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## Workplace Factors and Trunk Motion in Grocery Selector Tasks

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### INTRODUCTION

Thousands of workers in the United States are employed as grocery selectors, a job requiring manual selection of grocery products from a warehouse for delivery to individual grocery stores. The selection process consists of lifting and carrying large volumes of case-size grocery products from pallets located in storage racks to shipping pallets located on a motorized jack that is moved along the aisles. The national rate of back injuries for grocery selectors is not known, but as an occupation, males working in the wholesale grocery industry have an estimated annual prevalence of back pain caused by an 'activity at work' of 16.4% (Guo, 1993). Results of a survey of Workers' Compensation programs, supplied by the National Association of Wholesale Grocers Association (NAWGA) and the International Foodservice Distributors Association (IFDA) for the year 1990, revealed that back sprains/strains accounted for 30% of all injuries for food distribution warehouse workers. The report also indicated that in one case, more than 54% of the back injuries were attributable to manual lifting.

The job of grocery selector is generally recognized as physically demanding, primarily because of the frequent repetitive twisting, lateral bending, and asymmetric, heavy manual lifting demands associated with these jobs (Garg et al., 1983). It is believed that excessive rotation or rapid movements at the low back during manual materials handling may significantly increase a worker's risk of developing a low back disorder (LBD). Specifically, results of several epidemiological studies (Snook et al., 1978; Frymoyer et al., 1980; Bigos et al., 1986; Punnett et al., 1987; and, Marras, 1990) indicate that repetitive twisting or lateral bending and lifting, even for relatively light loads, are significant risk factors for overexertion injury.

Further research is needed to quantify the relationship between the magnitude of these trunk motions and the risk of developing a LBD. Specific studies would include measures of the worker's trunk position, velocity, and acceleration as he or she performs a lifting task.

Recently, Marras et al. (1993) developed a logistic regression model to estimate the probability that a specific job would be a member of a group of jobs with "high risk" for low back disorder (LBD). According to Marras, a "high risk" job is associated with at least 12 injuries per 200,000 hours of exposure. Marras' model is based on five workplace and trunk motion variables that include: (1) lift rate, (2) maximum static spinal moment, (3) maximum sagittal flexion, (4) average twisting velocity, and (5) maximum lateral velocity. A scaled average of these variables indicate a job's overall probability of high risk group membership.

### Purpose

A project was recently undertaken by the National Institute for Occupational Safety and Health (NIOSH) to evaluate the physical demands of warehouse grocery selectors. A small study was designed to collect workplace measures and trunk motion data to determine the level of physical stress associated with a particular lifting task. A subset of these measures was used to apply the model developed by Marras et al. (1993) to predict if warehouse grocery selectors were at high risk for LBD.

### METHOD

Three conditioned, male grocery selectors in good health participated in the study. All subjects were informed of the experimental procedures before the experiment began.

### Grocery Selector Job

For this study, the job of a grocery selector consists of a worker repetitively performing order selecting cycles, where each cycle takes between 15 and 45 minutes to complete. Each order selecting cycle consists of a worker obtaining an order from the central office, driving a motorized jack to a stack of empty pallets, placing one or two pallets on the jack, and then moving along the aisles where the products are stored to select cases of items listed on the order. The worker can either ride on or walk

beside the motorized jack when moving between various products. The selection of individual cases of products for the order involves various combinations of walking, carrying, lifting, lowering, bending, twisting, pushing, and pulling. Each of these activities requires varying amounts of tri-axial lumbar motion. Each grocery order represents a single work cycle.

#### Procedure

The study consisted of instrumenting the three subjects, one at a time, with a Lumbar Motion Monitor (LMM) (Chattecx Corp., Hixon, Tennessee). The LMM is a computer-monitored tri-axial goniometric system designed to measure the instantaneous position of the thoraco-lumbar spine of a subject engaged in a dynamic activity. The design of the LMM has been reported elsewhere (Marras and Fattalah, 1992). For this study, the LMM was used to collect tri-axial rotation angles, velocities, and accelerations about the L5/S1 intervertebral joint for a total of 216 individual lifts for the three subjects.

Data were collected on the position and motion of the lumbar trunk for as many individual lifts as practical during a single cycle for each subject. In addition, the weight of each grocery case and the vertical and horizontal location of the case relative to the worker's L5/S1 joint was recorded.

Prior to each lift, the subject was asked to identify the origin and destination of the lift, so that it could be assigned into one of three categories, depending on the vertical height of the lift. Because the output from the LMM could not differentiate between the origin and destination of the lift, each lift was assigned as follows: (1) any lift with either the origin or destination below 30 inches was assigned to the low height category; (2) any lift with both the origin and destination height between 30 and 50 inches was assigned to the medium height category; and, (3) all others were assigned to the high height category. The 30 and 50 inch height levels were chosen to correspond to the approximate knuckle and chest height of an average male. Finally, just prior to data collection, the subject was instructed to stand as still as possible in an erect posture, to obtain a baseline LMM reading that could be used to normalize the position and motion data.

Although the subjects were instructed to perform each lift as if they were working at their

normal pace, it was necessary to interrupt the worker between each lift of the job cycle to initialize the sampling software for the LMM. Therefore, the trunk motions collected in this study may differ from trunk motions that may have been collected under uninterrupted conditions.

## RESULTS

Summary statistics were determined for fourteen variables, including four workplace measures and ten trunk motion measures. The four workplace measures included average load weight, vertical height of the bottom of the box from the floor at liftoff, horizontal distance of the hands from the L5/S1 joint at liftoff, and the estimated lift rate. The ten trunk motion factors included the maximum rotation angle, maximum rotation velocity and maximum rotation acceleration of the L5/S1 joint about the three principal body planes (sagittal, frontal, and transverse), as well as the average transverse rotation velocity. Finally, the maximum spinal moment, which is needed to use Marras' multiple logistic regression risk assessment model, was determined by taking the product of the average load weight and horizontal distance.

#### Workplace Factors

Vertical Height. Table 1 summarizes the distribution of lifting height conditions by origin and destination for the 216 lifts that were monitored with the LMM.

Inspection of Table 1 reveals that the 216 lifts were fairly evenly distributed with regard to origin and destination height, with 37, 28, and 35 percent originating in the low, medium, and high range, respectively, and 23, 37, and 40 percent ending in the low, medium, and high range, respectively. Only 7 percent of the lifts started and ended in the medium range. This finding indicates that the majority of the tasks required lifting motions that began or ended either in the high or low range. As described previously, the lifts were assigned to one of three groups prior to data analysis, depending on the starting and ending heights. Thus, of the 216 lifts that were monitored, 53 percent started or ended in the low range and were assigned to the low category, 7 percent started and ended in the medium range and were assigned to the medium category, and the remaining 40 percent were assigned to the high category.

**Weight of Load.** The average weight of the load for the 216 lifts was 30.4 pounds (135 N).

**Horizontal Distance of Load from Spine.** The average horizontal distance of the load from the spine at the origin of the lift was 27.0 inches (.69 M).

**Lift Rate.** It was not possible to sample the lifting rate that actually would have occurred during the work cycles because the workers were interrupted between lifts. The estimated lifting rate, however, was determined from the performance data provided by the company for the three work cycles. Assuming 100% performance, the lifting rate for the three order selecting cycles was estimated to be 307 lifts/75 minutes, which is equivalent to 4.1 lifts/minute or 246 lifts/hour.

**Maximum Spinal Moment.** The maximum spinal moment for an average lift is the product of the average horizontal distance (27.0 inches) and the average load weight (30.4 pounds). Thus, the maximum spinal moment is 821 in·lbs or 93 N·M.

#### Lumbar Motion

**Rotation Angle.** As the height category increased, there was a significant decrease in the maximum sagittal rotation angle in flexion ( $p = 0.047$ ). The means for the maximum sagittal rotation angle recorded for the low, medium, and high categories were 56, 38, and 28 degrees, respectively. On the other hand, there was no significant difference in the maximum frontal or transverse rotations associated with changes in the height category. The means for the maximum frontal rotation for the low, medium, and high height categories were 10.3, 11.3, and 8.0 degrees, respectively. The means for the maximum transverse rotation for the low, medium, and high height categories were 13.2, 15.6, and 15.9 degrees, respectively.

**Rotation Velocity.** The maximum rotation velocities for each height category followed a pattern similar to the rotation angle values. As the height category increased, there was a significant decrease in the magnitude of the maximum sagittal flexion rotation velocity ( $p = 0.032$ ). The means for the maximum sagittal flexion velocity for the low, medium, and high height categories were 65.9, 51.8, and 34.0 degrees/second, respectively. As with the range of motion variable, there was no significant difference in the maximum frontal or transverse

velocity between the three height categories. The means for the maximum frontal velocity were 31.0, 33.3, and 26.0 degrees/second, for the low, medium, and high category, respectively. The means for the maximum transverse velocity for the low, medium, and high height categories were 42.6, 46.2, and 43.2 degrees/second, respectively. In a recent paper by Marras et al. (1993), it was reported that the average twisting (transverse) velocity during a dynamic activity was a better predictor of injury risk than the maximum twisting velocity. Therefore, the average transverse rotation velocity also was determined for each lift. The means for the average transverse rotation velocity for each of the three height categories were 5.9, 5.8, and 6.5 degrees/second for the low, medium, and high height categories, respectively.

**Rotation Acceleration.** The maximum accelerations also followed a pattern similar to the rotation angle and velocity parameters. As the height category increased, there was a decrease in the average peak sagittal rotation velocity, but it was not statistically significant ( $p = .079$ ). The means for the maximum sagittal acceleration for the low, medium, and high height categories were 266.0, 225.2, and 144.1 degrees/second<sup>2</sup>, respectively. Neither the maximum frontal acceleration nor the maximum transverse acceleration varied significantly between the three height categories. The means for the maximum frontal acceleration for the low, medium, and high height categories were 137.6, 151.6, and 120.2 degrees/second<sup>2</sup>, respectively. The means for the maximum transverse acceleration for the low, medium, and high height categories were 197.1, 209.7, and 196.2 degrees/second<sup>2</sup>, respectively.

#### Risk Assessment Benchmarks

The five variables needed to use Marras' multiple logistic regression risk assessment model were determined for each of the three lift categories. The probability of high risk group membership, as defined by Marras' model, was computed for each of the five variables for each of the three categories. The overall risk probability for each height category was then determined. The results are displayed in Table 2. As shown in Table 2, the overall probability of the lifting tasks posing a risk for the workers was 66%, 67%, and 65% for the low, medium, and high height categories, respectively.

### Incidence Rates

As part of the evaluation, the company's OSHA 200 logs were reviewed for the previous 5 years for evidence of back injuries, overexertion, sprains, and strains. Based on the OSHA logs and the work records of the company, grocery selectors had an incidence rate of approximately 28 back injuries per 200,000 hours of work exposure.

### DISCUSSION

The results were initially examined to determine which trunk motion and workplace factors might significantly increase a worker's risk of developing a low back disorder. The results indicate that movements in the sagittal plane required the greatest spinal movement, regardless of the height of the lift. In particular, the low height lifts were associated with the greatest sagittal rotation angle (56 degrees), and highest velocities and accelerations. Because spinal forces increase as the flexion angle increases, and more than 53% of lifts involve extreme sagittal flexion, these tasks would be associated with the greatest biomechanical spine loading, especially when the increased accelerations are considered. The spine, however, has the greatest mobility in the sagittal plane, and may tolerate forces associated with these motions more easily than motions outside of the sagittal plane. Although the magnitude of the motions in the transverse and frontal planes are smaller than those in the sagittal plane, it is possible that these non-sagittal motions may pose a greater risk for injury.

In terms of workplace factors, we were interested in three specific issues: lift rate, maximum spinal moment, and lifting duration. Two of these factors, lift rate and maximum spinal moment, are included in Marras's risk assessment model. Using Chaffin's 3-D strength prediction model (Chaffin and Anderson, 1984), the maximum spinal moment produced by an average lift would be 93 N·M, which would require between 4050 and 4950 N of erector spinae muscle force, depending on the vertical height of lift. These biomechanical loads would generate between 4250 and 5050 N of static, disc compression force, which exceeds the disc compression force criterion of 3400 N used in the revised NIOSH lifting equation (Waters et al. 1993). Moreover, Marras et al. (1993) indicated that the maximum moment was the single best predictor of risk of injury. The lift rate is important because the physiological energy demands of continuous lifting at

a rate of 4.1 lifts/minute (246 lifts/hour) could result in fatigued muscles, especially when extended shifts of more than eight hours are considered.

Finally, even though Marras' model has not been fully validated, it indicates that it is highly probable that warehouse grocery selecting would be categorized as a "high risk" job. This suggests that it is likely that there would be more than 12 injuries/200,000 hours of work exposure for grocery selectors. This is in agreement with the reported incidence rate of 28 back injuries per 200,000 hours of work exposure in this study, which is well above Marras' high risk limit of 12 injuries per 200,000 hours of exposure. On the other hand, the results displayed in Table 2 indicate that Marras' regression model may not provide a sufficient range of prediction for some variables, such as maximum spinal moment and maximum sagittal rotation angle. In this case, the model indicated that the probability of high risk group membership for a task with a maximum sagittal rotation angle of 28 degrees was the same as that for a task with a maximum sagittal rotation angle of 56 degrees. This suggests that the model may underestimate the overall probability of high risk group membership.

A larger more comprehensive follow-on study of warehouse grocery selectors is planned for the future.

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TABLE 1 Lifting Task Conditions by Origin and Destination  
Number (% of 216 Total)

Origin	Destination			Total
	Low	Medium	High	
Low	15 (7%)	36 (17%)	29 (37%)	80 (37%)
Medium	10 (5%)	16 (7%)	34 (16%)	60 (28%)
High	24 (11%)	28 (13%)	24 (11%)	76 (35%)
Total	49 (23%)	80 (37%)	87 (40%)	216 (100%)

TABLE 2 Probability of High Risk Group Membership  
Numbers in parenthesis represent individual risk factor probability

Vertical Height Range	Lift Rate (Lifts/HR)	Maximum Spinal Moment (N·M)	Maximum Sagittal Rotation Angle (Degrees)	Average Transverse Rotation Velocity (Deg/Sec)	Maximum Lateral Rotation Velocity (Deg/Sec)	Overall Probability
Low	246 (77%)	92.0 (99%)	55.7 (99%)	5.9 (26%)	31.0 (28%)	66%
Medium	246 (77%)	126.0 (99%)	37.5 (99%)	5.8 (26%)	33.3 (32%)	67%
High	246 (77%)	87.0 (99%)	28.0 (99%)	6.5 (30%)	26.0 (20%)	65%

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