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# Stiffness properties of the trunk in people with low back pain

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ABSTRACT

The purpose of this study was to examine the dynamic properties of the trunk during unstable sitting and to determine differences between healthy and low back pain (LBP) participants.

Participants sat on a custom-made chair that was able to swing freely in the sagittal plane. The chair was mounted on a force platform to measure loads acting at the trunk. Each participant was asked to find a balanced position after the chair was tilted backward and released. Movements of the trunk and chair were recorded. Effective moment of inertia, stiffness and damping coefficients were derived using a second order linear model. 10 participants were re-tested to assess reliability.

Trunk stiffness was found increased for LBP subjects ($p < .05$) while no difference was found for damping coefficient. Gender and initial tilt angle did not affect viscoelastic properties of the spine.

A second order linear model adequately described the biomechanical response of the trunk. It was shown that the trunk response was mainly elastic for all participants. The increase in trunk stiffness in LBP subjects could be a compensatory strategy to decrease pain and the risk of further injuries, but further investigations are needed to understand the nature of the viscoelastic alterations.



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## 1. Introduction

The stiffness of the trunk has been suggested as an important factor that contributes to postural control of the back in different activities (Cholewicki, Panjabi, & Khachatryan, 1997; Gardner-Morse & Stokes, 1998; Gardner-Morse, Stokes, & Laible, 1995). Trunk stability is achieved with different structures assuming different roles (Panjabi, 1992). The passive stiffness of the bones and ligaments of the spine are not sufficient to control the posture of the trunk (Cholewicki & McGill, 1996; Crisco & Panjabi, 1992; Crisco, Panjabi, Yamamoto, & Oxland, 1992). Stability is largely achieved by the stiffness of the muscles and modulated by the neural system (Crisco & Panjabi, 1992; Gardner-Morse & Stokes, 2001).

LBP and spine injuries can affect the viscoelastic properties of spinal structures and influence the trunk stability (Panjabi, 1992). Intrinsic alterations in viscoelastic properties of the spinal structures have been evaluated in cadaveric studies, which showed that motion segments with degenerated discs exhibited decreased stiffness and damping coefficients (Keller, Spengler, et al., 1987). Consequently, these segments were found less stable, with a higher creep rate compared to the less degenerates segments. Alterations in viscoelastic properties of the spine were also observed in vivo. For instance, the postero-anterior lumbar spine stiffness was examined in LBP and healthy participants by Latimer, Lee, Adams, and Moran (1996). They employed a device that delivered a force to the L3 level spinous process while the subject was lying on a table in prone position. Stiffness was calculated as function of force and displacement, and it was shown that LBP was found to have increased stiffness in the trunk. Symptomatic participants were also re-tested after that the pain was resolved by more than 80%, and a significant decrease in the stiffness was shown in this second test (Latimer et al., 1996), highlighting the association between increased stiffness and pain. An improved version of this device was used by Colloca and Keller (2001) to evaluate the posteroanterior stiffness at different levels of the trunk and similar results were found, showing that LBP subjects with high recurrence of pain had increased stiffness in the spinous processes in comparison to healthy subjects or subjects with less frequent LBP. Shum, Tsung, and Lee (2013) used same method to evaluate the effect of spinal mobilization and they found decreased stiffness and pain in LBP subject after spinal mobilization therapy.

Hodges, van den Hoorn, Dawson, and Cholewicki (2009) investigated viscoelastic parameters in a semi-upright sitting position, and they found an increase in the spine stiffness for LBP subjects. The researchers suggested that the alterations in the spine stiffness may be due to increased trunk muscle activity to protect spinal structures. This may be a mechanism to compensate for the reduced damping as a result of the physiological changes in passive structures.

Balance control of the trunk in response to a perturbation has been investigated using center of pressure trajectory. The findings showed that there was an increase in the postural sway in LBP subjects (Cholewicki, Polzhofer, & Radebold, 2000; Preuss, Grenier, & McGill, 2005; Van Dieen, Koppes, & Twisk, 2010). However, they did not determine how the balance mechanism was related to the viscoelastic properties of the trunk.

A limitation of previous studies is the lack of ecological validity as the participants were prone or semi-upright sitting, where the effect of gravity is altered and where there was no dynamic response to a perturbation (Gardner-Morse & Stokes, 2001; Hodges et al., 2009; Latimer et al., 1996; Brown & McGill, 2009; McGill, Seguin, & Bennett, 1994). Standing position has been also used to evaluate mechanical properties in healthy subjects, and due to the contributions of the lower limbs, the effectiveness of the trunk in maintaining balance cannot be ascertained (Moorhouse & Granata, 2005).

In order to remove the influence of the lower limbs, the viscoelastic properties of the trunk would be examined in a sitting position in this experimental study, while the participants will try to regain a balanced position after been tilted on a swinging chair. This would simulate common activities such as sitting on a bus or in a car. Motion and moment data will be used to determine the viscoelastic properties of the trunk in a dynamic situation.

The aim of this study was to employ a second order linear model to derive the viscoelastic parameters of the trunk while a subject was performing a balancing task, and to examine the differences in these properties between healthy and LBP subjects. It was expected that participants would alternatively flex and extend the trunk to find the balanced position; the relation between trunk