) chair and supplementary backrest with small lumbar pad (SPAD); (iv) chair and supplementary backrest with medium lumbar pad (MPAD); (v) chair and supplementary backrest with large lumbar pad (LPAD). The supplementary backrest used in this study has a polyurethane frame with a foam outer layer (ObusForme Lowback Backrest Support, ObusForme Ltd., Toronto, ON). It is supplied with a removable lumbar pad (6 cm thick) that is secured by Velcro. In addition to the standard lumbar pad, small (3 cm thick) and large (9 cm thick) pads were created as 50% and 150% of the standard (medium) pad thickness, respectively (Fig. 1). The location of the lumbar pad was standardized by aligning the most prominent part of the lumbar pad at the mid-lumbar level (L3). The seatpan was moved forward 5 cm to allow for the thickness of the supplementary backrest.

The workstation was adjusted for each participant according to the Canadian Standards Association (CSA) guidelines on office ergonomics (CSA-Z412-00, 2000). One individual required the use of a footrest to meet guidelines. Armrests and wheels were not used as both had the potential to be a confounding variable and complicated the assessment of pressure. Each of the five backrest conditions was tested for 15 min, separated by 5-min breaks, during which participants were allowed to move about as desired. To allow collection of both subjective and objective measures at set intervals, as well as to ensure that the measures were not interrupted by the protocol, specific intervals were used for collection and analysis of data. Seatpan and backrest pressure, as well as lumbar and cervical angles were measured over 5-min periods, beginning at the onset and 10th minute of each trial. Within each 5-min collection period, three 1-min samples were collected beginning at 0, 2, and 4 min (Fig. 2). Participants were informed that data would be collected intermittently throughout the trial, but were not told when the collection occurred. Three subjective measures were administered. First, a computer-based Body-Part Discomfort Questionnaire (BPDQ, adapted from Corlett and Bishop, 1976) was completed at the 5th, 9th and 15th minute of each condition so as to not interfere with pressure and angle data collection. The BPDQ consisted of a 13-body-part diagram of an individual on which participants indicated their level of discomfort based on a 5-point scale ranging from 0 (no discomfort) to 5 (very uncomfortable). Second, a Backrest Condition Rating (BCR) scale in which participants rated the backrest condition by placing a mark along a 5-point Likert Scale, ranging from 'Dislike Immensely' to 'Like Immensely', was completed at the end of each backrest condition (15th minute). Finally, at the end of the entire protocol, each backrest condition was ranked from "Best" (1) to "Worst" (5) and participants expressed any comments regarding each condition. Each trial was also photographed in the sagittal plane.

2.3. Backrest and seatpan pressure

A capacitive pressure-sensing system consisting of two 36×36 half inch element arrays ($46\,cm \times 46\,cm$) was used to measure the pressure on the backrest and the seatpan (X236, Xsensor Technology Corporation, Calgary, AB). The pressure mats were leased from the manufacturer and calibrated prior to arrival with application of the calibration data prior to each collection. Pressure data were sampled at 3 Hz