The Influence of Lumbar Spine Passive Stiffness on Spinal Stability: Applications of Lumbopelvic Sway

Joshua Lowery[1], Kayla Fewster[2]
[1] School of Kinesiology, The University of British Columbia, Vancouver, Canada
[2] School of Kinesiology, Faculty of Health Sciences, University of Western Ontario, London, Canada
Email: kfewste@uwo.ca

Summary

Lumbar spine passive stiffness (LSPS) is considered one of the three subsystems responsible for maintaining the lumbar spine. The current work aimed to determine if LSPS could be used to quantify the mechanical stability of the lumbar spine during static standing. Twenty participants were recruited. The relationship between the natural frequency of the trunk and the mean power frequency of lumbopelvic sway was assessed. A significant relationship was observed between the two variables. These results suggest that the natural frequency of the trunk may be a reliable method to predict the kinematics of the trunk during standing, and therefore, shed light on the mechanical stability of the trunk.

Introduction

The human lumbar spine is an inherently unstable structure due to the large weight that is carried by the trunk. LSPS can be defined as the lumped stiffness of the lumbar spine's passive tissues (e.g. ligaments, tendons, intervertebral discs, fascia, etc.) and is considered an important component of spine stability, along with reflexive and active components [1], [2]. During quiet standing, the active tissues surrounding the spinal column are largely inactive [3], leaving the passive tissues of the lumbar spine responsible for maintaining the mechanical stability of the spinal column. Interestingly, trunk muscle activity and co-contraction has been observed to increase in those that develop low-back pain following a two-hour period of standing, suggesting that the ability of the passive tissues to maintain mechanical stability of the spinal column could be diminished in those with low back pain [4]. However, the role of LSPS in maintaining the mechanical stability of the spinal column and trunk is yet to be directly quantified. Therefore, the current work aimed to determine if LSPS can be applied to predict the mechanical stability of the lumbar spine during quiet standing.

Methods

Twenty participants had their LSPS quantified using a frictionless jig and completed a five-minute static standing trial. The mean power frequency of their lumbar spine angle over the five-minute standing trial was determined using a Fourier transform. The natural frequency of their trunk was estimated using their trunk moment of inertia and the stiffness of the low stiffness zone in extension, similar to previous work on the inverted pendulum model of standing surrounding the ankle joint [5]. A linear regression model was used to determine if a relationship could be observed between the sway of the lumbar spine and the predicted natural frequency of the lumbar spine modelled as an inverted pendulum.

Results and Discussion

A significant relationship was observed between the natural frequency of the lumbar spine and the mean power frequency of lumbopelvic sway over the five-minute standing trial ($p= 0.007$, $R^2 = 0.345$; Figure 1).

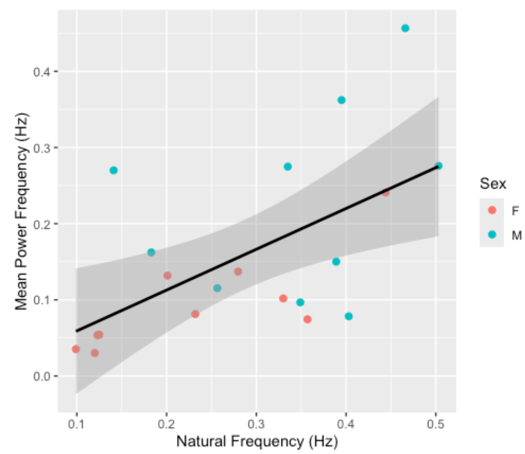

Figure 1: Natural Frequency vs. Mean Power Frequency

Results suggest that lumbopelvic sway can be accurately modelled using an inverted pendulum model atop a fixed pelvis with a tortional spring at the lumbopelvic joint. Furthermore, given that trunk kinematics during standing can be accurately modelled using exclusively lumbar spine passive stiffness, the current work suggests that LSPS is essential in maintaining the mechanical stability of the lumbar spine during quiet standing. Such findings could provide a new domain for spinal stability to be assessed, helping inform interventions and investigations aiming to understand and prevent the development of low back pain.

Conclusions

Lumbopelvic sway can be accurately modelled as an inverted pendulum using LSPS, suggesting that LSPS is essential in maintaining the mechanical stability of the lumbar spine during quiet standing.

References

[1] M. M. Panjabi. (1992a). *J Spinal Disord*, **5**: 383-389.
[2] M. M. Panjabi. (1992b). *J Spinal Disord*, **5**: 390-397.
[3] J. P. Callaghan and S. M. McGill. (2001). *Ergo*, **44**: 280-294.
[4] E. Nelson-Wong and J. P. Callaghan. (2010). *J EMG and Kinesiology*, **20**: 256-263.
[5] D. A. Winter, A. E. Patla, F. Prince, M. Ishac, and K. Gielo-Perczak. (1998). *J Neurophysiol*, **80**: 1211-1221.