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Changes in lumbar lordosis modify the role of the extensor muscles

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Abstract

Study Design. Fiber angles of longissimus thoracis and iliocostalis lumborum at L3 were documented in vivo, using high resolution ultrasound, with the lumbar spine in neutral curve and when fully flexed.

Objectives. To evaluate the effect of changes in lumbar curvature on the mechanics of these muscles.

Background. Full flexion modifies the failure tolerance of the lumbar spine, determines the load distribution among muscle and passive tissues, and modulates the types of tissue damage that occur. Related to this issue are the possible changes in muscle line of action with full flexion which changes the ability of the spine to support shear loads.

Methods. Nine normal men and 5 normal women were scanned in three positions: (1) an upright standing posture; (2) with the hips flexed to approximately 30° and the spine fully flexed; (3) hips flexed but the spine returned to a neutral curvature.

Results. Mean longissimus/iliocostalis fiber angles for upright standing, hips flexed-spine flexed, and hips flexed-spine neutral lordosis were 25.7°, 10.7° and 28.3°, respectively.

Conclusions. Anterior shear load on the lumbar spine has been recently shown to be highly related to the risk of reporting a back injury. Bending forward allowing the spine to fully flex changes the line of action of the largest lumbar extensor muscles compromising their role to support anterior shear forces.

Relevance

Fiber angles of longissimus thoracis and iliocostalis lumborum were documented with high resolution ultrasound at L3, with the spine in neutral curvature and fully flexed. Full lumbar flexion changes the line of action of these muscle compromising their role to support anterior shear forces on the spine – anterior shear forces have been recently documented to be highly related to the risk of reporting a back injury. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Shear force; Injury; Muscle action; Lordosis

1. Introduction

A recent review paper in *Clinical Biomechanics* [1] evaluated the biomechanical evidence to support some advantage for either stoop or squat style lifting. No unifying support could be found to preferentially advocate either. Perhaps the issue is more subtle – specifically the curvature of the lumbar spine during lifting, independent of the style of the lift may be important. Changes in lumbar lordosis have been documented to influence several aspects of spine mechanics and the potential for tissue damage. Specifically, a fully flexed lumbar spine, in contrast to a neutral posture, results in a reduced moment arm for the extensor muscles [2], a decreased tolerance to compressive load [3], and a transfer of load from muscle to passive tissues increasing the risk of injury to ligaments and more specifically increases for the risk of posterior disc herniation [4]. However, there may be yet another consideration regarding the negative effects of performing tasks with a fully flexed lumbar spine. The major lumbar extensors, namely longissimus thoracis and iliocostalis lumborum, do not run parallel to the compressive axis of the spine, but rather have an oblique orientation such that they support the anterior shear forces that result during forward flexion of the torso [5] (Fig. 1). Lumbar shear forces have been shown to be linked with elevated injury rates in industry [6]. When bending forward, one has the option of obtaining rotation from the hips, from the lumbar spine, or from a combination of both. Many

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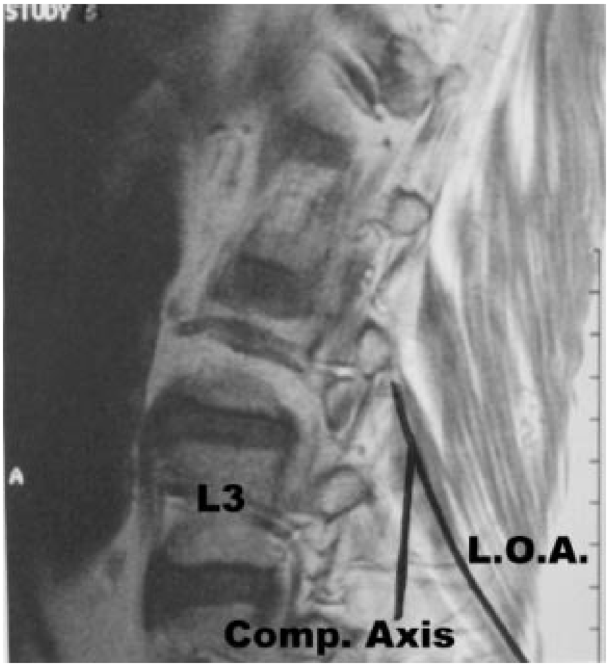

Fig. 1. Fibers of iliocostalis lumborum and longissimus thoracis originate from a common tendon arising from the posterior surface of the sacrum and medial aspect of the iliac crest. The muscle fibers branch from the tendon forming a laminated structure with a laminae to the accessory process of each lumbar vertebra. This results in a fiber orientation that resists anterior shear of the superior vertebrae on its inferior counterpart. The line of action (LOA) and the compressive axis at L3 are indicated.

have suggested it is safer to minimize spine flexion (neutral spine), requiring more hip rotation, when performing bending tasks such as lifting. In this work the question is asked "Does a change in lumbar curvature also affect the orientation angle of these major lumbar extensors thus modulating the ability to support shear forces?".

The purpose of this work, was to document the effect, if any, of changing lumbar curvature on the fiber directions of these extensor muscles thereby influencing the ability to support shear loads on the spine. Traditionally, the action of these muscles is interpreted from cadaveric specimens, however, in this study, muscle fibers were imaged in vivo using high resolution ultrasound.

2. Methods

2.1. Subjects

Nine men and five women participated in the study. The mean height of participants was 170.7 (SD, 9.2) cm, mean weight of 73.3 (SD, 12.6) kg; with a range in age from 18 to 31 years (mean 23 (SD, 3.4) years). All subjects were healthy and not experiencing any disabling low-back pain within the previous year.

Initially, subjects stood in an upright relaxed position, with feet shoulder-width apart, while anthropometric measures were taken. Body width (in mm) was measured at the level of T10, L3 and L5, using an anthropometer. Subjects were palpated and the location of the tip of the posterior spinous process of L3 was marked with a marking pen. The head of a 7.5 MHz linear array ultrasound probe (Toshiba Sonolayer, SSH 140A) was placed approximately 4 cm laterally (to the right) of L3 over the longissimus muscle group. The scanning head was coated with water-soluble transmission gel, which provided acoustic contact without depressing the skin. With the ultrasound head in place, subjects were asked to flex approximately 30° about the hips while maintaining a neutral lumbar curvature (Fig. 2). The ultrasound images of fibers within longissimus and iliocostalis were recorded using a video cassette recorder. Participants were then asked to fully flex the lumbar region while maintaining the flexed hip posture and ultrasound images recorded once again (Fig. 3). The third position for documenting fiber orientation consisted of subjects returning to relaxed upright standing.

2.2. Apparatus

Analysis of the videotape images consisted of placing a protractor on the monitor screen to document fiber angles with respect to the skin surface. Mean fiber angles for each subject in each of the three experimental positions were analyzed using a fixed-effect randomized block analysis of variance. Tukey's Multiple Comparisons post hoc test was then conducted to determine specific differences between means. Level of significance was accepted at 5% for all statistical tests.

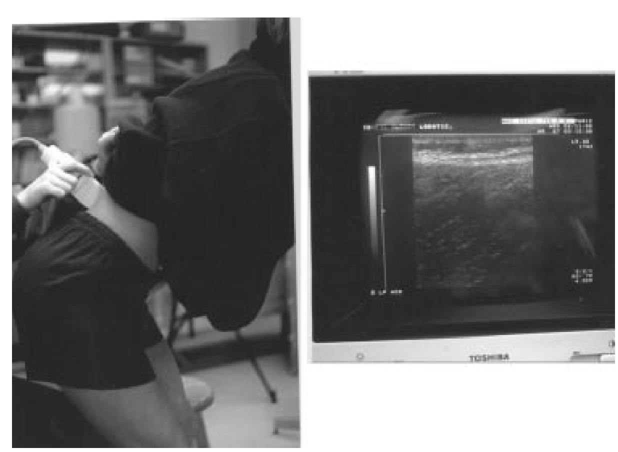

Fig. 2. Subjects rotated about the hips while maintaining a neutral lordosis to activate the longissimus/iliocostalis complex. Ultrasound images of the fibers show a large cosine at the L3 level with respect to the skin surface.

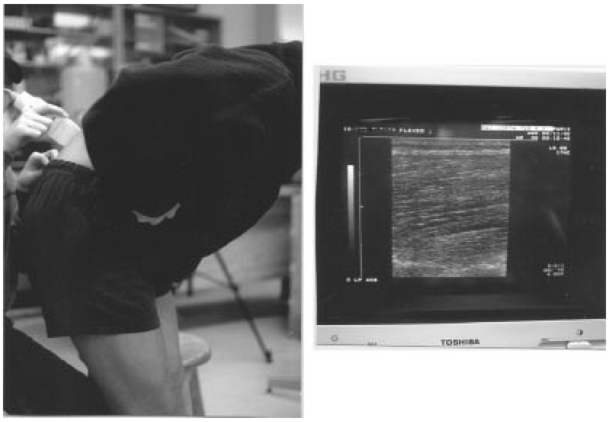

Fig. 3. Full flexion of the spine reduced the cosines of the fibers thereby reducing their ability to support anterior shear forces.

3. Results

Mean longissimus/iliocostalis fiber angles for each experimental position: full flexion, neutral lumbar curvature and relaxed standing were 10.7 (SD, 4.6°), 28.3 (SD, 4.7°) and 25.7 (SD, 5.3°), respectively. Post hoc tests revealed that longissimus/iliocostalis fiber angles were not different between standing vs. the neutral lumbar position ($P > 0.05$). However, a difference was found between fiber angles in the relaxed standing and the flexed positions ($P < 0.001$) and between the neutral lumbar and the flexed positions ($P < 0.001$). Mean body width for subjects at T10, L3 and L5 was 285.3 (SD, 33.7), 296.2 (SD, 26.9) and 314.9 (SD, 22.6) mm, respectively.

4. Discussion

Fully flexing the lumbar spine reduces the cosine of the orientation of the longissimus/iliocostalis complex thereby compromising the ability of the lumbar extensors to support shear forces that result from torso flexion. Given several other negative effects that result when the spine is fully flexed, listed in the introduction of this paper, it would appear that this spine posture should be avoided when the spine is subjected to load. Thus, the argument whether to stoop or squat lift should probably incorporate consideration of spine posture which is somewhat independent of whether a person elected to lift with bent knees or a stoop where torso flexion is achieved with hip flexion, or spine flexion, or both.

The line of action of the lumbar longissimus/iliocostalis complex has been qualitatively addressed before from cadaveric material in a neutral posture [7,8], and quantitatively examined from a combination of cadaveric sources and in vivo CT data [9] which noted the significant contribution to shear support. Macintosh et al. [10] examined the effects of flexion by tracing the attachments of the muscle fascicles onto X-ray films of subjects with flexed spines and concluded that the flexed posture resulted in major changes in shear support. In fact, there is a high degree of concordance between the data Macintosh and the directly measured in vivo data reported here: for longissimus at L3 (neutral posture) Macintosh found an orientation of 28° while this study found 25.7; when fully flexed Macintosh found 9° while this study found 10.7. Finally, it is well recognized that many muscles, including other paraspinal muscles such as multifidus, quadratus lumborum, psoas, and abdominal wall muscles possess shear vector components although these appear to be less affected by the amount of spine flexion [11].

There are several biomechanical tools/models available to assess the risk of injury in the workplace but few are sensitive to the effect of spine curvature on muscle line of action and contribution to joint compression and shear force. One model (e.g. 4D WATBAK – Ergowatch package – Univ. Waterloo, Waterloo, Canada) is sensitive to lumbar curvature and the changes in shear support for the lumbar joints which is coupled with industry based risk of injury data output forming a reasonably robust risk of injury index.

The 14 subjects used in this study were young and healthy. There results may not be applicable to atrophied patients or the elderly. Furthermore, these results were gathered from the L3 level to better control consistency in placement of the ultrasound head. However, the fiber orientation of the longissimus/iliocostalis complex at L4 and L5 have an even larger cosine (exceeding 45° at L5) implying that the compromise of the ability to resist shear at these lower levels are probably different than the data reported here from L3. Finally, interpretation of these data are limited to full lumbar flexion given the evidence of Adams et al. [12] of modest increases in compressive tolerance with mild lumbar flexion (but not full flexion).

In conclusion, this work provides one more piece of evidence for supporting the recommendation to avoid full spinal flexion during loading – this does not pertain to mild flexion. While most previous evidence was centered around the issue of compressive loading and the style of lift, data on the changing roll of the major lumbar extensor muscles from full lumbar flexion postures provides evidence documenting the compromise in low back shear force support. Workers in industry, and back patients alike would appear to benefit from the knowledge that allowing full lumbar flexion can compromise their safety.

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