



Seated postural neck and trunk reactions to sideways perturbations with or without a cognitive task



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ABSTRACT

Driving on irregular terrain will expose the driver to sideways mechanical shocks or perturbations that may cause musculoskeletal problems. How a cognitive task, imposed on the driver, affects seated postural reactions during perturbations is unknown. The aim of the present study was to investigate seated postural reactions in the neck and trunk among healthy adults exposed to sideways perturbations with or without a cognitive task. Twenty-three healthy male subjects aged 19–36 years, were seated on a chair mounted on a motion system and randomly exposed to 20 sideways perturbations (at two peak accelerations 5.1 or 13.2 m/s²) in two conditions: counting backwards or not. Kinematics were recorded for upper body segments using inertial measurement units attached to the body and electromyography (EMG) was recorded for four muscles bilaterally in the neck and trunk. Angular displacements (head, neck, trunk and pelvis) in the frontal plane, and EMG amplitude (normalised to maximum voluntary contractions, MVC) were analysed. The cognitive task provoked significantly larger angular displacements of the head, neck and trunk and significantly increased EMG mean amplitudes in the upper neck during deceleration, although 10% of MVC was never exceeded. A cognitive task seems to affect musculoskeletal reactions when exposed to sideways perturbations in a seated position.

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1. Introduction

Driving on irregular terrain, e.g. within forestry, mining or agriculture, will expose the seated driver to substantial mechanical shocks or perturbations. Exposure to mechanical shocks could, due to known health risks for the lower lumbar spine, be evaluated using the international standard ISO 2631-5 (2004). The standard does not, however, include muscle activities which may be overactive during unexpected shocks, thus creating excessive load on spinal joints (Bazrgari et al., 2008). Lately, studies have reported musculoskeletal problems in the neck region among drivers of various vehicles (Hagberg et al., 2006; Smith and Williams, 2014). Whether this is associated with the exposure to mechanical shocks and postural reactions in the driver remains unclear.

The biodynamic reaction after a mechanical shock or perturbation in a seated position results in – due to inertia in the trunk – a delay in subsequent head movement (Allum et al., 1997; Kumar

et al., 2005; Vibert et al., 2001). For an unpredictable perturbation, passive mechanics (inertia, stiffness, and viscosity) constitute the first stabilizing mechanism. Secondly, skeletal muscle reflexes are added (Tarkka, 1986). Thirdly, voluntary reactions contribute to the stabilisation process (Mazzini and Schieppati, 1992).

Postural reactions in the neck or trunk due to perturbations in seated positions depend on several factors attributed to the perturbation characteristics, such as the amplitude and direction (Masani et al., 2009; Preuss and Fung, 2008; Sacher et al., 2012; St-Onge et al., 2011; Zedka et al., 1998), acceleration (Kumar et al., 2004a; Siegmund and Blouin, 2009; Siegmund et al., 2002) and complexity (Xia et al., 2008). Other factors are awareness of an upcoming perturbation (Siegmund et al., 2003a) and the initial posture (Kumar et al., 2005, 2006). Studies investigating postural reactions from sideways perturbations are scarcer than those involving forward–backward directions. Still, sideways shocks are reported to be at high acceleration levels for some driver categories and thus important to analyse (Rehn et al., 2005; Solecki, 2007).

The neck and trunk muscles seem to have a reciprocal activation pattern in response to a sideways load (Kumar et al.,

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2004a,b; Masani et al., 2009; Preuss et al., 2005; Vibert et al., 2001; Zedka et al., 1998). Conversely, the reactions also include some co-contraction (Preuss et al., 2005; Vibert et al., 2001). Vibert et al. (2001) suggested two main categories of reaction strategies; stiff and sloppy. The stiff strategy includes more co-contraction while the sloppy strategy comprises of reciprocal activation where the head and trunk are more flexible, which Vibert et al. (2001) claims is a more passive and potentially harmful strategy.

The postural reactions, here called a primary task, could be affected by a cognitive task, here called a secondary task (ST). Dual task studies of various kinds, including balance recovery, have demonstrated impaired performance in one or both tasks and that cognitive processing is involved in controlling postural stability in standing (Maki and McIlroy, 2007; Quant et al., 2004; Rankin et al., 2000). The effect of a dual task on the upper body during perturbation in a seated position has not been studied.

The aim of the study was to investigate postural reactions in the neck and trunk in healthy adults exposed to sideways perturbations in a seated position with or without a secondary task. It was hypothesised that increased muscle activity and larger angular peak displacements of involved body segments would be observed when subjects performed a ST and when exposed to higher peak acceleration perturbations. It was suggested that increased postural reactions, i.e. muscle activity in the trunk, could affect the reactive muscle activity and angular displacement in the neck.

2. Methods

2.1. Participants

Twenty-three healthy male students, age 24 ± 5 years, height 1.81 ± 0.07 m, weight 79 ± 11 kg, participated in the study. Young participants were chosen to reduce occurrence of age-related problems such as degeneration and rigidity of the spine. Male participants were chosen because professional drivers are most commonly men. Subjects were excluded if they reported any neurological conditions or reduced ability to work during the last 12 months because of back or neck problems (Lundström et al., 2004). A sample size analysis was carried out from neck kinematic data, using a similar setup with a mean value difference of 1.08 and standard deviation of 1.58. The analysis revealed that 19 participants were needed to be able to reject the null hypothesis, power = 0.8 (alpha level 0.05). Four extra participants were added, since the risks were considered negligible, to ensure that at least 19 measurements could be included in the analyses. Written informed consent was obtained from each participant, and the Regional Ethical Review Board approved the study (No 2012-24-31M).

2.2. Experimental protocol

This study used a repeated-measurement design (Fig. 1) with low peak acceleration (LPA) and high peak acceleration (HPA), combined with or without a ST (i.e. attentional task counting backwards in steps of three starting from a number provided by the experimenter (Brown et al., 1999)). The resulting four combinations of perturbations (I. LPA with ST, II. LPA without ST, III. HPA with ST, IV. HPA without ST), all delivered from the participant's right side, were randomised in five different groups, i.e. each unique combination was repeated in total five times but could not exceed being repeated more than two times in a row. Participants sat on an experimental flat chair that was fixed to a movable platform controlled by electrohydraulic actuators (Micro Motion System, Bosch Rexroth, Netherlands). The participants were seated centred

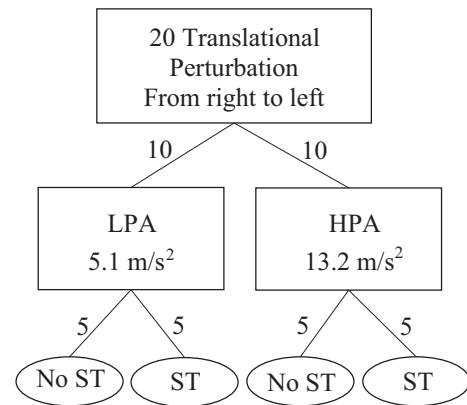


Fig. 1. Experimental protocol using a repeated-measurement design of 20 translational sideways perturbations from the participants right side. There were two different accelerations (low peak acceleration (LPA) and high peak acceleration (HPA)) combined with two conditions, i.e. secondary task (ST) or no secondary task (No ST).

on the chair facing forward, in what they considered to be a good but relaxed sitting posture. Feet were placed together on a height adjusted foot rest so that the thighs were horizontal and foot contact could still be maintained. A cushion was placed between the knees and a belt buckled around the thighs to minimize compensation of the effect of the perturbation by the feet, while maintaining a neutral position between legs and pelvis. The hands were placed on the thighs with palms upwards so that all motor response emanated from the trunk and neck. The perturbations parameters were acceleration ($a_{LPA} = 5.1 \text{ m/s}^2$, $a_{HPA} = 13.2 \text{ m/s}^2$), lateral translational stroke (distance = 0.24 m for both LPA and HPA), and time ($t_{LPA} = 1.2 \text{ s}$, $t_{HPA} = 0.8 \text{ s}$). The level of LPA was set to be less than used by Vibert et al. (2001) and the level of HPA was chosen to be approximately the same as that of Kumar et al. (2005). Subjects remained in the start position randomly 5–20 s before perturbation. Further, they were instructed to retain their initial posture until the perturbation and to reassume it subsequently following the perturbation. Before registration of data, the subjects had one test perturbation of each acceleration in order to reduce potential anxiety that could affect the reactions, but also to reduce adaptation between the first and the remaining perturbations (Blouin et al., 2003; Siegmund et al., 2003b).

2.3. Data acquisition

Motion of the body segments, as well as the chair, were recorded with a portable movement analysis system, developed by the Department of Biomedical Engineering, Research & Development, University Hospital of Umeå, Sweden. In this setting, the system consists of one data acquisition unit connected by cables to four inertial measurement units (IMUs). Each IMU (MPU-9150 InvenSense, USA) included tri-axial accelerometers and gyros that together detect motion such as the relative and absolute angles of the segments. A customised software program calculated the real-time orientation and motion of the IMUs (Madgwick, 2010; Öhberg et al., 2013). The IMUs were placed on the back of the head using an elastic Velcro strap and at the spine on processus spinosus at level Th2 and S2 using adhesive tape on the skin. One IMU was also mounted on the seat using adhesive tape. Data were collected with a sampling rate of 128 Hz. Movements were described as relative angles between two units and additionally the absolute angles for the head unit, due to more degrees of freedom in the neck. The combination of units gives three segments with relative joints; Neck (Head to Th2), Trunk (Th2 to S2) and Pelvis (S2 to seat). The IMUs were aligned with

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