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# Field evaluation of a continuous passive lumbar motion system among operators of earthmoving equipment

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## Abstract

Operating heavy mobile construction equipment is often associated with elevated rates of low back discomfort. However, few formal studies have evaluated interventions that may reduce low back discomfort among these workers. The objective of this study was to determine the effectiveness of a continuous passive lumbar motion system (CPLMS), which is an additional lumbar seat support that can cyclically inflate and deflate, in reducing low back discomfort among operators of heavy earth-moving equipment. This was a quasi-experimental intervention study with multiple observations in which body part discomfort surveys were collected from an intervention and a control group during normal working days. The intervention group also completed a CPLMS preference survey after completing use of the CPLMS for 646 h. Results from the body part discomfort survey showed no significant difference in low back discomfort between mornings and evenings for the first seven days, but a significant difference on the eighth and final day for the intervention group. In the control group, there was a significant difference between mornings and evenings on three out of five days for the low back discomfort score, where, the evening score was always higher than the morning score for all days. In addition, comparisons between the control and intervention groups indicated that the difference between morning and evening low back discomfort rating approached significance ($p = 0.06$). The CPLMS preference survey showed that 54% of the operators felt very comfortable using the CPLMS, 36% wanted one for their equipment, and 54% showed interest in experimenting with the CPLMS for a longer time period. Results from this study suggest that the use of this intervention may effectively reduce the development rate of low back discomfort experienced by operators of heavy earth-moving equipment throughout the work day.

## Relevance to industry

This study indicates that providing an intervention that promotes dynamic changes and improving lumbar curvature during prolonged static sitting in a whole body vibration environment may have a positive effect by reducing the development rate of low back discomfort.
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*Keywords:* Low back discomfort; Lumbar back support; Static seating; Operating engineers; Whole body vibration

## 1. Introduction and background

Low back pain is one of the leading occupational problems in the United States and is a major cause of industrial disability in the population under the age of 45 years (Pope et al., 1998). Heavy equipment operators, such as bulldozer and crane operators, experience a high incidence of musculoskeletal disorders (Pope et al., 1998); the incidence rate for musculoskeletal disorders among mobile equipment and vehicle drivers in 2002 was 12.1 per 100 workers per year, well above the national average of 5.3 (Bureau of Labor Statistics, 2004).

Kittusamy and Buchholz (2004) estimated, using the Bureau of Labor Statistics (2003) data, that there are currently 540,000 operators of heavy mobile equipment, who are generally referred to as operating engineers, in the United States. Their estimate also indicated that 90% of the operating engineers are involved in performing excavating and paving work, whereas the remaining 10%

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are crane operators and all of these operating engineers are exposed to whole body vibration. Two important risk factors for musculoskeletal disorders among operators of heavy earth-moving equipment are static sitting and whole body vibration (Boshuizen et al., 1990; Kittusamy and Buchholz, 2001; Kittusamy, 2002), where long term exposure to these risk factors have been associated with low back pain, disc degeneration, sciatic pain, and muscle fatigue (Dupuis and Zerlett, 1987; Ozkaya et al., 1994; Wilder, 1993).

Prolonged and unsupported sitting has the potential to harm the spine due to potentially higher lumbar intradiscal pressure when compared to standing (Andersson et al., 1974). The combination of prolonged sitting and exposure to whole body vibration was reported to result in more and longer work-related absenteeism as a result of intervertebral disc disorders and low back problems (Boshuizen et al., 1990). While sitting, the lumbar curve flattens, the posterior height of the intervertebral disc increases, the facets become disengaged and motion becomes significantly more flexible in the anteroposterior direction, and the intervertebral disc pressure increases (Wilder et al., 1988). When sitting occurs in a vibration environment, this leads to additional rocking of the pelvis rotation and amplifies the vibration transmitted to the spine (Wilder, 1993), leading to increased rates of spine degeneration.

Andersson et al. (1974) found that disc pressure and the electromyographic activity in the back muscles were less when the back rest of the seat and lumbar support was increased. They concluded that a seat should have a variable lumbar support in order to reduce disc pressure and muscle activity. Seidel (1988) indicated that vibration in the lower frequency range leads to higher intradiscal pressure and contributes to fatigue and pain in the erector spinae muscle. Hansson et al. (1991) showed that whole body vibration while seated increased the occurrence of back muscle fatigue and hypothesized that it could be because of constriction of arterial supply to the back muscles. Therefore, when a static seated posture is maintained, increased muscle tension to specific muscle groups can lead to muscle fatigue and strain (Cram and Vinitzky, 1992), where exposure to whole body vibration may exacerbate the situation. Solomonow et al. (2003) has shown that creep is developed in the viscoelastic tissues, when a static posture is maintained for 20 min with a constant load and is not completely recovered even after 7 h of rest. Thus, this highlights the need of providing lumbar support in seats, which may reduce the loading on the intervertebral disc and reduce muscle fatigue contributed by prolonged static sitting.

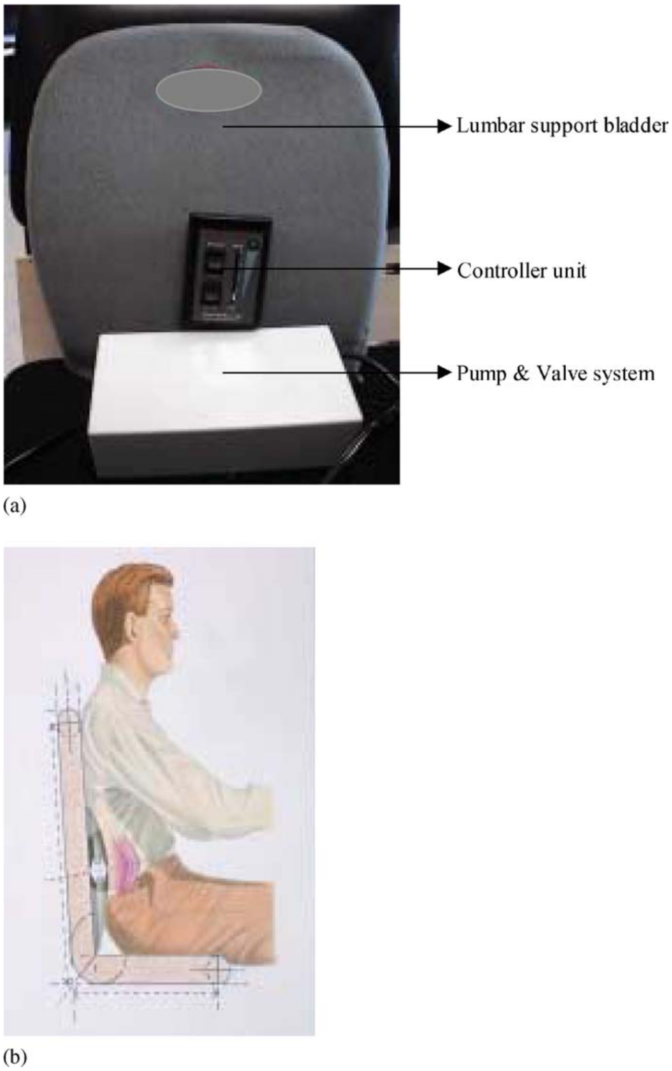

Fig. 1. (a) The continuous passive lumbar motion system and controlling units. (b) An operator using the continuous passive lumbar motion system (adapted from Hazard, 2001).

### 1.1. Continuous passive lumbar motion system (CPLMS)

The CPLMS was developed by researchers at the University of Vermont to reduce low back discomfort due to static sitting (Reinecke et al., 1994). As shown in Fig. 1a, the CPLMS consists of a lumbar support with an air bladder that inflates and deflates cyclically, a controller, and a microprocessor unit. Air is pumped to the air bladder with the help of the microprocessor unit. The amount of air pumped to the air bladder can be controlled by the user. Settings range from 0 to 5, with 0 being the lowest (no air) and 5 the highest setting (the most air to be pumped through). Fig. 1b shows an operator using the CPLMS unit. The time delay between inflation and deflation varies depending on the intensity level. Table 1 shows the time it takes to inflate from 0 to various intensity levels, duration of time in the same position and time to deflate. The thickness of the bladder at different intensity levels are also shown in Table 1.

### 1.2. Previous CPLMS research

Several laboratory studies were conducted by other researchers using the CPLMS. These studies have shown that using the CPLMS led to an increase in lumbar curvature. Reinecke et al. (1994) showed that the use of the CPLMS increased the lumbar lordosis angle for subjects with and with out low back pain, and both groups reported decreased discomfort to the low back while using the CPLMS. Similarly, Hazard and Reinecke (1995) measured lumbar lordosis while using the CPLMS; their results were consistent with the previous study by Reinecke et al. (1994). Whiteside and McGill (1996) found that spinal shrinkage was less for subjects using the CPLMS compared to subjects exposed to other seating conditions, such as sitting with the torso flexed (unsupported static sitting condition with lumbar spine flexed), torso extended (unsupported static sitting condition with lumbar spine extended), cyclical (unsupported dynamic condition alternating between lumbar spine flexed and extended), and static support (regular seat with lumbar support).

Although the CPLMS has shown positive results in controlled laboratory studies with respect to indicators of lumbar curvature, low back discomfort, and loading on the back, a void in our knowledge base exists with respect to its effectiveness in a work setting. Thus, the objective of this research was to assess the effectiveness of the CPLMS as an intervention for low back discomfort in an environment where workers are exposed to risk factors of low back pain, such as whole body vibration and static sitting.

Table 1
Characteristics of the continuous passive lumbar motion system (with no person sitting on it)

| Intensity | Time[a] (s) | | | Thickness[a] (cm) |
|---|---|---|---|---|
| | Deflation to inflation | Remain stationary | Inflation to deflation | |
| 1 | 3 | 83 | 46 | 3.8 |
| 2 | 10 | 66 | 33 | 5.1 |
| 3 | 13 | 63 | 51 | 5.5 |
| 4 | 16 | 58 | 54 | 5.7 |
| 5 | 19 | 55 | 56 | 5.9 |

[a] Estimates were derived from 2 trials.

## 2. Methods

### 2.1. Approach

A CPLMS was installed in several pieces of heavy earth-moving equipment, and two different subjective surveys were administered: (1) a body part discomfort survey, and (2) a CPLMS preference survey. In addition, a control group at another construction site where similar equipment was used to perform similar earth-moving work participated in this study.

### 2.2. Subjects

The subjects for this intervention study consisted of experienced operating engineers. The mean ages of the intervention group ($N = 11$) and the control group ($N = 9$) subjects were 46.1 years [S.D. 12.5] and 36.8 years [S.D. 16.1], respectively (Tables 2 and 3). All subjects were experienced operating engineers with an average experience of 12.2 [S.D. 13.5] and 8.0 [S.D. 5.9] years for the intervention and control groups, respectively. The mean body mass of the subjects was 81.9 kg [S.D. 13.7] for the intervention group ($N = 10$) and 101.0 kg [S.D. 20.8] for the control group ($N = 9$). The intervention group used the CPLMS for a total of 646 h, whereas the discomfort data collected from the control group covered a total duration of equipment use of 435.5 h. Prior to participation, each subject was briefed on the objectives of the study and signed an informed consent form approved by the Wichita State University Institutional Review Board for Human Subjects.

Table 2
Demographic data of the intervention group subjects with type of equipment and work performed

| Subject | Equipment type | Work performed | Age (yrs) | Experience (yrs) | Stature (cm) | Body mass (kg) |
|---|---|---|---|---|---|---|
| 1 | Excavator | Digging | 50 | 29.0 | 172.7 | 77 |
| 2 | Dozer | Leveling/loading | 25 | 5.0 | 182.9 | 72 |
| 3 | Dump truck | Moving dirt | 59 | 9.0 | 167.6 | 72 |
| 4 | Dump truck | Moving dirt | 40 | 7.0 | 170.2 | 81 |
| 5 | Dump truck | Moving dirt | 47 | 0.1 | 165.1 | 68 |
| 6 | Dump truck | Moving dirt | 37 | 1.0 | 175.3 | 77 |
| 7 | Dump truck, scrapper | Moving dirt, leveling | 28 | 4.0 | 177.8 | 81 |
| 8 | Dump truck | Moving dirt | 54 | 8.0 | 182.9 | 81 |
| 9 | Dump truck | Moving dirt | 63 | 40.0 | 170.2 | 113 |
| 10 | Tractor, motor grader, scrapper | Leveling/loading | 58 | 3.0 | 188.0 | 99 |
| 11 | Stump grinder | Mixing/pulverizing | 46 | 28 | [a] | [a] |
| Mean | | | 46.1 | 12.2 | 175.3 | 81.9 |
| Standard deviation | | | 12.5 | 13.5 | 7.5 | 13.7 |

[a] Missing data.

Table 3
Background data of operators in the control group with type of equipment and work performed

| Subject | Equipment type | Work performed | Age (yrs) | Experience (yrs) | Stature (cm) | Body mass (kg) |
|---|---|---|---|---|---|---|
| 1 | Dozer | Leveling/loading | 26 | 5.0 | 182.9 | 103.5 |
| 2 | Dump truck | Moving dirt | 28 | 6.0 | 182.9 | 94.5 |
| 3 | Dump truck | Moving dirt | 58 | 11.0 | 182.9 | 87.8 |
| 4 | Tractor | Leveling/loading | 21 | 1.5 | 165.1 | 81.0 |
| 5 | Dump truck | Moving dirt | 57 | 10.0 | 160.0 | 78.8 |
| 6 | Dozer | Leveling/loading | 25 | 7.0 | 188.9 | 135.0 |
| 7 | Excavator | Digging | 59 | 20.0 | 154.9 | 94.5 |
| 8 | Backhoe | Digging | 26 | 0.4 | 175.3 | 99.0 |
| 9 | Dozer | Leveling/loading | 31 | 11.0 | 180.3 | 135.0 |
| Mean | | | 36.8 | 8.0 | 174.8 | 101.0 |
| Standard deviation | | | 16.1 | 5.9 | 11.9 | 20.8 |


Old Dump Truck
New Dump Truck


Dozer
Excavator

Fig. 2. Some of the different types of earth moving equipment that were used at the construction sites.

### 2.3. Construction sites

Two different construction sites were selected for this study, one for intervention group and the other for the control group. The site for the intervention group was West Des Moines, IA (USA), whereas the site for the control group was 30 miles east of the intervention site (Ankeny, IA, USA). Both construction sites used similar equipment (Fig. 2) and performed similar work. The subjects at the control site and intervention site were not aware of each others involvement in this study.

### 2.4. Experimental design and procedure

This study was a quasi-experimental intervention design with multiple observations for the dependent variables (Robson et al., 2001). The effects of the CPLMS on the dependent variables were assessed using two subjective questionnaires—a body part discomfort survey and a CPLMS preference survey. The body part discomfort survey consisted of an outline of body parts (e.g., low back, upper back, neck, shoulder, elbow/forearm, wrist/hand, hip/thigh, knee, lower leg, ankle/foot) and a discomfort scale ranging from 0 (no discomfort) to 10 (worst discomfort imaginable); it was similar in format and content to those used in other field studies (Rosecrance et al., 2002; Stuart-Buttle, 1994; Kumar et al., 1999). Rosecrance et al. (2002) showed that for a similar body part discomfort survey the reliability ranged from low to high with kappa values for different body parts ranging from 0.13 to 0.71, and specifically low back and upper back the kappa values were 0.61 and 0.50, respectively. The CPLMS preference survey consisted of 15 questions, where the first five questions focused on how many days and hours, in what mode (static or dynamic), and at what level of inflation the CPLMS was used. The sixth question asked how much support the subjects felt the CPLMS provided (not enough, just right, or too much). Questions 7–10 asked about back stiffness, back fatigue, and back comfort, and how their current seat compared to the CPLMS. Responses to these questions were provided on a scale from 1 to 5, where 1 and 2 were "worse," 3 was the "same," and 4 and 5 were "better." Other questions were "what was the most important effect of the CPLMS" (not as stiff, not as tired, uncomfortable, feels good, or no change), "how does the CPLMS feel" (very comfortable, comfortable, fairly comfortable, uncomfortable, or very uncomfortable), "would you like to have a CPLMS in your equipment" (yes, no, or maybe), and "would you recommend CPLMS to a co-worker" (yes, no, or maybe).

The first day for the intervention group was spent identifying volunteer subjects', describing the objectives of the study, installing the CPLMS in the earth-moving equipment, and demonstrating to the subjects how to operate the settings of the CPLMS. The subjects were encouraged to try the different inflation level settings, as well as the static and dynamic inflation settings, during this first day to identify preferred settings as well as to become familiar with the operation of the CPLMS. The data collection using the body part discomfort survey commenced the next day. The subjects typically worked from 6:30 am to 6:00 pm, with a half-hour for lunch. The body part discomfort survey was collected from each subject before the beginning of the shift, at noon when operators returned to the site for lunch, and at the end of the shift. The CPLMS preference survey was collected from the intervention group once at the end of the data collection period. A similar procedure was followed for the control group, with the exception of the use of the CPLMS and the use of the CPLMS preference survey. The same experimenter collected and analyzed the data for both the intervention and control groups.

### 2.5. Data analysis

Descriptive statistics (mean and standard deviation [S.D.] for the different body parts) for the body part discomfort survey were derived for both groups. To assess the pattern of the discomfort scores during each day, the difference between the morning and evening body part discomfort scores were analyzed using a paired sample $t$-test. To assess the effectiveness of the CPLMS for controlling musculoskeletal discomfort, the body part discomfort scores were collapsed across all days for each group and compared. For each group for each day, the evening score for each subject was normalized to the morning score for each subject to obtain a body part discomfort difference score (e.g., evening score subtracted from the morning score). These body part discomfort difference scores were combined across all experimental days for both study groups, and the effectiveness of the CPLMS in controlling musculoskeletal discomfort was assessed by performing an independent sample $t$-test on the mean difference scores between the intervention and control groups. All statistical tests were conducted using $\alpha = 0.05$ to control for a Type I error.

Descriptive statistics were derived for the responses to questions from the CPLMS preference survey. For questions answered on a scale of 1–5, mean responses and 95% confidence intervals using the $t$-statistic for small samples were derived.

## 3. Results

### 3.1. Body part discomfort survey

Although the body part discomfort survey was collected three times a day, ratings could not be obtained from some subjects over their lunch break as some did not return to the site for lunch but remained out in the work area. Thus, the analysis of the discomfort survey used only the morning and evening data. In addition, although the body part discomfort survey consisted of responses of discomfort to multiple body parts, since the CPLMS is an intervention designed for the back during sitting, it was decided to assess only the upper back and low back discomfort scores. No significant differences for body part discomfort to the upper back were observed; thus, the remainder of the body part discomfort results described below focus on the lower back.

The mean morning and evening low back discomfort scores for the intervention group across all eight days of the study are shown in Fig. 3a. However, since not all of the subjects had both morning and evening data for each day (e.g., some operators moved to another site in the middle of the day), only the discomfort scores from operators who had both morning and evening data were assessed statistically, with the data shown in Fig. 3b. The paired sample $t$-tests on the differences between the morning and evening low back discomfort scores indicated that only day 8 resulted in a significant difference ($p \leqslant 0.05$) (see Fig. 3b).

The mean morning and evening low back discomfort scores for the control group are shown in Fig. 4a. Seven days of data collection were originally scheduled for the control group, however, days three and four were rained out. Fig. 4a shows that the evening low back discomfort

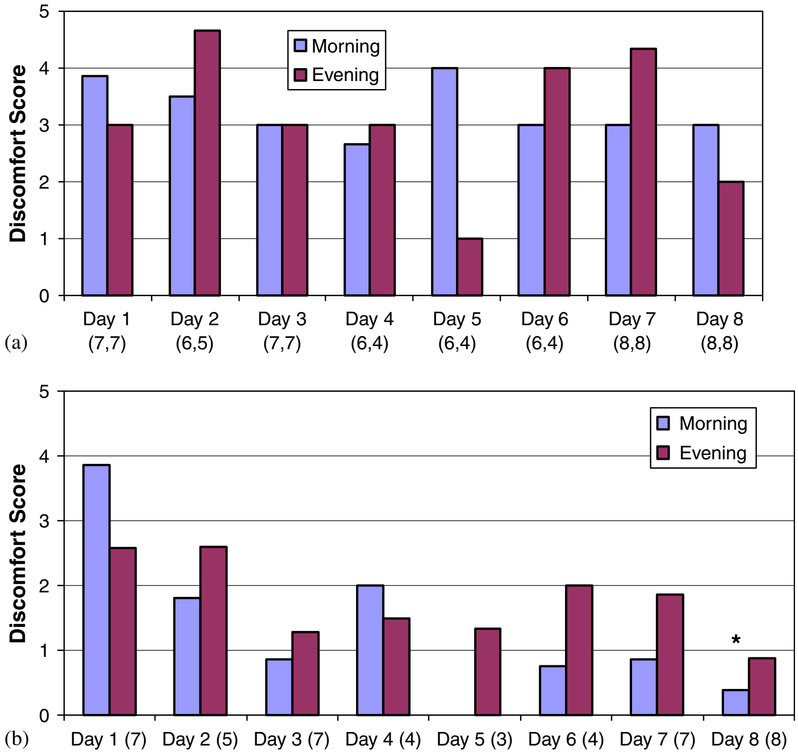

Fig. 3. (a) Mean low back discomfort scores for the intervention group for the morning and evening as a function of different study days. The data in the parenthesis indicates the number of subjects that took part in the study during morning and evening for each day. (b) Paired mean low back discomfort scores for the intervention group. The data in the parenthesis indicates the number of subjects that were used for the paired *t*-test analysis for each day. (*Indicates the days that are significant at $p \leqslant 0.05$.)

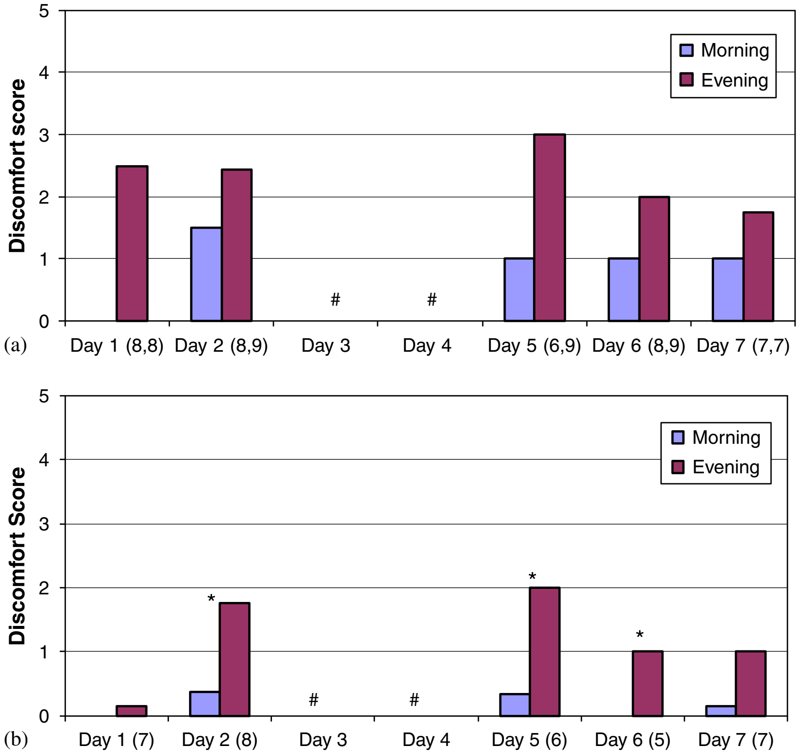

Fig. 4. (a) Mean low back discomfort scores for the control group for the morning and evening as a function of different study days. The data in the parenthesis indicates the number of subjects that took part in the study during morning and evening each day. (b) Paired mean low back discomfort scores for the control group. The data in the parenthesis indicates the number of subjects that were used for the paired *t*-test analysis for each day. (*Indicates the days that are significant at $p \leqslant 0.05$, $^{\#}$Days washed out due to rain.)

scores were always higher than the morning scores. Similar to the intervention group, some operators did not have both morning and evening scores due to being moved on and off the site during the day, thus, only the discomfort scores from the same individual from both morning and evening were used in the statistical analysis. The paired sample *t*-tests indicated that three of the five days resulted in significant differences between morning and evening scores (Fig. 4b).

The mean difference between the normalized low back discomfort scores (i.e., evening score subtracted from the morning score) as a function of experimental group is shown in Fig. 5. An independent sample *t*-test indicated that the difference between the intervention and control group with respect to the difference between morning and evening low back discomfort scores approached significance ($p = 0.06$) where the difference between morning and evening low back discomfort scores was less in the intervention group than in the control group.

### 3.2. CPLMS preference survey

The intervention group ($N = 11$) completed the CPLMS preference survey after they finished using the CPLMS (total hours used for all subjects = 646 h). When subjects were asked about the inflation levels and degree of comfort, none of the subjects were comfortable at the high inflation level (level 5 on the controller unit), 64% were comfortable at the medium levels of inflation (levels 3 or 4), and 36% of the subjects were comfortable at the low levels of CPLMS inflation (levels 1 or 2). When asked about how the CPLMS supported their backs, 64% felt that the CPLMS provided enough support, whereas 9% indicated not enough support, and 27% indicated too much support.

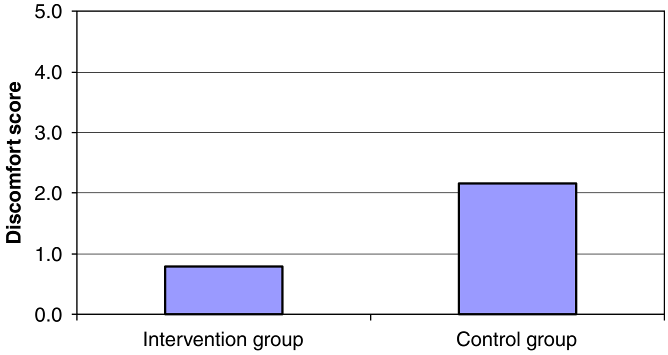

Fig. 5. Mean low back discomfort difference scores (evening minus morning) for the intervention and control groups across all experimental study days.

The questions in Table 4 were rated on a visual analogue discrete scale from 1 to 5, where 1 and 2 were "worse," 3 was the "same," and 4 and 5 were "better." Approximately 64% of the respondents felt that the CPLMS had a decreased effect on their back fatigue (mean response of 3.6). Similarly, 72% felt that the CPLMS had an improved effect on their back discomfort (e.g., "better," or scores of 4 or 5), with a mean rating of 3.9. Also, subjects indicated that use of the CPLMS marginally reduced their back stiffness, with a mean response of 3.3. When asked about how the CPLMS compared to their current seat, 60% indicated they felt the CPLMS was better with a mean response of 3.7. The 95% confidence interval for the mean response to the questions in Table 4 indicated the responses to questions about back fatigue (question 1), stiffness (question 3), and a comparison of the CPLMS to their current seat (question 4) ranged from slightly better than "same" to slightly less than "better." Thus, the subjective responses to these questions with respect to the CPLMS were slightly positive. For the 95% confidence interval on the mean response to the question about how the CPLMS affected their back discomfort, the mean response ranged from 3.68 to 4.14 (Table 4). Thus, the users felt that the CPLMS had a positive affect on their low back discomfort when compared to their usual seat. Finally, when subjects were asked if they would like to have a CPLMS installed in their equipment, 55% responded with a "maybe", 36% responded with a "yes" and 9% responded with a "no."

## 4. Discussion

Due to the nature of their work, operators of heavy earth-moving equipment are exposed to whole body vibration for prolonged periods of time. In addition, due to the long duration of the work shifts, these operators are exposed to static sitting. Thus, individuals in this occupation are exposed to two risk factors, whole-body vibration and static sitting, that have been associated with musculoskeletal disorders and discomfort of the low back region, including disc degeneration, sciatic pain, and other low back disorders (Boshuizen et al., 1990; Magnusson et al., 1996; Kittusamy, 2002; Kittusamy and Buchholz, 2001), where exposure to both risk factors together may increase the rate of disc degeneration leading to low back

Table 4
Results of the continuous passive lumbar motion system (CPLMS) preference survey (on a scale of 1–5, where 1 is "worse" and 5 is "better")

| Questions | Mean | 95% Confidence interval |
|---|---|---|
| (1) How did the CPLMS affect your back fatigue ($N = 11$) | 3.6 | 3.36–3.73 |
| (2) How did CPLMS affect your back comfort ($N = 11$) | 3.9 | 3.68–4.14 |
| (3) How did the CPLMS affect your back stiffness ($N = 10$) | 3.3 | 3.09–3.51 |
| (4) How would you compare the CPLMS to your current seat ($N = 10$) | 3.7 | 3.44–3.96 |

discomfort (Bovenzi, 2002). Thus, to reduce the risk of low back disorders or musculoskeletal discomfort in the low back region for operators of heavy earth-moving equipment, it may be necessary to either reduce the duration of exposure to static sitting and whole body vibration or provide interventions that reduce the level/amount of the exposures. The reduction in exposure hours may be difficult due to considerations such as time constraints to complete the job, lack of trained employees to operate the equipment, or budget issues. Thus, other interventions devised to reduce the level of the exposure may be more appropriate. The CPLMS, which was designed to reduce the effect of prolonged static sitting, was the intervention introduced and assessed for its ability to address musculoskeletal discomfort from static seating.

Prior to this study, evaluation of the CPLMS was limited to controlled laboratory settings (Reinecke et al., 1994; Hazard and Reinecke, 1995; Whiteside and McGill, 1996). These studies indicated improvements in lumbar curvature during sitting and an increase in comfort ratings when the CPLMS was used compared to when the CPLMS was not used. Although these prior studies were performed in a laboratory environment, considered 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 and less loading on the low back. However, since these studies were carried out in a laboratory setting, it is difficult to predict the effectiveness of the CPLMS in a practical setting, such as mobile construction equipment operation. Thus, the current study was carried out to assess the effectiveness of the CPLMS in an environment where low back discomfort is considered a problem. In addition, this study also sought to improve on the time frame for testing the effectiveness of the CPLMS. Thus, this study assessed the use of the CPLMS for a longer period of time (i.e., 646 h among 11 subjects) than in previous studies.

Similar to other studies (Reinecke et al., 1994; Hazard and Reinecke, 1995), this study had a control group that did not use the CPLMS and an intervention group that did use the device. When each day was tested for their statistical significance between morning and evening low back score, only one of the eight days resulted in significantly different morning and evening low back discomfort ratings ($p \leqslant 0.05$) for the intervention group. In contrast to the intervention group, three of the five days resulted in significantly different low back discomfort ratings between the morning and evening for the control group. Thus, an assessment within the intervention and control groups suggests that the CPLMS may have an overall effect of reducing the increase in low back discomfort throughout the day. This is also suggested when comparing the control and intervention groups against each other with respect to the difference between the morning and evening scores. For this comparison, the low back discomfort score difference between the intervention and control group approached significance ($p = 0.06$), where the intervention group demonstrated a smaller difference. Thus, this study suggests that the CPLMS may have a positive effect by not allowing the intensity of the back discomfort to increase throughout the day. Both intervention and control groups showed no significant differences between the mean discomfort scores for the upper back between morning and evening across all days. Thus, it appears that the effectiveness of the CPLMS may be specific to the lumbar region of the back. This is consistent with findings of improved lumbar curvature contributing to a more neutral spine when using the CPLMS (Hazard and Reinecke, 1995), as well as the decreased amount of discomfort in short-term driving of motor vehicles (Reinecke et al., 1994).

Finally, the effectiveness of any safety and health intervention in a field setting ultimately depends upon the user's subjective opinion as to whether or not the proposed intervention has the potential to improve his or her 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 subjects (72%) felt that the CPLMS reduced back discomfort, 55% felt that their back was not as stiff as it was before using the device, and 36% wanted a CPLMS installed permanently in their equipment.

The results of this study should be viewed in light of several methodological considerations. First, intervention and control groups at different site locations were used to reduce potential contamination effects of the intervention on discomfort responses. The two separate intervention and control group sites were chosen since both sites utilized similar earth-moving equipment and performed similar earth-moving work. However, this may have introduced factors that were uncontrolled that in theory could have an affect on the discomfort response and reduced the power of this study, such as differences in vibration magnitudes due to terrain, differences in earth-moving equipment related to seating and vibration, and differences in sample characteristics such as age and body mass. Second, this study had a small sample size limited by the number of CPLMS's that were available, as well as the number of subjects available at the study site. However, significant differences were found, suggesting this study has sufficient statistical power to detect differences. Third, the body part discomfort scores collected during the lunch period were not analyzed due to missing data points from subjects that stayed out in the field during lunch. However, this factor is not expected to affect the results as the intent of the study was to assess changes throughout the day as well as across days and this was achieved with morning and evening scores. Finally, pre-intervention discomfort scores were not collected from the intervention group, other than a morning score before trying the CPLMS on the first data collection day. However, multiple days of data collection indicated a consistent trend of no significant increase in low back discomfort scores, which, when combined with the significant increase in low back discomfort scores for the control group, suggests a positive affect of the CPLMS on low back discomfort.

## 5. Conclusion

The results from this field study suggest that the use of the CPLMS can potentially control the daily development of low back discomfort often experienced by operating engineers while working in environments exposed to whole body vibration and prolonged static sitting.

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**Disclaimer**. The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health (NIOSH). Mention of specific products and manufacturers does not imply endorsement by NIOSH.

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