FORCES AND MOMENTS AT THE L4/L5 VERTEBRAL LEVEL WHILE FORWARD BENDING IN A SUPPORTED POSTURE

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INTRODUCTION

With a reported $20 billion spent on the management of low back pain annually (Webster & Snook, 1990), employers and health care providers have a continual interest in research focused at the identification of pain-reducing mechanisms. From a biomechanical perspective, most low back studies have focused on industrial applications, for the purpose of identifying safe load levels during repetitive lifting (McGill & Norman, 1985; Kromodihardjo & Mital, 1987). Net reaction moments during forward bending (external flexion moments) are the most commonly reported variable from such investigations.

Moments imposed on the lumbar spine during manual materials handling were used by the National Institute for Occupational Safety and Health (NIOSH) to help develop an equation for maximum allowable loads as an aid in industrial settings. Similar information applied to a rehabilitation setting can aid in determining the load limits and safest lifting postures to reduce the detrimental effects of low back pain. A biomechanical model was developed to aid in determining the loads placed on the lumbar spine using altered postures.

The purpose of this study was to assess the magnitude of reaction forces and moments imposed on the L4/L5 functional spinal unit (FSU) while performing two styles of repetitive lifting. A second purpose was to determine the relationship between these imposed forces/moments and the subjects' level of low back pain.

METHODS

Seven men participating in a chronic back pain rehabilitation program (mean age 50.3 yrs.) served as subjects for the calculation of low back moments. Nine male subjects (mean age 49.6 yrs.) participating in the same program served as subjects for the calculation of the compressive and shear forces while lifting.

The lifting activity consisted of removing a wash cloth from a mock-up of a washing machine constructed of 5.08cm poly-vinyl chloride (PVC) piping in standard top-loading dimensions. A lifting session consisted of five repetitions of each of two lifting postures. The first posture was a common bowed-back lift, with forward flexion of the spine and hips performed with both feet in a weight-bearing stationary position. The second lifting posture was chosen based on the subjects' preference for maintaining the standing curvature of the spine while lifting, to minimize back pain. The lifting posture consisted of a rotation about the hip joint of the weight-bearing leg while the contralateral leg was allowed to rotate posteriorly to aid in maintaining the standing curvature of the spine ("golfer's lift"). The subjects were allowed to use one arm to support their weight against the washing machine mock-up while performing both styles of lifts.

An inverse, sagittal plane, dynamic model was used to compute joint reaction forces and net muscle moments at the ankle, knee, hip, and L4/L5 articulations of the weight-bearing side of the body. For the bowed-back trials (double support), body symmetry was assumed about the sagittal plane, and calculations were made on the side of the body facing the camera. Anthropometric data for each body segment (ie, mass, center of mass, radius of gyration, and moment of inertia) were estimated based on tabular data from Winter (foot, shank, leg) and Zatsiorsky and Selvyanov (pelvis) derived from measured segmental lengths and total body mass of the subjects.

Self-reported ratings of low back pain were taken before the lifting tasks and immediately following the last lift. Subjects were asked to rate their level of pain on an ordinal scale from 0 to 10, with 0 equal to no pain, and 10 equal to the worst pain they had ever experienced.

RESULTS

Two profiles of lift were identified based on the sign of the peak net lumbar spinal moment (PLSM). The first profile, characterized by a negative PLSM (external flexion moment) required a contraction of the spinal extensors in reaction to the forward bending moment imposed. The negative PLSM is a commonly reported biomechanical variable that would result from trunk flexion in an unsupported posture. A negative PLSM resulted in 5 of the 7 subjects using the bowed-back posture, and in only one subject using the golfer's lift posture (see Table 1).

The second profile was characterized by a positive PLSM (external extension moment), and would biomechanically reduce/eliminate the extensor load placed on the lumbar spine during trunk flexion. A positive PLSM resulted in 2 of the 7 subjects while performing the bowed-back posture, and in 6 of the 7 subjects while performing the golfer's lift posture.

The greatest net moment differences between lifting postures occurred just following mid-lift, when concentric spinal extensor contraction would be necessary to extend the spine back to standing position. The golfer's lift. posture produced higher extension (positive) peak moment values than the bowed-back style during this phase (156.7Nm vs. 72.4 Nm). This difference is most likely the result of greater counter-balancing moments produced by the non weight-bearing leg using the golfer's lift posture.

The compressive forces calculated at L4/L5 were divided into inertial (mass x acceleration) and muscular (net moment/lever arm) components (Table 2). Load shear was determined at L4/L5 and consisted solely of the component of the reaction forces along the shear axis. The majority of the total compression force partitioned to the muscular component.

STATISTICAL DIFFERENCES

An analysis of variance (ANOVA) procedure was used to test for differences between the lifting postures on peak L4/L5 moments. The golfer's lift peak L4/L5 moment was, on average, 121.7Nm, and the bowed-back peak moment was -43.3Nm. Statistically significant [$F(1,68)=64.74$, $p<.001$] differences were found between the peak L4/L5 moments for the two lifting postures.

Pre- and post-lift pain ratings were compared for each of the two lifting postures. A Wilcoxon matched-pairs signed-ranks test showed a statistically significant increase ($p<.01$) in reported low back pain using the bowed-back lifting posture. No differences were found in reported pain after using the golfer's lift posture.

The peak muscular compressive force was found to be statistically greater ($p<.001$) for the golfer's lift posture than the bowed-back posture. Peak L4/L5 load shear forces were not statistically different ($p<0.498$) between the two lifting postures.

Table 1. Means and Standard Deviations of Peak L4/L5 Moments for Subjects Performing Two Styles of Repetitive Lifting

	Bowed Back (Nm)		Golfer's Lift (Nm)	
Subject	Mean	SD	Mean	SD
1	-128.7	11.0	-88.3	35.0
2	70.2	9.0	175.7	14.3
3	-71.2	14.4	149.8	18.8
4	-68.0	10.4	188.7	31.3
5	-101.1	11.1	105.4	13.9
6	74.6	23.2	176.3	13.0
7	-79.6	18.1	144.5	21.5

Note. Positive signs indicate an external extension moment, and negative signs indicate an external flexion moment.

Table 2. Kinetic Summary of Compressive and Shear Forces for Three Subjects Performing Two Styles of Supported Lifting. Values Represent MeanÒSD (n=5) for Each Cell.

Subject	Posture	L4/L5 Inertial Compression (N)	L4/L5 Muscular Compression (N)	L4/L5 Load Shear (N)
1	G[1]	640±50	2861±233	129±22
	B[2]	673±34	1144±147	116f16
2	G	720±32	2353±349	170±21
	B	711f52	1297±294	168±20
3	G	727±35	2871±211	113±28
	B	718±79	1214±378	129±23

[1] Golfer's Lift Posture
[2] Bowed-Back Posture

DISCUSSION

Epidemiologicalevidence has been reported for the association between lifting tasks and the occurrence of low back pain (Troup, 1965; Andersson, 1971). This study utilized a dynamic inverse biomechanical model to analyze the forces and moments at the L4/L5 functional spinal unit while performing two styles of supported lifting. These biomechanical variables were compared to the lifter's self-reported levels of low back pain to determine which biomechanical variables might influence pain while lifting.

Significant differences were found between peak L4/L5 net reaction moments produced while using the two lifting postures. Biomechanically, these differences would be caused by the varied use of the supporting arm, and the counter-balancing leg used in the golfer's lift posture. The statistically higher reported levels of low back pain following the bowed-back posture would suggest that reducing the external flexion moment may reduce the pain for some patients.

Compression forces calculated at L4/L5 were statistically higher using the golfer's lift posture than the bowed-back posture. However, due to the changing geometry of the spine during spine flexion, interpretation of these results are speculative.

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