Exploring head and neck vibration exposure from quad bike use in agriculture

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Abstract

Objectives: Although musculoskeletal disorders of the low back have been linked to excessive whole body vibration during vehicle use, there is a need to explore head/neck vibration in occupational environments. Resonant frequencies may amplify vibration transmitted to the head/neck and increase risk of musculoskeletal disorders.

Methods: An observational fieldwork study directly measuring vibration exposure at the seat and head of 10 rural workers operating quad bikes over farm terrain for ~30 min.

Results: Vertical axis root-mean-squared acceleration was higher at the head/neck compared to the seat. Mean spectral coherence was strong (>0.8) in the vertical axis from 1.3 to 4.9 Hz, indicating a strong relationship between vertical vibrations measured at the seat and the head. Power spectral densities demonstrated system amplification, with mean and peak seat-to-head transfer functions of 1.44 (95% CI ± 0.08) and 1.66 (±0.14), respectively, from 1.3 to 4.9 Hz. There was also a peak phase lag of -66.5° (±13.9°) at 4.9 Hz for head relative to seat measured vertical vibration, which may increase compressive loads of the cervical spine.

Conclusions: While it is unknown whether these amplified and out-of-phase vibrations measured at the head/neck increase the risk of musculoskeletal disorder, the current biodynamic response to vibration exposure may help explain previously reported high prevalence of neck pain in farmers that use quad bikes. Our future laboratory based studies will aim to validate these fieldwork seat and head data and explore the effect of such vibration transmission on spinal biomechanical models as well as on proprioceptive and perceptual pathways that may also relate to injury.

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1. Introduction

Musculoskeletal disorders (MSDs) are common reasons for work related sick-leave, and incur substantial costs for modern society (Buckley and Devereux, 1999). Vehicle driving is an occupational task that often exposes the driver to whole body vibration (WBV) and mechanical shocks (Tiemessen et al., 2008). Such exposure can increase the risk of low back MSDs for drivers of a variety of vehicle types used in mining (McPhee, 2004; Eger et al., 2008), forestry (Rehn et al., 2002), passenger transport (Bovenzi and Zadani, 1992), and heavy machinery in shipping and construction (Boshuizen et al., 1992; Bovenzi et al., 2002; Waters et al., 2008). Farmers using tractors and other farm vehicles, including quad bikes, are also exposed to WBV and report a high prevalence of low back pain (LBP), often exacerbated during farm vehicle operation (Bovenzi and Betta, 1994; Walker-Bone and Palmer, 2002; Scarlett et al., 2005; Milosavljevic et al., 2011).

Although exposure thresholds for WBV and mechanical shocks are recommended in European Directive 2002/44/EC and in the ISO 2631-1 and 2631-5 standards, there is no established dose-response relationship between vibration exposure and MSD. Despite this, researchers have reported associations between drivers exposed to WBV and LBP (Bovenzi and Hulshof, 1998; Lings
and Leboeuf-Yde, 2000; Tiemessen et al., 2008; Milosavljevic et al., 2012b). In one study, exposure to WBV from rural quad-bike use was strongly associated with the 12-month prevalence of LBP (Milosavljevic et al., 2012b). Tiemessen et al. (2008) also found a significant association between WBV cumulative exposure and driving-related LBP in a prospective cohort of 229 drivers; however, they were unable to determine a dose-response relationship with the intensity or disability of LBP.

Many individuals also report neck problems from driving (Viikari-Juntura et al., 1996; Rehn et al., 2002; Eger et al., 2008), although the association is considered weak (Magnusson et al., 1996; Viikari-Juntura et al., 1996; Scutter et al., 1997; Ariëns et al., 2000; Walker-Bone and Palmer, 2002). Other than whiplash-associated disorders from vehicle accidents, ergonomic risk factors for the neck during driving have not been extensively studied. Suggested risk factors include: i) extreme forward flexion of the cervical spine, ii) static contraction of the neck and shoulder muscles to counteract the weight of the head, iii) elevated arms, and iv) twisted or bent working postures (Magnusson et al., 1996).

The transmission of translational seat vibration to the head and neck region has been previously identified in laboratory research, with a review identifying seat-to-head transmission (STHT) between 0.5 and 20 Hz (Rakheja et al., 2010). Wang et al. (2006) investigated vibration transmission using a helmet mounted accelerometer in response to randomly generated vertical vibration at the seat. They found peak seat-to-head amplification was 1.75 times greater at the head with a coinciding phase lag of 100° between 4 and 5 Hz in testing conditions without a back-rest. The biodynamic response to WBV is also influenced by several driving factors, including seated posture (Mansfield and Griffin, 2002; Rakheja et al., 2002; Wang et al., 2004), backrest inclination (Nawayseh and Griffin, 2004; Wang et al., 2006), and use of a steering wheel (Rakheja et al., 2002). Amplified and out-of-phase accelerations at the head/neck may increase compressive load of the cervical spine (Wang et al., 2010) and cause sensorimotor disturbances, including visual and vestibular perceptual deficits (Zahov and Medzhidieva, 2005; Santos et al., 2008). Mani et al. (2015) observed standing balance perturbations following 30 min of vibration exposure, indicating a somatosensory disturbance, which may also contribute to the development of LBP (Mok et al., 2007).

Paddan and Griffin (1988) found that fore-and-aft vibration produced at a seat contributed to both fore-and-aft and vertical head motion. Furthermore, head nodding has been observed in individuals during exposure to vertical vibration at the seat, likely due to the offset between the centre of gravity of the head and its pivot point (Sandover, 1991). Oscillatory motion of the head appears to have different characteristics from vertical axis vibration applied at the seat, with substantial between and within subject variability (Paddan and Griffin, 1998). An in vivo study also found horizontal and rotational motions in lumbar vertebrae subjected to pure vertical vibration in the resonant frequency span (Panjabi et al., 1986). These findings indicate that transmission of vibration from the seat to the head/neck is complex.

While the biodynamic response of STHT has been extensively studied under controlled laboratory conditions, further fieldwork of occupational vibration at the head/neck of drivers will help clarify exposure levels and the relationship to risk of injury or MSDs. Recent research of farmers found that daily WBV exposure from quad bike driving was high, and likely associated with the prevalence of low back and neck pain (Milosavljevic et al., 2010, 2011). Previous surveys also identified a high prevalence of neck pain and headache in farmers, with vibration exposure from farm vehicles considered a plausible source of symptoms (Scutter et al., 1997; Sjaastad and Bakkeiteig, 2002; Milosavljevic et al., 2012b).

The purpose of this fieldwork investigation was to compare the dose and spectral characteristics of vibration simultaneously measured at the seat and head while farmers used a quad bike on farm terrain over a 30-min sampling frame. While vibration dosage recorded at the head may differ from the seat, we hypothesized a strong spectral relationship between the measurements, and amplified STHT coinciding with resonant frequencies of the spine.

2. Methodology

2.1. Field testing

Following ethical approval from the University of Saskatchewan Behavioural Research Ethics Board, a convenience sample of 10 healthy full-time rural workers experienced in operating farm vehicles, including quad bikes, was recruited for this field-based study. Seat and head vibrations were simultaneously recorded as each rural worker operated one of two quad bikes, either a 2007 Yamaha King Quad 450 (n = 4) or a 2006 Arctic Cat 650 (n = 6). Each worker completed a standardized route over typical farm terrain, with the track length designed to accommodate a riding duration of approximately 30 min (Fig. 1). The farm terrain included a mix of surfaces typical in grain and pulse cultivation as well as livestock production, including gravel, packed earth, soft earth, and rough surfaces (e.g. ditches and stones). Prior to completing the test route, each worker received a detailed overview of the farm track. In addition, participants were instructed to: (a) operate the quad-bike continuously without stoppage; remain seated for the duration of the ride; (c) drive at a speed not exceeding 20 km/hr.

2.2. Data collection

Seat-based vibrations were measured with a 6-axis inertial measurement unit (IMU) encompassing a triaxial accelerometer and a triaxial gyroscope (AccelarateRate3D, MemSense LLC, Rapid City, SD). The full-scale range of the accelerometers and gyroscopes was ±10 g and ±1200°/s, respectively, with an operating

Fig. 1. Quad bike operation on a farm in Saskatchewan with inertial measurement units mounted in a rubber seat pad and on a helmet, and data loggers fixed to the rear carrying rack. Inset shows close-up of one inertial measurement unit.
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