INFLUENCE OF DYNAMIC FACTORS ON ERRORS IN CALCULATING CUMULATIVE LOW BACK LOADS DURING LIFTING

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INTRODUCTION

Cumulative low back loads such as spine compression and shear forces have been linked to the reporting of low back pain (Norman 1998, Kumar, 1990). Estimating cumulative loading presents the difficulty of documenting the variation of spinal loads over time. In order to reduce data collection and processing time when working with video records of dynamic tasks, estimates of cumulative loading from discrete static data points have been used (Norman et al., 1998; Kumar, 1990).

However, McGill & Norman (1985) reported peak L4/L5 moments from a static model of 19% lower than the dynamic model while the quasi-dynamic model findings were 25% greater than the dynamic model. Lindbeck (1991) also reported that static analyses underestimate the peak moment calculated during a dynamic lift by 23 to 100% depending on the type of lifting task. A quasi-static approach rendered data that agreed well with the dynamic model findings, with errors of less than 3%. The purpose of this study was to determine the error in cumulative spinal loads from a static or quasi-static modeling approach compared to a full dynamic model during sagittal plane lifting.

METHODS

Three males (age 23 ± 1 yr, height 1.81 ± 0.035 m, mass 88.3 ± 16.29 kg) performed each of three sagittal plane lifts, 5 times: from the floor to a table 73 cm above the ground; from a shelf height of 138.3 cm to a table 73 cm above the ground; and from the floor over a barrier of 55.3 cm to the floor. Lifts were performed at speeds of 0.2, 0.4, and 0.8 m/s with loads of 2.3, 8.8, and 15.9 kg for a total of 135 lifts. A jig equipped with a force transducer was used to measure the hand forces during lifting. The subjects performed each of the lifts five times. One lift per subject for each of the 27 lifting conditions was chosen for analysis. A complete lift cycle consisted of starting from upright relaxed standing, picking the load up, placing it on the appropriate surface, and returning to upright standing (Figure 1).

![Figure 1](image-url)  
**Figure 1**: L4/L5 joint compression for one trial, lift from floor to table, 8.8kg, medium speed, calculated by the three models.

Reflective markers at the wrist, elbow, shoulder, C7/T1, ear canal, and L4/L5 were auto-digitized using a PEAK Performance system at a rate of 60 Hz. Each trial was then run through a biomechanical model to yield
compression, joint shear, and reaction shear forces (N), and moment (N.m) at L4/L5 using a static, quasi-static, or dynamic link segment approach. Bone on bone forces were calculated for each frame using a single muscle equivalent approach with a 6 cm moment arm and 5.3/ angle of pull. Cumulative values were calculated by rectangular integration of each variable. A four way repeated measures ANOVA (dependent variables = task X approach X speed X mass, $\alpha = 0.05$) was used to compare the cumulative spine loading for the various tasks. Ryan-Einot-Gabriel-Welsch Multiple Range posttests were used to compare significant findings.

RESULTS AND DISCUSSION

Cumulative compression values were significantly different between each of the three modeling techniques across task, speed, and mass ($p<0.01$)(Figure 2). For reaction shear, joint shear and moment the static approach was significantly different ($p<0.01$) from each of the other two models while the dynamic and quasi-static models were not significantly different (Figure 1).

![Figure 2: Cumulative moment and force (+1sd) calculated using each of the three modeling approaches. Compression is plotted against the secondary y-axis.](image)

The relative differences between the static and dynamic approaches (Table 1) are smaller than those previously reported in the literature for peak loading (Lindbeck, 1991). The lower error for cumulative loading, compared with previously reported peak errors, can be attributed to the static and quasi-static models over predicting forces and moments when the accelerations are beneficial to the lifting action. These areas tend to offset the under prediction of joint loads at instances like the initiation of lifting, when the inertial forces contribute largely to the joint forces and moment (Figure 1).

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SUMMARY

Although there were statistically significant differences between the cumulative loading values determined from each of the models the relative differences were extremely small for quasi-static compared with dynamic and were in the range of 10% when a static model was used. These initial findings support the use of static models to estimate cumulative low back loading during sagittal plane lifting tasks of varying speeds and loads. Further study of more complex tasks involving asymmetrical postures is necessary.

REFERENCES