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LUMBAR SPINE LENGTH AND CURVATURE RESPONSES TO AN AXIAL LOAD USING AN MRI-COMPATIBLE COMPRESSION HARNESS

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SUMMARY

This study was undertaken to study the effect of axial compression on the lumbar spine using a MRI-compatible compression device. The lumbar spine of 8 young volunteers was axially compressed with a load of 50% of the subject's body weight. Sagittal lumbar MRI was performed to assess intervertebral angle, disc height and spinal length before and during compression. A significant increase in intervertebral angle was noted at L3/4 and a decrease at L5/S1. There was a significant decrease in disc height only at L4/5. Spinal length decreased in all subjects following compression. The use of the compression device at a load of 50% body weight provides morphological simulation of the lumbar spine in upright posture. These results provide possible insights related to the relatively high frequency of lumbar disc diseases at L4/5.

INTRODUCTION

Eighty percent of humans at some time during adult life will experience significant back pain (Nachemson 1974). However, the mechanism underlying low back pain is not completely understood. A number of investigators have reported that interaction between low back pain and biomechanical changes of the lumbar spine, suggesting that low back pain is related to malalignment of lumbar curvature (Jackson et al. 1994) and disc-space narrowing (Frymoyer et al. 1984).

Willen et al. (1997) have reported that axial loading of the lumbar spine causes significant narrowing of the lumbar dural tube in patients with lumbar degenerative diseases. The purpose of this study is to determine the effectiveness of axial compression of the lumbar spine for morphological simulation of the upright lumbar spine, and to study the change of lumbar intervertebral angle, disc height, and spinal length before and during axial compression of the lumbar spine in young volunteers using sagittal MR images.

MATERIALS AND METHODS

Eight volunteers (7 men, 1 woman) with a mean age of 27 (22-36) years old participated in this study. The subjects had no previous history of spinal injuries or lower back pain. Axial compression was applied to the body, between the shoulders and the feet, in supine posture using a MRI-compatible compression device (DynaWell, DynaMed AB, Sweden). This apparatus consists of a footplate, inter-connecting straps, a vest and shoulder harness. Fifty percent body weight was applied to approximate the normal load experienced by the lumbar spine in upright posture. Sagittal T1-weighted MR images were acquired before and during compression using a 1.5T system (Magnetom Symphony, Siemens, Germany). Straight lines were drawn on the upper margin of each vertebral body at T12 to S1 to assess the intervertebral angles. Positive values reflect lordosis; negative values reflect kyphosis. The disc height was obtained from the average of anterior and posterior disc height (Dabbs et al. 1990). To measure spinal length, a horizontal line was drawn at the anterior inferior corner of the T12 vertebra and another horizontal line was drawn at anterior superior corner of the S1 vertebra. The spinal length was determined as the perpendicular distance between these two horizontal lines. To evaluate the interobserver reliability of the measurements, the first 25 measurements were compared between two independent researchers. Similarly, intraobserver reliability was compared between two sets of measurements performed by a singles researcher well. The interobserver and intraobserver reliability revealed high correlation (each correlation coefficient>0.93) between observations. Therefore, one researcher measured all parameters three times and the mean values for each of these parameters were evaluated.

Data were expressed as mean ± standard error of the means (SEM). Correlations were performed using Spearman's ranked correlation coefficient. Differences in intervertebral angle and disc height before and during compression were tested by Wilcoxon rank sum test. A P-value of less than 0.05 was considered statistically significant.

RESULTS

MR imaging during compression took 11 ± 1 min and subsequent the compression force was 48.1 ± 0.3% of subject's body weight at the end of the scanning session. The intervertebral angle was measured before and during axial compression with the results as follows: T12/L1: -0.8 ± 0.9°, -1.5 ± 0.9°, L1/2: 0.7 ± 0.5°, 3.3 ± 1.0°, L2/3: 4.7 ± 1.2°, 7.3 ± 2.1°, L3/4: 7.9 ± 0.8°, 11.1 ± 1.6°, L4/5: 14.3 ± 1.2°, 14.9 ± 0.6°, L5/S1: 25.8 ± 1.8°, 20.8 ± 2.1°, L1/S1: 53.4 ± 4.2°, 57.3 ± 5.9°. The intervertebral angle at L3/4 was significantly increased (p<0.03) during compression. In contrast, the intervertebral angle at L5/S1 was significantly decreased (p<0.02) during compression. However, that at L4/5 was not significantly altered. There was no significant change in the intervertebral angle at T12/L1, L1/2, L2/3, or L1/S1. A significant decrease in the disc height was found only at L4/5 (p<0.05). Actual disc height at L4/5 was 10.1 ± 0.4 mm before compression and 9.3 ± 0.5 mm during compression. The lumbar spinal length before and during compression was 194.4 ± 5.4 mm and 191.8 ± 5.8 mm, respectively. The decrease of spinal length averaged 2.5 ± 0.5 mm (range: 0.3 to

4.7 mm). A significant decrease in spinal length between the two conditions ($p<0.02$) was noted. However, there was no significant correlation between the spinal length and change in the overall lumbar intervertebral angle (T12/S1, $p=0.23$) or in the accumulative disc height (T12/L1 to L5/S1, $p=0.13$).

DISCUSSION

To confirm whether our device can simulate the lumbar spine in upright posture, we compared our intervertebral angles with the other those measured using plain radiographs. Wood et al. (1996) have reported that radiological intervertebral angles of the lumbar spine in supine posture in 50 asymptomatic subjects with results similar to those measured in this study. Wood et al. also measured intervertebral angles in upright posture and the results were similar to this datum in supine posture with axial compression. Furthermore, this device allows subjects to maintain stable and reasonable compression force during MRI scanning. In conclusion, these data suggest that the compression device and applied load provides close simulation of the lumbar spine in upright posture as well as a stable compression force over the scanning period.

The clinical significance of these results is likely related to the findings in the region around L4/5. The change in intervertebral angle at L4/5 was minimal and not statistically significant, however the disc height at L4/5 was significantly decreased during axial compression. Also of interest, the intervertebral angle at L3/4 increased significantly while that at L5/S1 decreased significantly during axial compression. These results suggest that the biomechanical axial stress for the intervertebral disc increases the most at L4/5 in upright posture. Interestingly, the highest incidence of lumbar disc diseases has generally been accepted to occur at L4/5 (Wisneski et al. 1999). White et al. (1990) have discussed that the relative wide range of motion at L4/5 and L5/S1 during lumbar flexion or extension may be one reason for the relatively high frequency of localized lumbar disc diseases. The results from this study may provide further insights into the understanding of the relatively high frequency of lumbar disc disease at L4/5.

In the previous studies using a similar compression device (Willen et al. 1997), axial compression of the lumbar spine resulted in significant reduction of cross sectional area of the lumbar dural sac at L3/4 to L5/S1 in patients with lumbar degenerative diseases. Furthermore, the site at L4/5 was the most frequently noted. These data may be in agreement with our data regarding the significant reduction of disc height at L4/5 during axial compression. Axial compression of the lumbar spine experienced by upright posture, leads to an increase in lumbar intradiscal pressure (Sato et al. 1999), resulting in disc bulging, and thus significant narrowing of cross sectional area of the lumbar dural sac (Willen et al. 1997).

Many *in vivo* studies have been conducted to elucidate diurnal height changes due to different positions such as quiet standing, sitting, and recumbency. Keller et al. (1999) reported an instantaneous loss in height of 11.7 mm (0.67% of body height) during quiet standing. Subsequently, contribution in the lumbar spine was 32% (3.7 mm). This datum is nearly consistent with our datum where axial compression of the lumbar spine (50% of body weight) resulted in 2.5 mm shortening at T12 to S1. However, the lumbar spinal length is correlated with neither the overall lumbar intervertebral angle nor accumulative disc height. Therefore, shortening of the lumbar spine in upright posture may result from a complex relationship of increased lordosis and shrinkage of the disc.

Astronauts often experience low back pain for first several days during space flight (Wing et al. 1991). In addition, subjects during 15 days of 6°

head-down bedrest simulated microgravity, also experience low back pain for the first several days (Hargens et al. 1998). These facts suggest that microgravity is related in the etiology of low back pain during space flight, such as changes of lumbar alignment, fluid distribution in the disc material, and tension in the intervertebral ligaments (Hargens et al. 1998). This compression device may provide new insights into postural and diurnal body height changes and the etiology of low back pain during exposure to microgravity.

CONCLUSIONS

Using a compression device, the lumbar spine of 8 young volunteers was axially compressed using a load of 50% body weight. MRI was performed to compare changes of lumbar intervertebral angles, disc height and spinal length before and during compression. This device provides close simulation of the lumbar spine in upright posture. The changes in intervertebral angle at L4/5 were minimal, however the disc height at L4/5 was significantly decreased during compression. These results may bring some understanding regarding the relatively high frequency of lumbar disc diseases at L4/5.

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