EFFECTS OF THE GRIPSYSTEM^{TM} ON MUSCLE ACTIVITY AND KINEMATICS OF THE LOWER BACK

Jessica Paskiewicz & Fadi Fathallah
University of California, Davis, California, USA
fathallah@ucdavis.edu

Furniture movers handle awkward and heavy objects on a daily basis. As a result, low back injuries are prevalent among this population. The purpose of this study is to quantify the efficiency of a manual handling device, the GRIPSystem^{TM}, in reducing the levels of low back disorder risk factors during simulated furniture handling tasks. Twelve health subjects (9 male and 3 female) participated in this study. Subjects lifted a couch, refrigerator, and a bed frame each at three different weights with and without the GRIPSystem^{TM}. Trunk EMG and trunk kinematics were monitored. The results showed that there is a significant decrease in both trunk kinematics and back muscle EMGs when the GRIPSystem^{TM} is used. The use of this device may have a positive impact on team lifting in the moving industry, and could lead to a reduction in the number of low back disorders among movers.

INTRODUCTION

Low back pain (LBP) is known for its high incidence rate in the workplace. LBP accounts for around 40% of absences from work, and is second only to the common cold as the most frequent cause for sick leave (Guo et al., 1999). Jobs involving manual material handling (MMH) have shown higher than average injury rates. One study of MMH workers in Hong Kong showed that over half of this population reported a prevalence of low back injury symptoms (Yeung et al., 2002). Many studies have shown that risk factors for low back injury include, lifting and/or carrying of loads, whole body vibration, frequent bending and twisting, and heavy physical work (NRCIM, 2001).

Moving large pieces of furniture is a physically demanding task. Furniture moving was shown to be one of the top five industries in the state of Washington with the greatest number of worker's compensation claims for non-traumatic soft tissues musculoskeletal disorders. In addition it was ranked number 6 in the top 10 high-risk occupations in the state of Washington (Silverstein et al., 2002).

Little has been done to decrease the risk to the lower back these lifting tasks. Few practical lifting aids are available for use by professional furniture movers or the general public. Most lifting hoists and other lifting aids are often designed for industrial setting. These devices are difficult or impossible to use in moving furniture from a home. Furniture is therefore typically moved by hand, often in awkward lifting positions. Space constraints limit the types of devices that can be used to move furniture. Furthermore, furniture is often awkwardly shaped limiting the use of dollies and carts for moving these objects; therefore, requiring manual lifting. Traditional back belts have been recommended for use during heavy lifting but their effectiveness and functionality have been questioned (Lee et al., 1999; Thomas et al., 1999; Woodhouse et al., 1995).

This study was designed to explore the effectiveness of a new manual assist lifting device called the GRIPSystem^{TM}. This lifting apparatus was designed by two professional movers to assist movers lift home furniture with decreased risk to the lower back. Moving of objects is achieved by placing two straps under the object to be moved and then attaching the straps to harnesses on the mover's bodies. The movers then squat down and tighten the straps, push against the object for balance and then stand up. The null hypothesis of this study was that the GRIPSystem^{TM} will not significantly change the kinematics and trunk EMG signals during lifting and lowering of household furniture.

METHODS

Subjects

Twelve subjects (9 male and 3 female) volunteered to participate in this study. The average age of the subjects was 30 years (std. dev., 9), average height was 1.75m (0.1), and average weight was 102.06 kg (23.59). The participants were screened for any previous or current low back pain. Each participant signed a consent form prior to beginning the testing and anthropometric data was gathered for each subject. All subjects had furniture moving experience, and were compensated for their participation in this study.

Apparatus

The Lumbar Motion Monitor (LMM) (Chattecx Corp., Hixon, TX), was used to collect the kinematic data of the spine. Details and validation of the LMM can elsewhere (Gill and Callaghan., 1996; Marras et al., 1999; Marras et al., 1992). The trunk EMG data was collected using a bipolar surface electrode system (Biopac MP150: Biopac, Santa Barbara, CA).

The objects used to represent household furniture in this study were a couch (27 kg), a bed frame (36 kg), and a refrigerator (61 kg). The weight of these objects was varied from light to heavy with sandbags which weighed 23.1 kg (*light* = object with no sandbag; *medium* = object with one sandbag; *heavy* = object with two sandbags). These items were chosen because they are typical household items, which in shape and size represent many other items that might be lifted by two furniture movers.

The GRIPSystem^{TM} is a device that has been developed to lift heavy and awkward objects in a two-person team. To use the GRIPSystem^{TM} two movers place straps underneath the object to be moved. They then squat down, attach these straps to harnesses which have been designed to transfer the load (object) from the straps to the movers' shoulders and back. Once the straps are attached to the harness, the two movers simultaneously stand up to lift the object (Figure 1).

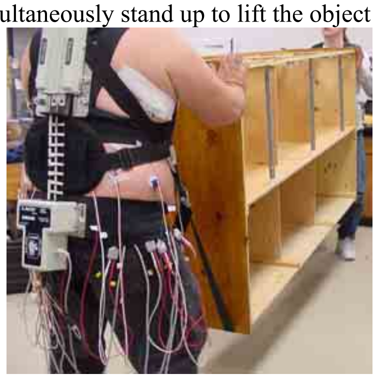

Figure 1. A subject lifting the bed frame with the GIPSystem.

Experimental Procedures

Electrodes were placed on ten of the subject's trunk muscles. This included the right and left erector spinae, latissimus dorsi, rectus abdominal, internal abdominal oblique, and external abdominal oblique. The exact placements of these electrodes can be found in the literature (Mirka and Marras, 1993). The skin where the electrodes were placed was cleaned and shaven if necessary. Extra electrode gel was added to the electrodes to assure good conductivity. Medical tape was used to assure the electrodes were firmly attached to the skin. AcqKnowledge software (Biopac, Santa Barbara, CA) was used to collect the EMG data at 1000 Hz. These data were then stored in a personal computer. Using a custom built apparatus, the maximum EMG signals were taken for the trunk muscles prior to beginning the lifting trials.

The LMM was placed on the subject using a shoulder and a waist harness. The LMM software package recorded the data at 60 Hz and stored it on a personal computer. The LMM raw data were also collected using the AcqKnowledge software at 1000 Hz to aid in the data analysis. Neutral positions were recorded for each subject at the beginning of the first trial and again when the belt condition was changed.

The subjects were asked to lift three objects (a bed frame, couch, and refrigerator) at three different weights, twice each. During each lift, EMG and LMM data were recorded. The subjects were given auditory clues as to when to lift and lower the objects. Video record was also taken during each trail.

Data Analysis

The LMM data were analyzed by subtracting the neutral postures from each subject's trials. The LMM data files were then divided into lift and lower sections by visual cues. To compare the differences between belt conditions, weight, and objects the average sagittal, lateral, and twisting kinematics were used.

The EMG data were analyzed by calculating a 5-point root mean square (RMS) averaged signal from the filtered (10-500 Hz band-pass filtered) raw EMG signal (NIOSH, 1992). The RMS signals were then smoothed with a 5 Hz low pass filter. The EMG signals were then split into lift and lower segments using the LMM voltages recorded in the AcqKnowledge program and by examining the muscle activation patterns of the erector spinae. The EMG signals were then normalized using the maximum EMG signals. To compare the different conditions, the average normalized signal was used.

To test for statistical differences for each dependent variable, analysis of variance (ANOVA) was performed. A Newman Keuls post hoc analysis was used to determine the source of any identified significant differences (*alpha* of 0.01 and 0.05 were used in this analysis).

RESULTS

The ANOVA results for the average percent of maximum EMG for the right erector spinae showed a significant decreased between lifting and lowering with and without the device ($p<0.05$; Figure 2). The left erector spinae also showed the same pattern of significant differences between lifting and lowering with and without the device.

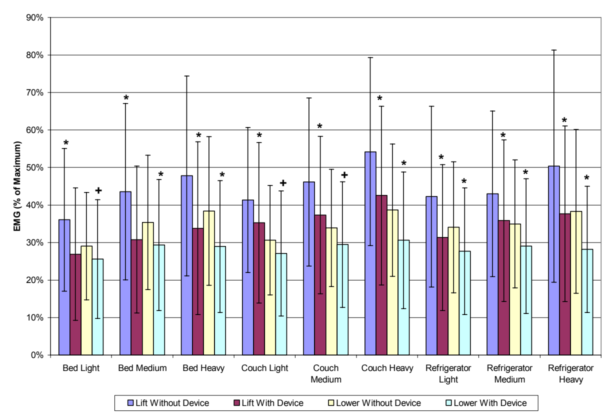

Figure 2. Average (+/- std. dev.) for the right erector spinae EMG (% of max) for each lifting and lowering condition. (* Denotes with device is significantly different than without device ($p<0.01$) + Denotes with device is significantly different than without device ($p<0.05$))

Similar results were seen for the left and right internal obliques. These results from the left internal obliques can be seen in Figure 3.

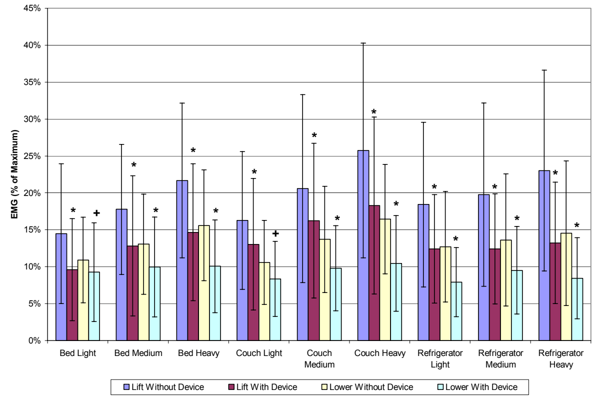

Figure 3. Average (+/- std. dev.) for the left internal oblique EMG (% of max) for each lifting and lowering condition. (* Denotes with device is significantly different than without device ($p<0.01$) + Denotes with device is significantly different than without device ($p<0.05$))

In general, the right and left external obliques, latissimus dorsi, and rectus abdominal muscles did not show significant differences.

Figure 4 shows the ANOVA results for the average sagittal flexion. This graph shows a significant decrease in each condition when comparing lifting and lowering with and without the device ($p<0.05$).

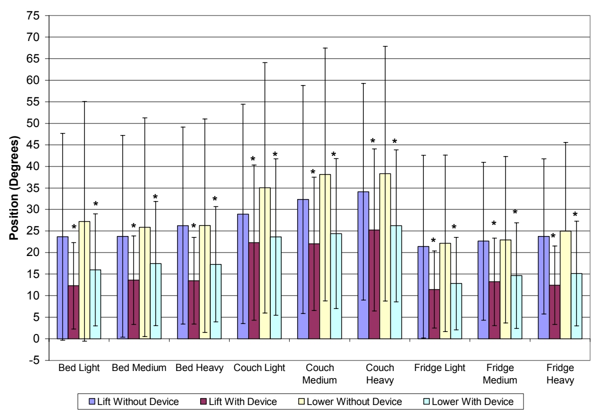

Figure 4. Average (+/- std. dev.) absolute sagittal flexion during each experimental condition. (* Denotes with device is significantly different than without device ($p<0.01$))

Comparable results were found for lateral and twisting positions, as well as for the velocity and acceleration in all three planes. The use of the device resulted in a consistent decrease in the "probability of high risk group membership" as defined by Marras et al. (1993).

DISCUSSION

Many people suffer from low back pain during the course of their lives. Occupational low back pain (LBP) can be costly both in terms of effects on the health of the workers and the financial impact on the workers and the employers. Research shows that heavy and awkward lifting is one of the main causes of this disabling pain. Furniture movers often have to resort to lifting manually due to the awkward shapes of some furniture and space constraints. The GRIPSystem™ has been developed to reduce the loading on the back.

The results show a significant decrease in the average EMG (% of max) signal for the right and left erector spinae and the right and left internal obliques. The muscle activity of the right erector spinae muscle was reduced an average of 23%, while the left internal oblique muscle was reduced by 31% on average. This is important because reducing muscle activity in the back can help to reduce the likelihood of injury by reducing the internal spinal forces. The decrease may be due to a transfer of the load from the back to the legs because of the more upright posture and squatting technique caused by using the GRIPSystem™.

The GRIPSystem™ was also able to significantly reduce the trunk kinematic indices. The sagittal flexion during lifting was reduced by 40%. This decrease is important because this variable has been previously identified to contribute to the risk of LBDs (Marras et al., 1993; Punnett et al., 1991).

Additional Considerations

The GRIPSystem seems to be a safer system to use than lifting with the arms. Because the arms are free to keep the balance of the object instead of holding it, there is a greater sense of safety. The lifter's arms are free to balance the object being lifted, hold onto railings, or push the object away from their bodies to allow more room for walking.

Another important feature of the GRIPSystem is its ability to compensate for differences in heights between a pair of movers. Because the straps on the bottom hold the object parallel to the ground, the length of the straps from the object to the shoulder of the lifter can be of different lengths on each side. This eliminates the awkwardness and unbalanced loading created when a very tall person and very short person try to lift an object as mentioned in previous studies involving team lifting (Sharp et al., 1997). This same principal also reduces the effect of the awkwardness of carrying something up or down a set of stairs. If the person on the bottom pushes on the object they can raise it up higher without actually lifting the weight of the object. This allows the object to remain closer to parallel with the ground.

Awkwardly shaped objects, which are either too wide or do not have good hand holds are lifted easily with the GRIPSystem. As seen in the data presented in this report, cumbersome objects can, at times, create an uncomfortable lifting position which should be avoided. The GRIPSystem only depends on being able to get the straps underneath the object not on whether the lifter can get their arms around the object or under the object.

Study Limitations

Although this study shows substantial potential benefit from using the GRIPSystem, more testing must be done to demonstrate its overall effectiveness in reducing back injuries in the moving and other industries. One major limitation of this study is that it did not address the whole body's response to the device. Because the load had been shown to be relieved from the back, concerns about the hip, knee, and ankle joints arise. Studies should be performed on the leg joints to rule out potential problems that may occur from using the GRIPSystem. The loading on the arms was also not addressed in this study. However, it is expected that since the arms are no longer holding the full weight of the object, the loading on the arms will be greatly reduced.

Additionally, this study did not take into account the force-length relationship of muscle. Investigation into this relationship may show the benefits of the GRIPSystem since it is expected that trunk muscles are the most active in non-neutral positions.

This study only considered three objects at three different weights each. This device should be tested using different shaped and weighted objects to assess the full range of potential benefits.

Suggestions for Further Research

Due to the apparent effectiveness of the GRIPSystem shown in this study, a larger epidemiological study is suggested. This study should examine the health records of companies before and after beginning to use the GRIPSystem, or between companies who are using this system and those who are not, to see if back injury rates are reduced. The GRIPSystem may also reduce injuries due to dropping objects or tripping. Therefore, it would be advantageous to track all injuries to see if the GRIPSystem was able to provide a safer working environment.

A study on the efficiency of the GRIPSystem from an object moving standpoint is another important study to undertake. It is important to investigate if the GRIPSystem, once the users are comfortable with the device, affects the productivity of furniture movers. A large decrease in productivity may keep workers from using the device even if it is shown to reduce the risk of injury.

CONCLUSION

This study was designed to determine the effectiveness of the GRIPSystem in reducing trunk kinematics and muscle activity during team lifting. The results demonstrate that the kinematics and muscle activity have been substantially reduced and it is recommended that this device be studied further to determine the benefits of long term usage. The results of this study can be summarized as follows:

- The GRIPSystem substantially reduced the magnitudes of sagittal flexion, lateral bending, and twisting when lifting and lowering household furniture.
- The GRIPSystem reduced the 3-D velocities during lifting and lowering household furniture.
- The GRIPSystem reduced the probability of low back disorder risk while lifting and lowering household furniture.
- The GRIPSystem reduced the muscle activity of the back extensors when lifting and lowering household furniture.

The information presented in this study shows a clear potential benefit to the furniture mover's lower back when using the GRIPSystem. It is hoped that this research will lead to further studies to demonstrate the long term effects of using the GRIPSystem in the field, and will ultimately be widely distributed to furniture moving companies to help reduce the number of low back injuries in the workplace.

REFERENCES

Gill, K. P. and M. J. Callaghan. 1996. Intratester and intertester reproducibility of the lumbar motion monitor as a measure of range, velocity and acceleration of the thoracolumbar spine. Clin Biomech, 11(7), 418-421.

Guo, H. R., S. Tanaka, W. E. Halperin and L. L. Cameron. 1999. Back pain prevalence in US industry and estimates of lost workdays. Am J Public Health, 89(7), 1029-35.

Lee, Y. H. and C. Y. Chen. 1999. Lumbar vertebral angles and back muscle loading with belts. Ind Health, 37(4), 390-7.

Marras, W., W. G. Allread and R. G. Ried. 1999. Occupational Low Back Disorder Risk Assessment Using the Lumbar Motion Monitor. The Occupational Ergonomics Handbook. CRC Press, New York. 1075-1100

Marras, W., F. A. Fathallah, R. J. Miller, S. W. Davis and G. A. Mirka. 1992. Accuracy of a three-dimensional lumbar motion monitor for recording dynamic trunk motion in occupationally-related low back disorders. Spine, 18(5), 617-628.

Marras, W. S., S. A. Lavender, S. E. Leurgans, S. L. Rajulu, W. G. Allread, F. A. Fathallah and S. A. Ferguson. 1993. The role of dynamic three-dimensional trunk motion in occupationally-related low back disorders. The effects of workplace factors, trunk position, and trunk motion characteristics on risk of injury. Spine, 18(5), 617-28.

Mirka, G. A. and W. S. Marras. 1993. A stochastic model of trunk muscle coactivation during trunk bending. Spine, 18(11), 1396-409.

NIOSH. 1992. Selected topics in surface electromyography for use in the occupational setting: Expert perspectives. U.S. Departement of Health and Human Services,

NRCIM. 2001. Musculoskeletal disorders and the workplace: low back and upper extremities. National Research Council and Institute of Medicine, Washington, D.C.

Punnett, L., L. J. Fine, W. M. Keyserling, G. D. Herrin and D. B. Chaffin. 1991. Back disorders and nonneutral trunk postures of automobile assembly workers. Scandinavian Journal of Work, Environment and Health, 17, 337-346.

Sharp, M. A., V. J. Rice, B. C. Nindl and T. L. Williamson. 1997. Effects of Team Size on the Maximum Weight Bar Lifting Strength of Military Personnel. Human Factors, 39(3), 481-488.

Silverstein, B., E. Viikari-Juntura and J. Kalat. 2002. Use of a prevention index to identify industries at high risk for work-related musculoskeletal disorders of the neck, back, and upper extremity in Washington state, 1990-1998. Am J Ind Med, 41(3), 149-69.

Thomas, J. S., S. A. Lavender, D. M. Corcos and G. B. Andersson. 1999. Effect of lifting belts on trunk muscle activation during a suddenly applied load. Hum Factors, 41(4), 670-6.

Woodhouse, M. L., R. W. McCoy, D. R. Redondo and L. M. Shall. 1995. Effects of back support on intra-abdominal pressure and lumbar kinetics during heavy lifting. Hum Factors, 37(3), 582-90.

Yeung, S. S., A. Genaidy, J. Deddens, A. Alhemood and P. C. Leung. 2002. Prevalence of musculoskeletal symptoms in single and multiple body regions and effects of perceived risk of injury among manual handling workers. Spine, 27(19), 2166-72.