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Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine

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Abstract

BACKGROUND CONTEXT: Prolonged sitting may alter the passive stiffness of the lumbar spine. Consequently, performing full lumbar flexion movements after extended periods of sitting may increase the risk of low back injury.
PURPOSE: The purpose was to quantify time-varying changes in the passive flexion stiffness of the lumbar spine with exposure to prolonged sitting and to link these changes to lumbar postures and trunk extensor muscle activation while sitting. A secondary objective was to determine whether men and women responded differently to prolonged sitting.
STUDY DESIGN: Passive lumbar flexion moment-angle curves were generated before, during and after 2 hours of sitting. Lumbar flexion/extension postures and extensor muscle activation levels were measured while sitting.
SAMPLE: Twelve (6 men, 6 women) university students with no recent low back pain were studied.
OUTCOME MEASURES: Quantified changes in the shapes of the passive flexion moment-angle curves (slopes, breakpoints and maximum lumbar flexion angles) were the outcome measures. While sitting, average lumbar flexion/extension angles, the distribution of lumbar flexion/extension postures, average electromyogram (EMG) amplitude, the number and average length of EMG gaps, and trunk extensor muscle rest levels were measured.
METHODS: Participants performed deskwork for 2 hours while sitting on the seat pan of an office chair. Moment-angle relationships for the lumbar spine were derived by pulling participants through their full voluntary range of lumbar flexion on a customized frictionless table.
RESULTS: Lumbar spine stiffness increased in men after only 1 hour of sitting, whereas the responses of women were variable over the 2-hour trial. Men appeared to compensate for this increase in stiffness by assuming less lumbar flexion in the second hour of sitting.
CONCLUSIONS: Changes in the passive flexion stiffness of the lumbar spine may increase the risk of low back injury after prolonged sitting and may contribute to low back pain in sitting.

Keywords: Lumbar spine; Low back; Sitting posture; Flexion; Muscle activation; Passive stiffness; Injury prevention; Office ergonomics; Gender

Introduction

As a strategy to prevent or reduce low back pain associated with prolonged sitting, many advocate that extended periods of sitting be interrupted with other non-sedentary activities. In the workplace, for example, individuals who perform extended periods of seated deskwork may be encouraged or required to periodically engage in other occupational tasks to promote changes in posture. However, the time-varying changes in the stiffness of the lumbar spine while sitting are largely unknown, and consequently

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performing certain movements after prolonged sitting may increase the risk of low back injury.

When performing deskwork, individuals adopt flexed lumbar spine postures [1], which may result in an increase in the relative contribution of the passive tissues to the maintenance of an upright torso during sitting [2]. If flexed lumbar postures are sustained, the passive flexion stiffness (PFS) of the lumbar spine can decrease over time because of viscoelastic creep [3] or stress-relaxation [4] in the posterior lumbar tissues. Increased intervertebral joint laxity observed with sustained flexion loading [5] was also attributed to fluid loss in the intervertebral discs [6]. Decreased PFS can increase the risk of a hyperflexion injury in situations whereby prolonged sitting is followed by tasks that involve full lumbar flexion.

Alternatively, evidence suggests that PFS can increase in response to prolonged sitting. Previous studies reported increased height of the spine [7,8] and decreased range of lumbar motion [1] after exposure to prolonged sitting. Although the mechanisms responsible for these observations are not completely understood, it is possible that intervertebral discs recovered height during sitting because of time-varying postural adjustments [9] and/or because of decreased magnitude of spinal loading in sitting relative to that endured in preceding activities [10]. Regardless of the mechanism, increased intervertebral disc height is believed to increase PFS by reducing slack in the flexion-resisting ligaments and posterior fibers of the annulus [5]. This reduction in intervertebral joint laxity could also subject ligaments and intervertebral discs to injurious stresses if lumbar flexion movements are performed after prolonged sitting. These two mechanisms for altered spine mechanics (ie, increased or decreased PFS) would influence the development of injury prevention strategies (eg, job-rotation schemes), depending on the specific time-varying changes in PFS with exposure to prolonged sitting.

The primary purpose of this investigation was to quantify time-varying changes in PFS with exposure to prolonged (2 hours) sitting and link any observed changes in PFS with lumbar postures and activation patterns of the trunk extensor musculature measured during sitting. A secondary objective was to determine whether men and women exhibit different responses to this exposure.

Methods

Participants

Twelve volunteers (6 men and 6 women) were recruited from a university student population (Table 1). All individuals reported no low back pain at the time of collection and had not experienced any bouts of disabling low back pain for a minimum of 1 year before testing. Informed consent was obtained from all participants for the protocol, which had been reviewed and approved by the university's office of research.

Table 1
Average (1 standard deviation) of participant characteristics

Participants	n	Age, y (SD)	Height, m (SD)	Mass, kg (SD)
Men	6	24.5 (1.9)	1.77 (0.06)	76.8 (15.0)
Women	6	23.3 (1.8)	1.62 (0.06)	58.6 (7.0)

Instrumentation

Four pairs of disposable surface electromyogram (EMG) recording electrodes (Ag-AgCl; Medi-Trace; Kendall-LTP, Chicopee, MA) were adhered to the skin bilaterally over the muscle bellies of the lumbar (L3 spinal level) and thoracic (T9 spinal level) erector spinae (ES) muscle groups [11]. A reference electrode was applied over the acromion process of the left scapula. Raw EMG signals were bandpass filtered (10–1000 Hz) and differentially amplified (common-mode rejection ratio: 115 dB at 60 Hz; input impedance: 10 GΩ) (model AMT-8; Bortec, Calgary, AB, Canada) to produce a ±2.5 V signal. The amplified EMG signals were then A/D converted at 2048 samples/second using a 12-bit ±2.5 V A/D conversion system.

A force transducer (model LC101-500; Omegadyne Inc, Sunbury, OH) was used during passive flexion trials to measure cable tension. Force transducer outputs were amplified (model S7DC; RDP Electrosense Inc, Pottstown, PA) to produce a ±1 V signal and were A/D converted at 2048 samples/second using a 12-bit ±1 V A/D conversion system.

A 3-SPACE Isotrak II system (Polhemus Inc, Colchester, VT) was used to measure lumbar flexion/extension angles. The source, emitting pulsed electromagnetic waves, was mounted over the sacrum with a specialized nylon strap, and the signal-sensing module was taped to the skin overlying the L1 spinous process. As mounted, this system was shown to provide both accurate and reliable measurements of lumbar and flexion motion in vivo [12]. Custom software was used to compute time-varying lumbar flexion and extension angles, based on the position of the source with respect to the sensor and to A/D conversion of the outputs at 30 samples/second. This software also controlled the EMG collection system so that EMG, 3-SPACE and force data were all synchronized.

Normalization procedures

An isometric maximum voluntary contraction (MVC) of the monitored muscle groups was executed according to the procedures described by McGill [11], and baseline EMG values were collected while participants rested quietly in the prone position. Digitized EMG signals were full-wave rectified before being passed through a digital Butterworth low-pass filter (2.5 Hz cut-off frequency) [13] to produce linear-enveloped EMG. All EMG signals were normalized to the maximum values obtained in the MVC task.

After the EMG MVC trial, two maximum voluntary lumbar spine flexion trials were performed. From a normal relaxed upright standing posture (regarded as the zero position), participants were instructed to maximally flex the