DOES A LIFTING BELT REDUCE THE SPINE MOMENTS DURING SUDDEN UNEXPECTED LOADING?

+++Lavender, S.A., +++Shakedel, K., +Andersson, G.B.J., +++Thomas, J.S. +++Department of Orthopedic Surgery, Rush-Presbyterian-St. Luke’s Medical Center, 1653 West Congress Parkway, Chicago, IL 60612, P:312-942-5000 X29724, F:312-942-2101. slavende@rush.edu

INTRODUCTION: Several occupational factors have been explored as to their contribution to low back disorders (LBD’s). In many cases the onset of back pain stems from an unanticipated loading that occurs during the material handling task, for example, when lifted objects stick together, when a multiple person lift fails, when preventing an accident, or during a loss of footing (slip). The biomechanical consequences of these sudden unexpected loads have been investigated as sudden loads were applied to the torso via the hands, and via direct application to the torso. In all studies the unexpected sudden loads led to increased loading of the spine and it’s supporting tissues. In part this occurs because of the destabilizing effects of the perturbation, and in part there may be an over reaction to the unforeseen event.

Recent research into the effects of lifting belts on trunk kinematics has indicated that the belts limit the trunk motion in the frontal and transverse planes. Limiting the torso displacement during a sudden perturbation could potentially reduce the bending and torsional moments generated by the perturbation and hence, prevent low back injury. The following specific hypotheses were tested:

1. A lifting belt reduces the trunk motion in the sagittal, frontal, and transverse planes following unexpected sudden loading.
2. A lifting belt reduces the peak dynamic external moments acting on the spine during sudden unexpected loading.

METHODS: Experimental Design: Ten males and eight females participated in the within subject repeated measures experiment. Each subject participated in a randomized sequence of 8 unexpected loading trials, one for each combination of the following three independent variables: the tension of a lifting belt (tensioned or not tensioned), the symmetry of the applied load (symmetric or 45 degrees asymmetric), and the initial weight of the box (pre-loaded or not pre-loaded). Gender was also used as a factor in the analysis. Electromyographic (EMG), dynamometric, kinematic, and kinetic measures were obtained for each trial.

Apparatus: Subjects stood on two Bertec force plates holding a plastic box with a 15 kg weight in it. An apparatus was constructed to allow a weight, attached to the bottom of the box, to fall one meter before applying a force to the box. A force gauge, in series with the weight, measured the impulse force and served as event marker within the data stream. Two equally weighted bags of lead shot were used for the sudden load and the pre-load. The weight of each bag was normalized to 7.5% of each subject’s maximum trunk extension strength measured isometrically (5 degrees/sec) with a Lido Back machine.

A magnetic tracking system, The Motion Monitor™, was used to obtain kinematic data. Twelve sensors were positioned on the head, first thoracic vertebrae (T1), first lumbar vertebrae (L1), top of sacrum (S1), left and right upper arm, forearm, thigh and shank. Sensors are connected via cable to the data collection computer and sampled at 144 Hz. The sensors were used within a calibrated region and had a mean static error of ± 6 cm.

The lifting belt was made of webbed material covered by an elastic band and tensioned at 1 cm wide by 17 cm wide that stretched anteriorly and attached with Velcro. The two lifting belt conditions consisted of the elastic being tensioned or the elastic being slack.

Procedure: After signing informed consent forms, the subject’s maximal trunk extension strength was obtained. Prior to each trial the subject was blindfolded and instructed to the belt tension condition, box orientation (sagittal symmetric or asymmetric). The box was handed to the subject and the pre-load was applied if required for the current trial. The weight was raised one meter and dropped freely after a variable interval of 3 to 8 seconds. Data were collected for 3 seconds prior to and 1 second after the loading.

Data Analysis: Kinetic and kinematic data were used to compute the external moments on the spine using a 3-dimensional dynamic linked segment model. The model calculated the bilateral reaction forces and moments up the kinetic chain from the ankles, to the knees, to the hips, and then to the junction of the pelvis and the spine (L5/S1). Peak moments and angular displacements following the load onset were analyzed using a repeated measures ANOVA.

RESULTS: Kinematic Analysis: The forward bending motion of the torso was significantly reduced when the belt was tensioned, but only during the symmetric loadings (p<0.01). On average, the decrease with the lifting belt tensioned was 1.6 degrees, or 17 percent of the sagittal plane motion measured in the thoracic and lumbar spine. The lateral flexion of the spine was significantly reduced in both symmetric and asymmetric loadings when the belt was tensioned, although, the magnitude of this change was quite small; about a third of a degree in the symmetric loadings and about .7 degrees during the asymmetric loadings. The twisting motions in the spine were unaffected by the lifting belt, even during the asymmetric loadings.

Kinetic Analysis: The forces measured by the strain gauge placed in series with the load averaged 387 N (SD = 67 N) for males and 322 N (SD =57.8 N) for females. Statistical analysis of the force data indicated a significant belt by pre-load interaction. Without pre-load there was no change in the applied force due to the belt. With pre-load, the force significantly increased (p=0.01) from 320 N (sem=9.6 N) to 338 N (sem=8.8 N) when the belt was tensioned.

Statistical analyses of the peak localized joint moments indicated significant decreases in the forward flexion moments at the spine and the right hip when the lifting belt was tensioned, although, this only occurred in the males (Spine: p=0.013; R.Hip: p=0.049). Figure 1 shows the spine moments in the males decreased from a mean of 200 Nm (SD=49 Nm) to 181 Nm (sd=43 Nm), a 9 percent change. The male right hip flexion moment decreased by 12 Nm, also a 9 percent change. There were no significant changes in the lateral bending or twisting moments at the spine associated with the lifting belt.

DISCUSSION: This study provides evidence that the lifting belt stiffened the torso through the reduction in sagittal plane motion. This is consistent with the work of others who have previously showed reduced sagittal plane motion when lifting with the lifting belt as compared to without the lifting belt. The small decrease in the lateral bending motions of the torso with the belt tensioned are consistent with earlier studies of passive trunk motion and asymmetric loading in which the belt was found to reduce only frontal and transverse plane spine motions. By itself, the small change in lateral bending motions seems of little practical significance. However, others, who loaded the torso directly via a chest harness have also identified a similar decrement in the lateral bending during asymmetric sudden loadings.

Hence, there is now some support for the hypothesis that the belt increases spinal stability during sudden unexpected loading events, even when the loading is sagittally symmetric. In summary, this study showed that a tensioning belt reduced the forward bending in all subjects and the forward bending moments in males. Admittedly, however, these are only surrogate measures for the true internal forces acting on the spine and it’s supporting tissues. While and the moments are well correlated with the spine reaction forces, the relationship becomes weaker where there is co-contraction of the trunk musculature. Clearly, a limitation of this study was the need to restrict the loads applied such that the subjects’ safety would not be compromised. Thus, given that the static loads were small compared to those typically handled in industry, one can only speculate as to the effectiveness of the belts in a lifting belt during an unexpected loading event of larger magnitude.

References: (1) Magnusson et al. ISSLS, Abstracts, Burlington, 134, 1996.