Manual Materials Handling

Training in Lifting

Do good lifting techniques adversely affect case-handling times?

By Steven A. Lavender, Eric Lorenz and Gunnar B.J. Andersson

PERSUADING EMPLOYEES TO MODIFY their lifting behavior is a challenge due to the perception that use of good lifting techniques takes too much time. This is particularly important in distribution jobs where performance is continuously monitored relative to productivity standards. This study attempted to quantify the change in case-handling times associated with a new method for training lifting techniques. The training process used a combination biofeedback instrumentation and one-on-one coaching to guide participants toward improved lifting behaviors. Each of the 265 participating employees received a 30-minute training session. At completion of the session, each participant was classified by the coach as adopting either a two-step, pivot or swing technique.

Overall, the training led to a non-significant increase (0.1 seconds) in the mean case-handling time. However, those adopting the two-step technique took an average of 0.33 seconds longer per case ($p<.001$). Those adopting the pivot technique showed no difference in case-handling times and those adopting the swing technique reduced their times by 0.36 seconds ($p<.001$). While those adopting the two-step procedure fared best with regard to spine loads, on average, all techniques reduced the 3-D spine loads (moments). Thus, it is possible to provide training on lifting behaviors that work within the context of productivity demands which, while not necessarily optimal, have the potential to a significantly reduce the internal spine loads experienced in fast-paced repetitive lifting jobs.

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Biomechanical loading of the spine when lifting is dependent, in part, on the way a given lifting task is structured in terms of physical parameters that describe the work layout and the way the task is performed [Buseck, et al; Bush-Joseph, et al; Danz and Ayoub; Delisle, et al; Marras and Davis; Marras, et al(a); Schipplein, et al]. Therefore, given what is known about the relationships between spine tissue loading and injury mechanisms, it is reasonable to believe that the manual materials handling techniques used by workers will affect their likelihood of back injury.

As a result, considerable effort has been expended to train individuals in proper lifting techniques. However, research has found that classical back education is largely ineffective in terms of actually controlling injuries and losses (Daltroy, et al; van Poppel, et al). In fact, these studies have shown that while participants understand the concepts behind good manual materials handling techniques, few elect to use them. As with many types of ergonomics controls, a training intervention must result in a behavioral change in order to achieve the desired reduction in tissue loads and the reduced potential for cumulative trauma injuries.

Why has training in lifting techniques not achieved behavioral change? First, one must consider the method of training. Teaching intellectual concepts is not the same as teaching a motor skill. Typical lifting training covers how the back is constructed; the types and magnitudes of loads placed on the spine; and how "good" lifting techniques affect spine loads; it may also include demonstrations of proper lifts and, in some cases, employees are asked to practice lifts at the end of the program.

Second, trainees must buy in to the notion that the behaviors learned will be effective in their work environment. In the authors' experience, many workers believe that improving their lifting methods will impede their ability to meet productivity demands. This is particularly true in grocery distribution centers, where most "selector" employees are continuously monitored for productivity levels that are, in turn, compared with a productivity-based work standard.

The current analysis was designed to determine how much extra time it actually takes to lift using techniques that effectively reduce spine load. Specifically, the following hypotheses were tested:

1) Overall, training employees in lifting techniques that demonstrably reduce the 3-D spine moments do not result in significantly longer case-handling times.

2) The change in case-handling times following training depends on the case-handling style adopted.

Study Methods

Sample

These data are from a larger study designed to quantify the efficacy of a biofeedback training approach to prevent low back disorders among those working in distribution jobs. The current sample is comprised of 265 participants who work as selectors in four grocery distribution centers. Their primary job function is to fill orders placed by individual grocery stores by palletizing the requested items. Cases typically weigh between five and 80 lbs. At the participating distribution centers, productivity measures mandate that 160 to 260 cases be palletized per hour. The higher number is typically associated with departments that have a higher pick density and usually lighter cases (e.g., freezer or dairy). However, selectors often lift more than one smaller case at a time, thereby reducing the number of lifts per hour to between 160 and 180.

Lifting Training

Consistent with research that advocates an interactive training process (Barker and Atha), each 30-minute training session was conducted by a coach using a one-on-one format. At the core of this process was a motion measurement system called The LiftTrainer™. With this system, each participant was instrumented with sensors used to track his/her movements as lifts were performed (Photo 1); software then used movement data and case weight data to instantaneously calculate the 3-D dynamic moment (torque) vector acting on the spine. The magnitude of this moment vector was used to adjust the pitch of a tone—the biofeedback signal—heard by the participant. The higher the instantaneous spine moment magnitude, the higher the pitch.

Moments were calculated using a dynamic 3-D-linked segment model that started with the weight held in the hand and computed the moments bilaterally in the elbows and shoulders, and that at the L5/S1 joint at the base of the spine. Thus, the moments were affected by the 3-D lifting posture, the case's trajectory, the speed of the lifting motion, the amount of weight lifted, and how quickly the case and body were accelerated. Data were sampled and the moment vector calculated at 103 Hz. Thus, the biofeedback signal provided the participant with information regarding both the instantaneous magnitude of the resultant moment, as well as when and where during the lifting process the moment peaked. At the completion of each series of lifts (usually four lifts), the 3-D spine stresses were displayed graphically, providing the trainee with additional visual feedback.

Photo 1: The LiftTrainer™ system used a magnetic motion measurement system. Cases were moved between the two scales sitting on the pallets.

Study Protocol

After signing an approved informed consent document, sensors from the magnetic motion measurement system were placed on the left and right lower and upper arms, over the superior portion of the sacrum, over the first thoracic vertebrae and on the back of the head. Sensors placed on the arms were attached with Velcro cuffs; on the torso (T1) with a harness arrangement; on the sacrum with a belt; and on the head with a clip attached to a cap worn by the participant. Once instrumented, each individual's height, weight and body segment lengths were measured; these data were used to customize the biomechanical model for each participant.

Participants performed a case-handling task that simulated the essential functions of the order-selecting job. To complete this task, the operator, after driving and/or walking a pallet jack to the warehouse slot location identified in a work order, transfers one or more cases from the pallet in the slot to the shipping pallet carried on the pallet jack. This function was simulated by having several identical cases sitting on a scale placed on top of a pallet in the slot. Cases would be transferred to another scale that was at the same height and location as the delivery pallet on the pallet jack (Photo 1). The task required the participant to move four cases at his/her normal pace from one pallet to another. Cases handled at the three distribution centers were items normally shipped by each. Therefore, while the actual product handled varied between sites, the cases used in the training all weighed 12 to 13 kg (26.45 to 28.66 lbs.) and were consistent for each individual.

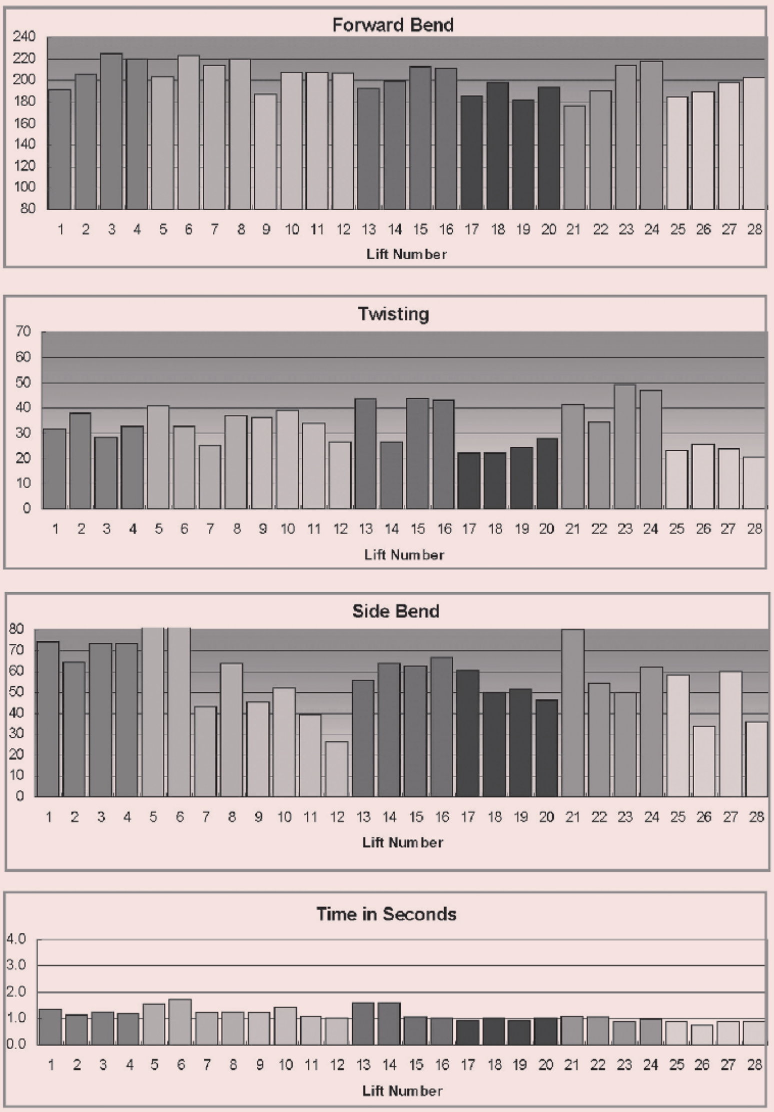
At the beginning of each training session, the participant was asked to demonstrate how s/he would normally complete the lifting task. Data collected during this first set of lifts served as baseline data. Following each set of lifts, the peak 3-D moments were displayed graphically (Figure 1). This provided the participant with feedback on the peak forward-bending, twisting and side-bending moments incurred during each lift. Case-handling times, defined as the interval of time that the lifted cases were not on either scale, were also presented (Figure 1).

The coach explained the charts following each set of lifts and identified opportunities for improve-

Figure 1

The LiftTrainer™ Moment Evaluations

LiftTrainer™ progress charts shown to the trainee following each set of lifts. Sets are separated by different shading of the bars. The top chart shows the peak forward-bending moment that occurred during each lift. The second and third charts show the peak spine-twisting and side- bending moments, respectively. All charts that show moment data are in Newton-meters (Nm). The bottom chart shows the duration of each lift in seconds.



ment. In the example shown in Figure 1, the baseline set (first four bars on the left) indicated that the employee's lifting technique resulted in high forward-bending and side-bending moments (referred to as "stresses" by the coach). The coach then introduced the biofeedback tone and explained the relationship between the participant's lifting behavior and the pitch of the tone. Once the employee was familiar with this relationship, the coach guided him/her toward lifting behaviors that lowered the spine moments and, consequently, the pitch of the tone. At the end of the session, the tone was turned off and the participant was asked to repeat the task. This final set of lifts provided the evaluation data (last set of bars on the right in each chart of Figure 1) and was subsequently compared with baseline data to quantify the improvement in spine moments achieved during training.

Characterization of Lifting Style

At the completion of a session, the coach classified each participant's final lifting style. In general, participants adopted one of three lifting styles. Subjects were classified as using the "two-step" style if they initiated lifts by facing the case, taking two steps to complete the 180-degree turn, then completing the lift again facing the case. A participant using the "pivot" style usually initiated the lift by picking up the case from the side, taking one step, then pivoting on the leg closest to the lift destination, and completing the lift facing the scale on which the case was placed. Those adopting the "swing" style did not move their feet; their lifts were initiated and terminated with lateral reaches.

Data Analysis

For each trainee, data from the four baseline lifts were averaged, as were the data from the four evaluation lifts. Changes in lifting times and directional spine moments were quantified by taking the difference between baseline and evaluation means for each participant. Baseline and evaluation means were used as the dependent measures in two-way repeated measures analyses of variance with the two factors being the within-subject training effect (before vs. after) and the lifting style (three styles). A multivariate analysis of variance was conducted for the 3-D components of the moment data. Then, separate analyses of variance were conducted for each moment direction using SAS software.

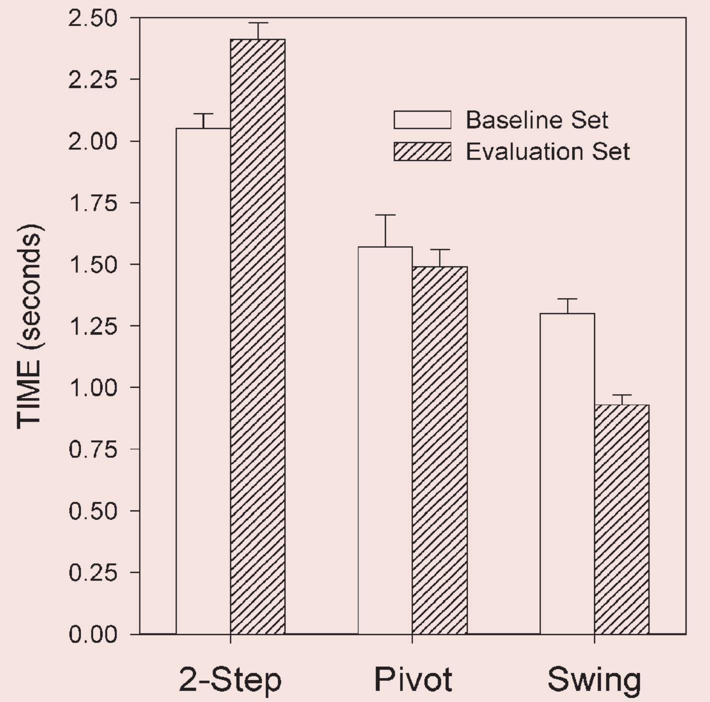
Study Results

The mean case-handling time during baseline sets was 1.8 seconds (s.d. = 0.8 seconds). At the completion of the training, case-handling times increased only slightly to 1.9 seconds (s.d. = 1.0 seconds). Thus, overall, no significant change was found in case-handling time with the training ($p>.05$). However, when data were analyzed as a function of lifting style, case-handling times changed with training.

Statistical analyses indicated that the final case-handling times and the change in these times differed significantly across the three identified lifting styles ($p<.001$). Figure 2 shows the shortest lift duration was found for those using the swing technique, followed by those using the pivot technique, then those using the two-step technique. Two-step lifters increased their case-handling time by 0.33 seconds ($p<.001$); those adopting the swing technique reduced their case-handling time by 0.36 seconds ($p<.001$); and those using the pivot technique showed essentially no change. It is interesting to note that while the style characterization was based on the lifting style at the conclusion of training, those who adopted the two-step technique had significantly longer case-handling times in the baseline session

Figure 2
Lifting Style

The mean lift duration during the baseline and evaluation sets as a function of style. Error bars are one standard error of the mean (SEM).



when compared with those who adopted the pivot technique (p<.05). Those who adopted the pivot technique had significantly longer case-handling times than those using the swing technique (p<.05).

The 3-D spine moments changed as a function of the training (p<.001). However, the magnitude of the change was largely dependent on the trainee's lifting style. Figure 3a shows that while the forward-bending moments were reduced regardless of lifting style, they were reduced the most (15 percent) when trainees adopted the two-step technique. Reductions in the forward-bending moment were much more modest (four to five percent) with the pivot and swing techniques. Figure 3b shows the distribution of improvements as a function of lifting style; it indicates that more than 80 percent of employees who adopted the two-step technique reduced their forward-bending moments as compared with only 65 to 70 percent of those who used the other two techniques.

The twisting moments were significantly reduced by an average of 23 percent with the training. Figure 4a shows that twisting moments in the final set were significantly lower for those adopting the two-step technique. Across the three lifting styles, twisting moments were reduced by between 10 and 12 Nm. The larger percent change observed with the two-step technique (Figure 4b) was attributable to the fact that those using it showed lower twisting moments during their baseline sets (p<.05).

Side-bending spine moments were reduced on average 25 percent, from 68 to 46 Nm. These moments were reduced by essentially the same amount regardless of the final lifting style adopted (Figure 5a). However, like the twisting moments, the side-bending moments in the final set were significantly smaller for those using the two-step technique (Figure 5b).

Discussion

Overall, this training program quantifiably and significantly reduced spine loads without adversely affecting case-handling times. However, this result was dependent on the lifting style adopted. The two-step technique increased average case-handling time by just under one-third of a second, while the pivot and swing techniques did not add to case-handling times. While one-third of a second for a single lift may appear insignificant, some trainees noted that the cumulative effect of this time increment across 160 cases picked in an hour would increase total case-handing time by just under one minute per hour, or seven minutes per day. In reality, most participants indicated that they typically work at rates 10 to 40 percent above those required by the productivity standard, which often buys them "free" time during a shift. Thus, each worker must decide whether s/he wants to spend some of that extra time using better lifting techniques.

Moment data show that the two-step technique resulted in the lowest forward-bending, twisting and side-bending moments. This suggests that if the employees can be convinced to use this technique, the payoff will be reduced spine moments in all three directions. A casual observation was that those who adopted the two-step technique often said it felt slower than it actually was. This further illustrates the value of obtaining objective data when attempting to convince employees to modify their behavior.

Persuading employees to modify their lifting behavior is a challenge due to the perception that use of good lifting techniques takes too much time.

For those unwilling to take the extra time, the training program was still beneficial. Marras, et al(a; b) have shown that repetitive lifting which includes twisting and side-bending motions increases the risk of low-back disorders. It is likely that what underlies the twisting and side-bending motion measures found to be related to low-back disorders in that research are the rotational forces applied to the spine in creating the motion—in other words, the twisting and side-bending moments.

However, lateral bending and/or twisting moments can be created about the L5/S1 joint even in the absence of these spine motions. Lifting objects from the side, for example, introduces lateral bending moments. Once the trunk is flexed forward, these lateral bending moments become twisting moments as the gravitational forces acting on the object now work to rotate the trunk about its long axis. So, while it has not been directly shown that reducing twisting and side-bending moments lowers the risk of injury, it has been shown that when these moments are part of an activity, the co-contraction of the trunk muscles and the internal spine loads are increased [Lavender, et al(a); (b); Marras, et al(b); Marras and Granata]. Hence, reducing side-bending and twisting moments should ultimately have a desirable biologic effect in terms of reduced muscle force and reduced loads on the intervertebral discs.

Most of the literature on lifting techniques has

Figure 3

Forward-Bending Moment

(a) The mean percent change (+ SEM) in the forward-bending moment over the training session as a function of lifting style. The break in the line above the bars indicates that the forward moment reduction with the two-step style was statistically different from the pivot and swing styles. (b) Cumulative distributions of the changes in the forward-bending moment by lifting style. Positive values indicate a reduction with training.

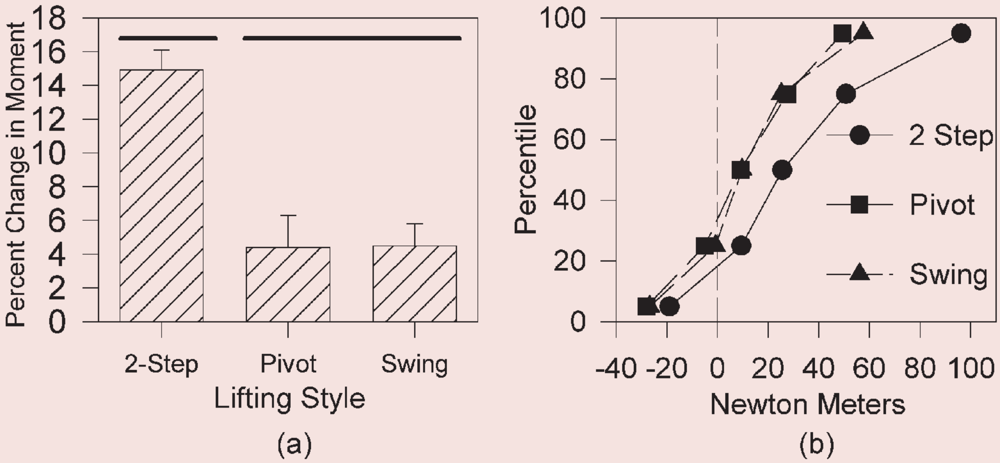
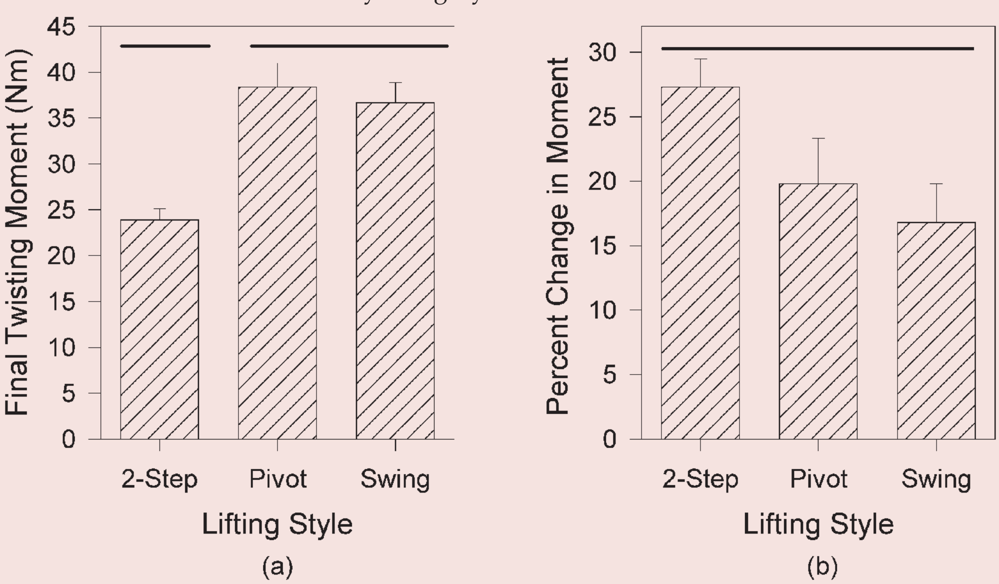


Figure 4

Twisting Moment

The final twisting moment (a) and percent (b) changes in the twisting moment between the baseline and evaluation sets by lifting style.



focused on stooping versus squatting (Buseck, et al; Bush-Joseph, et al; de Looze, et al; Leskinen, et al; Troup). In these studies, lifting tasks were in the mid-sagittal plane. Van Dieen's review of the lifting styles in those studies indicated that unless the handled object can pass between the legs, none of these lifting techniques has a clear advantage over another (van Dieen, et al).

From a practical perspective, most workers in this sample who adopted the two-step technique appeared to use a lifting style that would likely fall somewhere between the traditional "stoop" or "squat" postures. However, distribution center employees typically face lifting situations that encourage asymmetric lifting 1,200 to 1,300 times per day; given the time pressures, these employees favor the swing technique. Those using this technique were nearly always in the stooped posture (Kuorinka, et al). Those adopting the pivot technique typically initiated lifts from a stooped posture and ended their lifts in the same half-stooped/half-squat posture observed in those using the two-step technique.

The direction of this individualized training varied from employee to employee, often based on each one's perception of the time pressures inherent in his/her job. Given the potential for the two-step technique to reduce forward-bending moments, in addition to twisting and side-bending moments, the coach promoted it wherever possible. Its greatest advantage is that it keeps the case in front of the employee, thereby limiting side-bending and twisting moments. Training also emphasized the need to move the case and the body together, especially at the completion of the lift. Other behavior modification suggestions given to two-step lifters were to (where appropriate) widen the stance; grasp opposite corners of the case and rotate the case so one of the nonhandled corners could pass between the legs; lead the lift with the eyes; raise cases to the appropriate level; and slide the cartons down the legs when placing them.

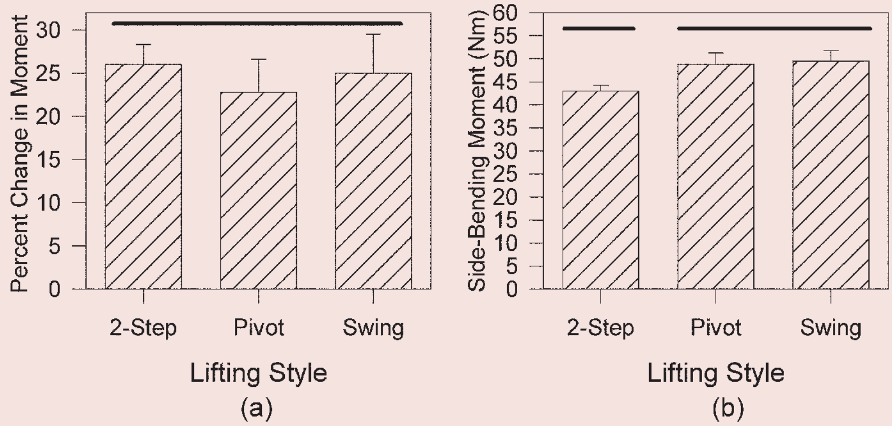
Employees who used a swing technique at baseline and throughout the course of training and who were unwilling to take the one or two steps associated with the other techniques, were shown ways to improve their existing technique. For example, they were encouraged to rotate ("swivel") cases while still on the stack so that the long axis of the case was perpendicular to the direction the workers were facing. The case would then be transferred from one location to another in a more straight-line trajectory that passed closer to the spine. At the completion of the transfer (once the case was on the stack), it was then swiveled into the final position. This process accomplishes three things:

1) It minimizes the moment arm of the case throughout the lift.

Figure 5

Side-Bending Moment

The percent change in the side-bending moment between the baseline and evaluation sets (a). The mean side-bending moment at the completion of the training (b).



2) Swiveling the case prior to—and after completing—the lift removes the moments that would be incurred by rotating the case in the air.

3) It minimizes the lateral bending and twisting motion of the spine and the moments associated with this motion. These participants were also coached to minimize the raising of their torsos in the middle of the lift because such motion is often unnecessary.

The pivot technique incorporates a combination of the two-step and swing approaches; however, the focus was usually on initial case orientation and finishing the transfer with the case directly in front of the torso. With all techniques, employees were encouraged to slide cases as close as possible prior to actually lifting, to move smoothly, and to think strategically about the sequencing of their lifts. For example, by removing cases by layer, they were able to slide the farthest case closer prior to lifting.

Conclusions

The findings of this study show that people can learn lifting behaviors that will reduce spine loads without adversely affecting their productivity. By using a one-on-one training approach, employees were able to learn what worked for them within the context of their perceived time constraints. Given that the most-frequently mentioned barrier to changing lifting behaviors among this group was the potential adverse effects on job performance measures, the objectively measured case-handling times were essential to getting these workers to buy in to the learned techniques.

Due to its larger impact on forward-bending moments, the two-step technique was the best from a biomechanical point of view. While it is likely that the time difference between the two-step and other techniques would be reduced with additional practice, this was a tough sell to the workers who participated in this study.

However, all lifting styles adopted through this biofeedback training process reduced side-bending and twisting spine moments. Therefore, trainers were still able to help those reluctant to adopt lifting behaviors they believed would slow them down. The underlying belief behind this approach is that it is better to have these employees walk away from training having learned useable, although perhaps suboptimal, lifting behaviors than to have learned behaviors that while optimal are not usable. It is likely that all employees who adopted behaviors learned into their regular work practices could expect that the cumulative loading of their spines over the course of the workday would be reduced no matter which technique was adopted. ■

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