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Effect of whole body vibration on the postural control of the spine in sitting

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ABSTRACT

Stability is defined by the ability to return to the initial (or unperturbed) state following a perturbation and hence can be assessed by quantifying the post-perturbation response. This response may be divided into two phases: an initial passive response phase, dependent upon both the steady state of the system and the system's intrinsic mechanical properties; and a recovery phase, dependent upon active control and reflexes. These two phases overlap and interact with each other. Whole body vibration (WBV) is assumed to influence neuro-sensory functions and perhaps both response stages. The current study observed the effect of WBV on several novel response factors that quantify the two phases in response to an external perturbation. The results indicate a significant effect of vibration exposure on: (1) the normalized maximum distance traveled by center of pressure (COP) from the neutral seated posture, and (2) the normalized time to maximum distance (τ), such that B and τ increased after WBV exposure and decreased after sitting without WBV. These changes may be indicative of passive visco-elastic changes caused by WBV exposure on the spinal tissues which has been indicated as a creep deformation of tissues post-exposure. This change may make the spine vulnerable to injury. Similar trends were noticed in the variables calculated from center of mass data.

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1. Introduction

Stability can be defined as the ability to return to the initial (unperturbed) state following a perturbation (Peter Reeves, Narendra, & Cholewicki, 2007). Trunk stability is provided by three complementary subsystems. When functioning normally the three subsystems; passive tissue support (passive), steady-state muscle recruitment (active), and time-dependent reflex response (neural control), provide the trunk with sufficient robustness to successfully accommodate biomechanical and postural perturbations and avoid injury (Panjabi, 1992a).

Postural stability presents a dynamic response, or the kinematic change in the body position, in response to a perturbation (Prieto, Myklebust, & Myklebust, 1993). Thus, stability responses can be assessed by perturbing the system and quantifying the response to the change in body position. When an external perturbation affects the equilibrium of the body, a recovery strategy must encompass the maintenance of postural stability to avoid injuries (Cholewicki & McGill, 1996; Radebold, Cholewicki, Polzhofer, & Greene, 2001).

Impairments in postural responses have been associated with low back pain (LBP) (Radebold et al., 2001). In postural tasks, accurate detection of body configuration, and its interactions with the environment are based on the sensory messages originating from muscles and skin sensors throughout the body (Roll & Roll, 1988). Mechanical vibration has been found to alter these messages and thus alters position sense and kinesthesia (Oullier et al., 2009). Cyclic muscular activity in the muscles of the lower back has been observed during exposure to 3–10 Hz vertical vibrations (Blüthner, Seidel, & Hinz, 2001; Wilder et al., 1996). Wakeling and Nigg (2001) suggested that this increased muscle activity is necessary to dampen the vibratory waves and leads to muscle fatigue (Hansson, Magnusson, & Broman, 1991; Wilder, Magnusson, Fenwick, & Pope, 1994). Fatigue appears to occur with an increase in efforts to maintain equilibrium of the body; thus affecting neuromuscular coordination (Ng, Parnianpour, Richardson, & Kippers, 2003) and proprioception (Cordo, Gurfinkel, Bevan, & Kerr, 1995; Li, Lamis, & Wilson, 2008; Roll & Vedel, 1982; Taimela, Kankaanpää, & Luoto, 1999).

Seated whole body vibration (WBV) also decreases the height of the spine beyond the normal diurnal changes (Klingenstierna & Pope, 1987), due to the creep of the intervertebral disc (Keller & Nathan, 1999). This creep deformation, characterized by decreased passive stiffness of the tissue, is a viscoelastic response of the passive tissues to vibration exposure (Keller & Nathan, 1999) and has been found to disrupt the passive stability of the trunk and related sensory organs (Slota, Granata, & Madigan, 2008) making the spine vulnerable to a buckling event. WBV has also been reported to increase spinal load (Fritz, 2000). This spinal loading induced by WBV causes muscle fatigue and has been shown to cause intervertebral disc thinning and herniation (Griffin, 1996). These factors, including degraded proprioception and kinesthesia; and development of fatigue, can hamper postural control (Wilder et al., 1996). Hence, WBV has been identified as a major risk factor that leads to occupational back injuries (Bernard, 1997; Bovenzi, 1996; Lis, Black, Korn, & Nordin, 2007; Nachemson & Jonsson, 2000; Seidel, 1993). Other external physical risk factors such as repetitive movements, high force demands and/or work posture may be additive with WBV in their effect on trunk stability (Santos et al., 2008).

Postural stability can be measured by quantifying the response to a perturbation, and in a feedback-controlled system like the human body this response can be divided into two phases: an initial/passive response phase and a reactive/recovery phase (Bruijn, Meijer, Beek, & Van Dieën, 2010). The initial phase depends on the steady state of the system and its intrinsic mechanical properties like the viscoelasticity of tissues; and the reactive phase is dependent on active control and time-dependent reflexes (Bruijn et al., 2010). These two phases clearly describe the essential role of the passive, active and neural subsystems in maintaining overall stability. Recently, evaluation of center of pressure (COP) data has been used as a reliable method to investigate sitting postural control (Kyvelidou, Harbourne, Stuberg, Sun, & Stergiou, 2009; van Dieën, Koppes, & Twisk, 2010).

The purpose of the present study was to investigate if 3–5 Hz (occupational) WBV alters the two phased response after a sudden perturbation is applied to the trunk. The analysis was based on a method that evaluates COP and COM excursions to distinguish between the initial phase and the recovery phase as described by Bruijn et al. (2010). It was hypothesized that when compared to control condition, WBV would impede performance in the initial phase of the reaction and the recovery from these effects would be delayed.