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Lumbar postures, seat interface pressures and discomfort responses to a novel thoracic support for police officers during prolonged simulated driving exposures

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ABSTRACT

A high prevalence of low back pain has been reported among professional drivers, including mobile police officers. The purpose of this investigation was to develop and evaluate a novel thoracic support designed for mobile police officers. Fourteen participants (7 male, 7 female) attended two 120-min driving simulations using a Crown Victoria Interceptor seat and the same seat equipped with a surface mounted thoracic support. Time-varying spine postures, seat pressures and ratings of discomfort were measured. Averaged discomfort values were low (less than 10 mm of a possible 100 mm) for both seating conditions. The postures in the thoracic support condition were more similar to non-occupational driving without occupational equipment than the Crown Victoria seating condition. The reduction in pressure area at the low back with the thoracic support has the potential to reduce discomfort reporting in officers compared to a standard vehicle package.

1. Introduction

The in-vehicle space has become a mobile work environment for many professions. A link has been demonstrated in the literature between low back pain reporting and prolonged occupational driving exposures (Alperovitch-Najenson et al., 2010; Chen et al., 2005; Krause et al., 2004; Okunribido et al., 2007; Pietri et al., 1992; Porter and Gyi, 2002). Mobile police officers are considered prolonged occupational drivers based on annual mileage, which can exceed 40,000 km among some groups of officers (Gyi and Porter, 1998). Workers who drive in excess of 20 h a week are reportedly six times more likely to be absent from work with back pain than those who drive less than 10 h per week (Porter and Gyi, 2002). The reduction in lumbar lordosis that occurs during sitting (De Carvalho et al., 2010; Keegan, 1953; Dunk and Callaghan, 2005) has been associated with increased intradiscal pressure (Makhsous et al., 2003; Andersson et al., 1974) and increased tension on the posterior elements of the spinal column (Andersson et al., 1974; De Carvalho et al., 2010). During sitting in an automotive seat, previous research has demonstrated that lumbar lordosis decreases by an average of 43° compared to standing (De Carvalho et al., 2010).

In addition to prolonged occupational driving exposures, many modern mobile occupations require workers to complete office-based tasks within the vehicle's occupant compartment space. Approximately 50 percent of a police officer's shift is spent seated in a vehicle (Brown et al., 1998; McKinnon et al., 2011) and up to 33 percent of this in-vehicle time is spent performing data entry or retrieval activities on a dash board mounted laptop or mobile data terminal (MDT) (McKinnon et al., 2011). The introduction of MDTs in cruisers increases access to information (Agrawal et al., 2003), which in turn increases officer productivity (Hampton and Langham, 2005). However, use of these mobile devices also increases the potential for discomfort reporting. During lab simulated driving, the introduction of a typing task on an MDT increased discomfort reporting and increased posterior pelvic inclinations compared to driving alone (Gruevski et al., 2013). In a survey of municipal officers from a Canadian police force, the mean

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discomfort associated with in-vehicle computer use was 64 mm with 100 mm representing extreme discomfort (Donnelly et al., 2009).

There is evidence to suggest that in-vehicle lumbar supports are effective at increasing lordotic postures (De Carvalho and Callaghan, 2011a; Reed and Schneider, 1996; Andersson et al., 1974), reducing muscle activity (Kingma and van Dieën, 2009; Andersson et al., 1974) and reducing discomfort reporting among drivers (Chen et al., 2005). In a study conducted by Porter and Gyi (2002), drivers with seats that featured an adjustable lumbar support had fewer days absent from work with low back pain than drivers without a low back support. However, the mandatory equipment worn by officers (duty belt and Kevlar vest) makes a traditional lumbar support an infeasible ergonomic intervention for this population. In a recent investigation, the lumbar support was the seat feature that caused the greatest discomfort among surveyed officers with a mean rating of 50.9 mm out of a possible 100 mm (Donnelly et al., 2009). The duty belt and protective vest worn by officers create a unique interface between the seat and occupant that further increases the potential for discomfort reporting. The duty belt, side arm, radio and body armour were identified as causing the highest perceived discomfort of all equipment worn by officers throughout an 8-h shift (Donnelly et al., 2009). Interface pressure has been previously hypothesized as the objective measure with the strongest link to discomfort reporting during seated exposures (De Looze et al., 2003). It is possible that an intervention that reduces the seat back pressure in the location of the duty belt may also mitigate discomfort reporting in this region.

An Active Lumbar Support (ALS) seat was developed to accommodate the mandatory equipment worn by officers and successfully reduced discomfort reporting in both field and laboratory simulated driving environments (Donnelly et al., 2009). The ALS seat is a modified Crown Victoria seat with foam structural modifications to the thoracic region, a shortened seat pan and a mechanical component that translates in both superior/inferior and anterior/posterior directions (Donnelly et al., 2009). However, previous work has not examined if a thoracic support can induce changes to mitigate lumbar discomfort, improve lumbar lordosis or reduce interface pressures of the duty belt worn by police officers.

Assessing a novel thoracic intervention to provide support to the lumbar region and reduce discomfort while accommodating the body armour and duty belt was the focus of this investigation. The purpose of this study was to evaluate changes in lumbar spine posture and discomfort induced by a novel thoracic support during prolonged lab simulated driving. It was hypothesized that the thoracic support condition will lead to changes in posture and seat back contact to reduce low back discomfort, reduce seat pressure in the location of the duty belt and increase lumbar lordosis compared to a Crown Victoria seat alone.

2. Methods

2.1. Thoracic support development

A prototype thoracic support (TS) was developed to mimic the stiffness and shape of the ALS seat when the thoracic support was applied to a Crown Victoria seat. Differences in the seat back thickness and contours between the Crown Victoria and the ALS seats were used to design the dimensions and shape of the TS. Point cloud meshes of the surface contours of each seat were collected using a four marker digitizing probe (Northern Digital Inc., Waterloo, ON). Given that The ALS and Crown Victoria seats have identical metal frames, manually digitized points on the surface of both the Crown Victoria and ALS seats were expressed relative to a common local coordinate system with its origin in the head rest of each seat. A one dimensional linear interpolation was applied to the point clouds collected from each seat to create 100 equally spaced points along the vertical dimension of the backrest in a custom MATLAB program (v.7.11.0, R2010b, Natick, MA, USA) so the points along the surface of each seat could later be aligned. A linear interpolation was selected due to the fine resolution (~1 mm) and the linear relationship between data points (Coburn and Crisco, 2005) with interpolated vertical slices of points on the surface of each seat calculated every 5 mm. The aligned surfaces were superimposed and the distance between interpolated points in the depth dimension were plotted to determine the difference between the Crown Victoria and ALS seats. The support mechanism in the ALS seat was scanned in three different positions within the range of the mechanism's translational adjustability including; highest, lowest and intermediate positions. The mechanism was tested in all three positions in both its fully extended and fully retracted states for a total of six surface scans of the ALS seat back. Surface contour differences between thoracic support locations were determined and a composite series of vertical cross-sections of the ALS seat were compared with the Crown Victoria seat. The scan of the ALS seat in the maximally extended and highest vertical position was used to design the support. The depth difference between this scan and the Crown Victoria seat was approximately 15 mm (Fig. 1). The edges of the thoracic support were tapered according to the scans to accommodate trunk rotation during MDT usage.

The stiffness of the ALS seat in its fully extended state was measured to select thoracic support foam to mimic its properties. The deflection properties of the ALS seat in the maximally extended setting were tested using an hand force dynamometer (Hoggan Health Industries, West Jordan, UT, USA), which was outfitted with 2 infrared markers (Northern Digital Inc, Waterloo, ON) to measure the excursion of the foam during the manual application of 100 N compared to the application of 0 N. The deflection properties of three 2.5 cm thick closed-cell foam samples were tested overlying the surface of the Crown Victoria seat and compared to the characteristics of the ALS seat. The Evazote EV50 foam (Zotefoams, Croydon, Surrey, England) deflected 0.54 mm more than the ALS and was used to build the prototype thoracic support. As the ALS seat was found to be stiffer than all of the foam samples tested, an extra 10 mm of thickness was added to the final prototype (Fig. 2). The uncompressed maximum thickness of the support was 2.5 cm, with outer dimensions of 30 cm long and 20 cm wide. The prototype was covered with a light textile fabric (Signature Textiles, Ref No. 87821, Saint-Laurent Québec).

2.2. Evaluation of thoracic support

2.2.1. Participants

Fourteen participants (7 male and 7 female) were recruited from a university student population (Table 1). Participants were free of any low back or upper extremity musculoskeletal disorders or pain at the time of the study. Informed written consent was obtained prior to testing. The study was approved by the University of Waterloo Office of Research Ethics. Participants were paired with similar absolute heights between genders (Table 1). Previous work examining prolonged driving exposures has demonstrated that when heights are matched between genders, postural differences in sitting disappear (Reed et al., 2000). A two-tailed t-test confirmed that the standing heights of female and male participants were not statistically different ($p = 0.2718$). Absolute participant heights represented a range of the male and female population (ANSUR, 1998). Ranges fell between 164–182 cm and 161–178 cm for males and females respectively.