FIELD STUDY TO EVALUATE THE EFFECTIVENESS OF A CONTINUOUS PASSIVE LUMBAR MOTION SYSTEM

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Abstract: Operating heavy construction equipment is often associated with elevated rates of low back discomfort (LBD). However, there have been few formal studies that dealt with evaluating controls that can reduce the LBD among these workers. The objective of this study was to determine the effectiveness of using a continuous passive lumbar motion system (CPLMS) in reducing low back discomfort among operators of heavy earthmoving equipment. The CPLMS is an additional seat support that has a lumbar support bladder and a pump to provide cyclic inflation and deflation. Two groups of operators were identified as potential subjects for this intervention study, the intervention group with a mean age of 41.2 years and experience of 9.7 years used the CPLMS, and the control group with a mean age of 37.5 years and experience of 7.6 years did not use the CPLMS. Body part discomfort surveys were collected from both groups. In addition, the intervention group completed a CPLMS preference survey. The body part discomfort survey was collected up to eight days at three different times of the day. Results from the body part discomfort survey showed a decreasing trend the longer the CPLMS was used, for both the upper and low back region. A decreasing trend for the low back was also found comparing morning to evening discomfort scores across the days when using the CPLMS. When compared to their regular seat, 54% of the operators felt very comfortable in using the CPLMS, 36% of them wanted one for their equipment, and 54% showed interest in experimenting with the CPLMS for a longer time period. Results from this study indicate that the use of a CPLMS can effectively reduce the low back discomfort experienced by operators of heavy construction equipment.

1. INTRODUCTION

Low back pain (LBP) is one of the most common occupational problems in the United States, where back injuries are the most costly non fatal injuries. Heavy equipment operators in the construction industry experience a high incidence of musculoskeletal disorders, which is evident from the Bureau of Labor Statistics data (BLS, 2004). The lost work day case rate is also high for the construction industry workers when compared to the workers of other industries. Operators of heavy mobile equipment, who are generally referred to as operating engineers (OEs), currently number about 540,000 OEs in the United States, where 90% are involved in performing excavating and paving work and the remaining 10% are crane operators (Kittusamy and Buchholz 2004).

Potential risk factors for the development of LBP among mobile equipment operators include exposure to whole body vibration (WBV) and static seating posture (Kittusamy, 2002; Kittusamy and Buchholz, 2004). Long term exposure to these risk factors has been shown to increase the symptoms of LBP (i.e. intervertebral disc degeneration, muscle fatigue, and sciatic pain). When one maintains a seated posture with inadequate lumbar support, the lumbar spine flattens leading to increased tensile force on the posterior part of the intervertebral discs and more muscle activity occurs in order to stabilize the spine. This type of seating posture is more reflective of mobile equipment drivers, as they must maintain a static seated posture while maneuvering the equipment over rough terrain, resulting in exposure to WBV for long periods of time.

Sitting has the potential to harm the spine due to potentially higher intradiscal pressure and compressive stress on the annulus (Boshuizen et al., 1990). Static postures can also contribute to LBP along with other factors such as WBV. The combination of prolonged sitting and exposure to WBV was reported to result in more and longer work-related absenteeism due to intervertebral disc disorders and low back problems (Boshuizen et al., 1990). From the epidemiological studies it is evident that prolonged sitting is a risk factor for LBP. When one sits the lumbar curve flattens, the posterior height of the intervertebral disc increases, the facets becomes disengaged and motion becomes significantly more flexible in the anterior posterior direction, and the intervertebral disc pressure increases (Wilder et al., 1988). During prolonged sitting, the balance point (the point on intervertebral disc where the load acting is less) will change and lead to greater coupled displacements of vertebral bodies, which may eventually lead to a break down of tissues (Wilder et al., 1988).

Several interventions have been introduced with the objective of alleviating the static sitting posture in order to reduce the discomfort developed from muscle fatigue and constant loading of intervertebral disc. This study specifically evaluated the effectiveness of a continuous passive lumbar motion system (CPLMS) that was developed by Reinecke et al. (1994). The CPLMS has a lumbar support with an air bladder, which provides cyclic motion to the spine thereby increasing the lumbar lordosis angle. Studies on the CPLMS have been shown to reduce the muscle discomfort of the low back during tests in simulated driving conditions. The clinical and laboratory research on the CPLMS indicates there is a potential to reduce LBP from static sitting, thus, this merits further research in a field setting.

2. METHODOLOGY

This study evaluated the effectiveness of the CPLMS in reducing low back discomfort among operators of heavy earthmoving equipment. The OEs in this study worked at two different construction sites and were employed by the same contractor. The study site for the intervention group was West Des Moines, Iowa, whereas the control group study site was at Ankeny, Iowa which was 30 miles to the east of the intervention study site. Both sites were spread over an area of 100 acres. Different types of earth moving equipment such as backhoe, dump trucks and different kinds of excavators were used to perform the fieldwork. A typical work day consisted of 11 hours where every OE started their job at 6:30 am in the morning, took a 30 minute break for lunch, and ended their work at 6 pm. The same kind of work was performed using similar equipment at both construction sites.

The OEs at the intervention site received the CPLMS whereas the OEs at the control site did not receive the CPLMS. The mean ages of the intervention and control groups were 41.2 years [S.D 10.4] and 37.5 years [17.1], respectively. All of the OEs were experienced (journey-level) operators with an average experience of 9.7 [S.D 11.1] years for the intervention group and 7.6 [S.D 6.2] years for the control group. The mean body mass of the OEs was 83.7 kg [S.D 14.2] for the intervention group and 97.5 kg [17.8] for the control group.

Two different surveys were used in this study to evaluate the effectiveness of the CPLMS, a body part discomfort survey and a subjective preference of the CPLMS survey. The body discomfort survey was administered to both the intervention group and the control group, while the subjective preference of the CPLMS survey was only administered to the intervention group. The body part discomfort survey, a continuous visual analog scale, focused on the discomfort severity rating for various body parts. The discomfort rating ranged from zero to ten, zero representing the least or no discomfort and ten representing the worst discomfort experienced by the operator. This survey was collected each day three times a day: before the start of work, during lunch and at the end of work. This pattern of data collection was performed in order to identify whether there were any differences in the discomfort ratings from using the CPLMS throughout the day. Additionally, a preference survey was administered to the intervention group on the final day of the data collection period to evaluate the operator's preferences and opinions regarding the use of the CPLMS, as well as their opinions on how the CPLMS affected the back with respect to discomfort, fatigue and stiffness on a scale of 1 to 5.

The CPLMS, developed by Reinecke et al. (1994), was installed in several pieces of heavy earth-moving equipment (Figure 1). The CPLMS has an additional seat support with an air bladder in it. The air is pumped in and out of the air bladder through a pump electronically controlled by a microprocessor. The amount of air supplied to the air bladder can be varied by the user via a hand held control, which has a pressure intensity rating from 1 to 5, where 1 corresponds to low and 5 is high intensity. Greater intensities result in greater thickness in the lumbar region, thereby producing larger lumbar curvature to the operator.

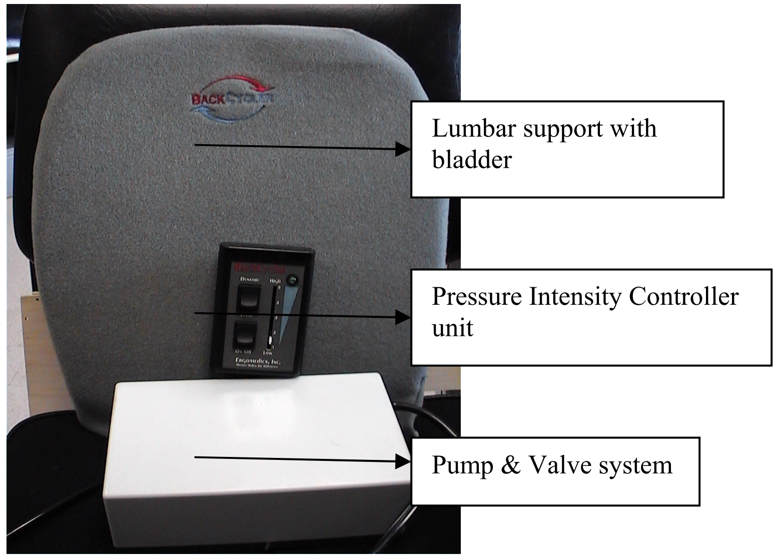

Figure 1: Continuous Passive Lumbar Motion System.

Experimental Procedure

On the first day of data collection, all of the participating operators were briefed about the study and each signed a consent form that was approved by the Wichita State University's Institutional Review Board for Human Subjects. A CPLMS was installed in the construction equipment and a detailed explanation was provided to the operator on how to use the CPLMS. They were also asked to return the CPLMS if they felt it wasn't comfortable. The first half-day was a trial period for the OEs that allowed them to become familiar with the CPLMS operation and determine their preferred pressure intensity level. The body part discomfort survey was not collected on that day. Starting with the second day (the Day 1 of the study), the body part discomfort survey was collected for every OE: 1) at the beginning of the shift, 2) during their lunch break, and 3) at the end of the shift. However, due to field constraints only start of the shift (morning) and end of the shift (evening) data were analyzed. On the last day of the data collection all participants were asked to fill out the CPLMS preference survey. Personal comments from every participant were noted on the data collection sheet.

Initially there were 12 OEs at the intervention site, of which 11 were males. However, the female operator was replaced by another female and one male operator was shifted to another site. Therefore ten males and one female completed the study for the intervention group. In the control group there were nine OEs that volunteered for the study (8 males and 1 female) and there were no dropouts.

Data Analysis

The CPLMS subjective preference survey was analyzed by determining the proportion of intervention participants that indicated a reduction in back discomfort, fatigue and stiffness, as well as the proportion of operators that wanted to use a CPLMS permanently in their construction equipment. To assess the trends of discomfort from the body part discomfort surveys, two-tailed dependent sample t-tests were performed for each day on the difference between the discomfort scores between the morning and evening. This was performed independently for each day, for both the intervention and control groups.

3. RESULTS

On a given data collection day at least six employees took part in the study during both morning and evening sessions, except for two days in the intervention group. There were two days in the intervention group were the number of participants were less than six.

As shown in Figure 2, there were very few differences in the mean low back discomfort scores between the morning and evening rating times across the eight days the CPLMS was utilized at the intervention site, where a significant difference was only observed for the last day of observation ($p = 0.033$). However, as shown in Figure 3, the control group reported significant differences in the low back discomfort scores between the morning and evening rating times for three of the five study days ($p<0.05$), where the trend can be seen visually that the mean low back discomfort scores were higher for the evening than in the morning.

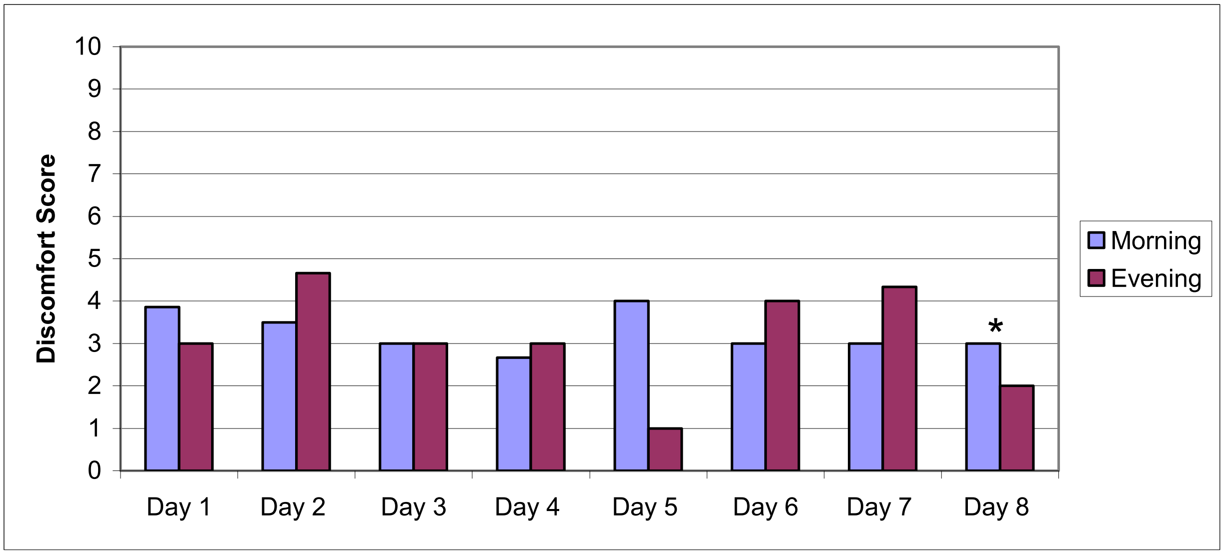

Figure 2. Mean low back discomfort score for the intervention group for the morning and evening rating times as a function of the different study days (* indicates significant difference between morning and evening discomfort score).

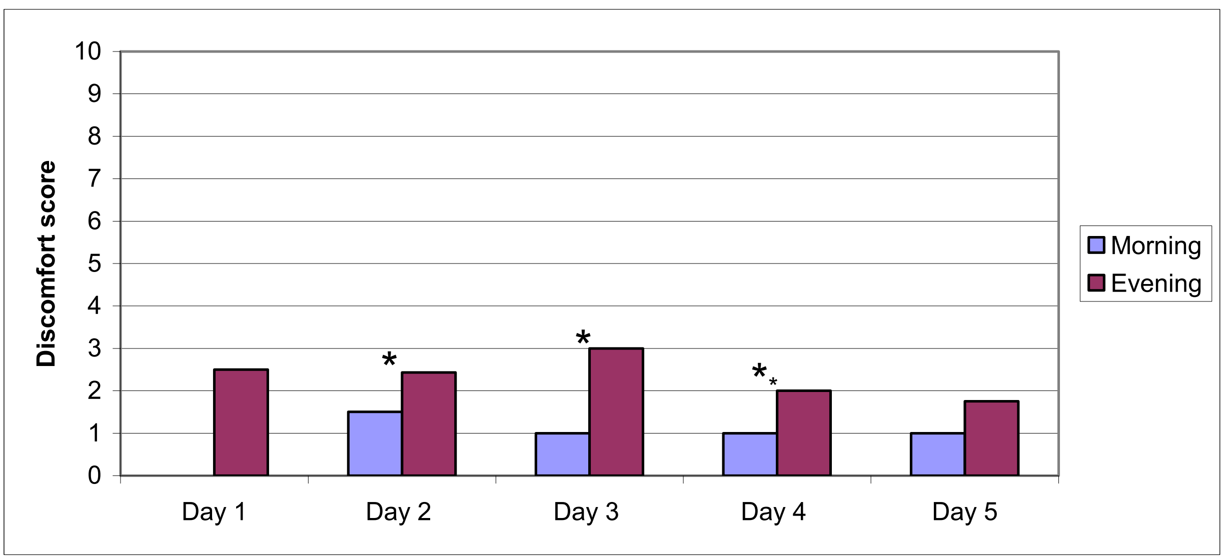

Figure 3. Mean low back discomfort score for the control group for the morning and evening rating times as a function of the different study days (* indicates significant difference between morning and evening score).

There were no significant differences between the morning and evening score of the mean upper back discomfort for both the intervention and control groups on any of the study days.

The results of the CPLMS preference survey conducted for the intervention group found that approximately 63% of the OEs felt the CPLMS provided support to the back, 55% felt the CPLMS reduced back fatigue, and 36% felt the CPLMS reduced back stiffness while operating their equipment. With respect to back discomfort, 72% of the OEs felt that using the CPLMS reduced back discomfort, thus allowing them to be more comfortable while driving. Finally, 54% of the OEs wanted to evaluate the CPLMS for more days, and 36% of the OEs indicated they wanted a CPLMS installed permanently in their equipment.

4. DISCUSSION

Although the CPLMS was developed more than a decade ago, only a few studies have attempted to evaluate its effectiveness. Reinecke et al. (1994) assessed the affect of the CPLMS on back discomfort during driving of motor vehicles. Subjects were asked to perform a driving task in a simulation environment after which they were asked to complete a discomfort questionnaire. Additionally, subjects with low back pain were asked to perform the same task. Results indicated that utilizing the CPLMS in the simulation environment and the real environment decreased the subjective estimate of discomfort and stiffness of the low back. Hazard and Reinecke (1995) reported that using the CPLMS while seated in a chair resulted in larger curvature of the L1-S1 lumbar lordosis than when sitting in the chair without the CPLMS. Thus, the authors suggested that use of the CPLMS would have a positive effect on an individual while sitting. Further positive benefits of using the CPLMS were also reported by Whiteside and McGill (1996). Spinal shrinkage, which is thought to increase loading on the intervertebral discs as well as the facet joints, was assessed during static and dynamic seated postures. Use of the CPLMS resulted in significantly less spinal shrinkage than when not using the CPLMS, and perceived discomfort ratings also indicated lower discomfort than when not using the CPLMS.

Although these prior studies were performed in a laboratory environment, viewed collectively they suggest that using the CPLMS may have positive benefits through decreased discomfort, stiffness and fatigue of the low back, possibly as a result of improved lumbar curvature, but also less loading on the low back. However, since these studies were carried out in a laboratory setting, little can be concluded about the effectiveness of the CPLMS in a real work environment. Thus, this study was carried out to assess the effectiveness of the CPLMS in an environment where low back discomfort is known to be a large problem. Additionally, this study also sought to improve on the time frame of testing the effectiveness of the CPLMS; as such this study assessed the use of the CPLMS for a longer period of time than the previous studies. In this study the CPLMS was field tested for approximately 450 hours.

The results from this study are comparable and similar to the results of other studies. Similar to other studies, we had two groups one with CPLMS and one without the CPLMS, where there were little or no demographic differences between these two groups. The results from the discomfort survey showed a very slight decreasing trend for the low back from day 1 to day 8 for the intervention group. However, more important were the differences, or more appropriately, the lack of differences in the mean discomfort scores within a day when using the CPLMS. Out of the eight days that the intervention group utilized the CPLMS, only the eighth day showed a statistical difference in terms of the discomfort score between morning and evening. Contrast this trend with the results from the control group, where three of the five study days resulted in significantly different mean low back discomfort scores between the morning and evening, with the evening scores being higher than the morning scores. This trend suggests that the CPLMS may have a positive effect in reducing the intensity of low back discomfort between morning and evening that may be associated with prolonged sitting and exposure to whole body vibration. This is also supported from anecdotal reports from some of the intervention group participants that their back was not as sore or tight the next morning after using the CPLMS. It can also be observed that the CPLMS may have more of an affect on the lower back than the upper back. Both the intervention and control group showed no significant differences between the mean discomfort scores, for the upper back, from morning to evening across all days. Thus, the CPLMS may be specific to the lumbar region of the back. This is consistent with the findings of improved lumbar curvature contributing to a more neutral spine when using the CPLMS (Hazard and Reinecke 1995) as well as the decreased discomfort in short term driving of motor vehicles (Reinecke et al. 1994).

Finally, the effectiveness of any safety and health intervention in the field will ultimately depend upon the users feeling that the proposed intervention works or at least has the potential to improve their working conditions, or reduce the risk of injury. The results of the CPLMS preference survey collected from the intervention group after the extended use of the CPLMS indicated that the majority of OEs (approximately 72%) felt that the CPLMS reduced back discomfort and 36% actually wanted a CPLMS installed permanently in their equipment.

5. CONCLUSION

The Continuous Passive Lumbar Motion System (CPLMS) produces cyclic changes in the lumbar curvature while sitting, which in theory may improve muscle function of the low back during prolonged sitting. The results from this study indicate that the use of a CPLMS can effectively reduce the low back discomfort experienced by operators of heavy construction equipment.

6. REFERENCES

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