Quantifying Stiffness Changes Following Passive Spinal Joint Creep: The Predictive Role of Initial Stiffness

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Summary

Lumbar spine passive tissue creep alters spinal stability and risk of low back injury. However, the role of initial tissue stiffness in moderating stiffness changes following creep remain unclear. Sixty rat tail caudal joints underwent in-vivo passive range-of-motion trials before and after the completion of a creep protocol. The relationships between stiffness change, creep amount, and initial stiffness were evaluated. A relationship existed between initial tissue stiffness and stiffness change following creep, with stiffer tissues having larger stiffness decreases. No relationship occurred between creep amount and stiffness change following creep. These findings suggest that individuals with stiffer spines may be more at risk for stiffness changes following creep.

Introduction

Passive lumbar spine tissues help maintain lumbar spine stability and limit range of motion during daily life [1], [2]. However, their viscoelastic behavior makes them susceptible to deformation and increased compliance when placed under a constant moment, termed the creep response [3]. Creep of the lumbar spine's passive tissues is associated with decreased spinal stability [2], [4], and can be initiated following prolonged lumbar flexion and repetitive lifting tasks [5], [6]. To better understand risk factors for changes in spinal stability and low back injury following creep, this investigation aimed to determine the role of initial tissue stiffness in moderating stiffness changes following creep.

Methods

Fifty-one skeletally mature Sprague-Dawley rats underwent a one-hour creep protocol with one of two moment magnitudes (15 or 75 Nmm). Moments were applied about the motion segment between the eighth and ninth caudal vertebrae using a six-degree-of freedom robotic arm with a clamp attachment and imbedded load cell. Range-of-motion trials were completed using the described apparatus before and after the creep protocol. Stiffness was quantified using a piecewise linear function. A linear regression analysis was conducted to test if initial flexion stiffness, creep amount, or moment magnitude were significant predictors of tissue stiffness change following the completion of a creep protocol.

Results and Discussion

A relationship existed between initial joint stiffness and stiffness changes following creep ($p=0.002$), with more compliant tissues having less change (Fig. 1). No relationship occurred between change in joint stiffness and creep amount or moment magnitude.

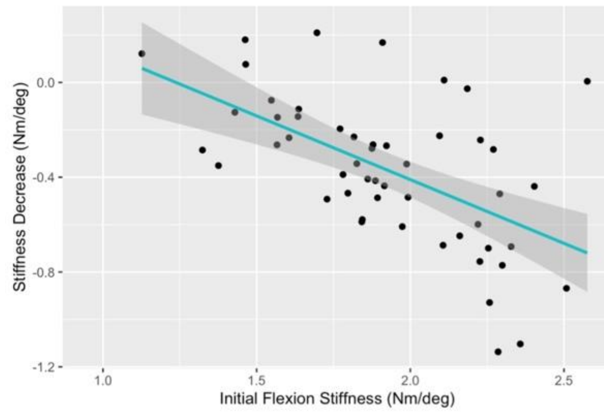

Figure 1: Stiffness Decreases vs. Initial Flexion Stiffness

Considering that the passive stiffness of the lumbar spine is essential for stabilizing the spinal column, those with stiffer tissues may be more susceptible to changes in their spinal stability following creep of their spinal passive tissues, making them more at risk for low back pain development.

One potential mechanism for this relationship could relate to the proportional contents of collagen to viscoelastic extracellular molecules within the tested tissues. In the present study, such extracellular molecules may account for much of the deformation observed on the whole tissue level, limiting the overall strain experienced by the collagen fibrils, and diminishing the resulting stiffness change in the tissue. Such findings could be of particular interest in workplace settings where prolonged flexion, and repetitive lifting are common, as they can induce creep of the spinal passive tissues.

Conclusions

Initial tissue stiffness can moderate stiffness changes following creep, possibly leaving those with stiffer lumbar spine passive tissues more susceptible to spinal instability and low back pain development.

References

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