THE INFLUENCE OF TORSO FLEXION ON FATIGUE FAILURE OF LUMBOSACRAL MOTION SEGMENTS

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INTRODUCTION:

Recent reviews of the epidemiology literature have concluded that a number of work-related physical factors show consistent and positive associations with the occurrence of low back disorders (National Research Council, 2001). Among the workplace factors exhibiting positive associations are jobs involving manual materials handling activities, jobs involving frequent bending and twisting, and jobs where workers endure heavy loads. One common thread among the workplace factors linked to low back disorders is that they all involve situations where the tissues of the lumbar spine will be repeatedly be placed under high levels of compression and shear loading.

An important determinant of the load experienced by the lumbar spine in manual load lifting is the degree to which the torso is flexed. Torso flexion is quite common in occupational lifting activities, and epidemiologic studies have indicated that torso flexion is an important risk factor for low back disorders. Biomechanical analyses suggest that spinal loads can double or triple as a function of torso flexion angle when lifting a given weight. Not only is the load magnitude greater when the torso is flexed, but the mixture of compression and shear forces acting on the spinal segments are altered, with an increasing shear component in flexed postures. Moreover, the rate at which these loads are applied to the spine becomes greater when the torso is flexed. All of these factors may have a significant impact on the development of fatigue failure in tissues of the lumbosacral spine.

SPECIFIC AIM:

The purpose of this experiment was to carefully simulate the postures and loads experienced by the lumbar spine during repetitive lifting of moderate weights in different torso flexion postures, and to analyze the fatigue failure response of cadaver lumbosacral motion segments.

METHOD:

Twelve fresh, frozen lumbosacral spines (average age: 81 years ± 8) were obtained from the Anatomical Gift Program at Wright State University. Specimens were excised within 24 hours after death from subjects having no history of spinal disease or prolonged bed rest prior to death. Specimens were thawed at room temperature prior to dissection and testing. Intact lumbar spines were dissected into three separate motion segments: L1-L2, L3-L4, and L5-S1.

Care was taken to faithfully reproduce the loads and spinal postures adopted when lifting a 9 kg box in three trunk flexion angles: 0 degrees (neutral), 22.5 degrees (partial flexion), and 45 degrees (full flexion). A dynamic EMG-assisted biomechanical model was used to develop appropriate loads and load rates at each torso flexion angle and lumbar level (Granata and Marras, 1995). Motion segments were randomly assigned to torso flexion postures using a partially-balanced incomplete block design. Vertebral bodies were potted in trays containing polymethylmethacrylate (PMMA), the flexion angle of each motion segment being confirmed by endplate measurements obtained via multiple radiographs during the fixation process. Once specimens were properly oriented according to the torso flexion posture being simulated, they were placed in test fixtures attached to a servohydraulic test frame [Bionix 858, MTS Systems, Eden Prairie, MN]. The test fixtures were situated within an environmental chamber whose temperature was kept at approximately 37 degrees C. Moisture was introduced into the chamber to maintain a humid environment. Motion segments were creep loaded for 15 minutes and then cyclically loaded at 0.33 Hz until failure or the maximum number of cycles (10,000) was completed. Failure was defined as a displacement of 10 mm after termination of the period of creep loading. The primary dependent measure was the number of cycles to failure.

RESULTS:

The degree of torso flexion simulated when lifting a 9 kg box had a dramatic impact on the number of cycles to failure of lumbar motion segments. Motion segments experiencing the 0 degree torso flexion condition averaged 8253 cycles to failure (± 2895), while the 22.5 degree torso flexion angle averaged 3257 (± 4443) cycles to failure, and motion segments at the 45 degree torso flexion angle lasted only 263 cycles (± 646), on average (Figure 1). The difference was significant at $p < 0.0001$, and torso flexion was found to account for 50% of the total variance in cycles to failure.

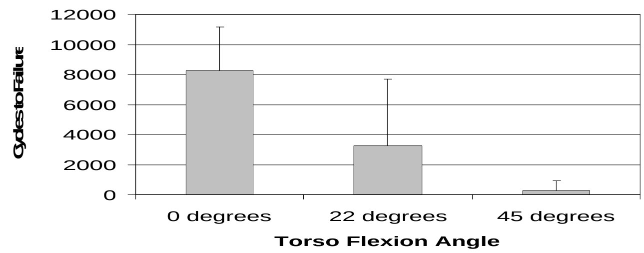

Figure 1. Average cycles to failure of lumbar motion segments at different torso flexion angles.

Differences in lumbar motion segment level did not significantly affect fatigue failure, nor did the interaction between torso flexion angle and lumbar level ($p > 0.05$).

DISCUSSION:

These results are congruent with evidence from various sources suggesting the dangers associated with torso flexion. Recent epidemiologic studies have indicated that torso flexion is an important risk factor for low back pain (e.g., Punnett et al., 1991). In the cited study, an exposure-response relationship was discovered whereby increasing duration of time in torso flexion brought about increased risk of low back pain. Furthermore, interventions designed to reduce trunk flexion (particularly early in the workday) have been shown to be effective in reducing the incidence of low back pain (Snook et al., 2002). Given the results of the current study, it seems reasonable to speculate that rapid development of fatigue failure in flexed torso positions may have considerable etiologic significance regarding these associations.

The findings of this study would appear to have important implications for the current and future manual lifting guidelines. Based on the data presented in this study, current lifting guidelines may not pay sufficient attention to the role that fatigue failure may play in the development of low back disorders, particularly the rapid development of fatigue failure under conditions of full flexion of the lumbar spine. For example, the current NIOSH lifting equation provides a variable discounting factor for frequent lifting based upon whether a load originates at above or below waist height (75 cm). However, it should be recognized that trunk flexion may vary considerably with lifts below waist height. Some may involve little or no torso flexion, while others may require full flexion. According to the data collected in this study, the difference in cycles to failure of spinal tissues between these torso flexion angles in frequent lifting may be over 30-fold.

A limitation of this study is the relatively old cohort of cadaver spines. Younger specimens are currently being sought for an additional replication of the experimental design.

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