Safety and Health Investment Projects

FINAL REPORT

Randomized Controlled Trial of a Whole Body Vibration Intervention in Truck Drivers

2011WH00171
02/01/2012 – 09/30/2013

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University of Washington / Washington Trucking Association / Harvard School of Public Health

1/27/2015

Peter W Johnson

Funding and support for this project has been provided by the State of Washington, Department of Labor & Industries, Safety & Health Investment Projects.

PART I

Narrative Report

Organization Profile:

For awarded organizations, to include partners and collaborators, provide a brief description of each organization. Mission, vision, and purpose for each of the organizations who applied (this includes partners and collaborators) for the grant.

Brief history of organization

The University of Washington (UW) Department of Environmental and Occupational Health Sciences (DEOHS) has been conducting applied occupational health and safety research in Washington state since the 1960s. As a part of this department, the Ergonomics Team has studied and characterized physical occupational exposures across many sectors and in many contexts including: orchard workers in the agricultural sector, computer input device and workstation design, and whole body vibration exposure and remediation of whole body vibration exposures in semi-trucks, transit buses, front loaders and forklifts.

Brief Statement of organization's vision/mission

The mission of the UW DEOHS is to identify agents in the environment and the work place that affects human health, to elucidate their mechanisms, to develop strategies for confronting their effects, and to share the knowledge obtained. Within this greater context, our research team works towards advancing the science of ergonomics and human factors through field and laboratory exposure assessment investigations with the goal of protecting working populations from the onset and development of preventable work-related musculoskeletal disorders.

Brief description of track record of achievement

The UW DEOHS has an excellent track record of applied research on occupational safety and health hazards. Within the department, our research team, led by Dr. Pete Johnson, a respected expert in the field of whole body vibration exposure assessment and has published 15 peer-reviewed manuscripts and conference proceedings summarizing the results of our research to the scientific community (See Annotated Bibliography). Through this process, we have fostered partnerships with King County Metro Transit, Boeing, Bose Corporation, Microsoft, Hewlett-Packard, Steelcase and Logitech, among others, and worked together to improve products, tools and workplaces through investigation and innovation.

Our Team demonstrates leadership in the field of Whole Body Vibration, promoting innovation and evaluating exposures across a variety of exposure scenarios, including the occupational environments of transit bus drivers, fork-lift operators, snow removal loader operators, and semi-truck drivers. We have a successful track record of developing techniques for evaluating seating and vehicle design studies in field settings, while collaborating with professional drivers, heavy equipment operators, and business managers.

Our assessments of computer input device design provides insight on redefining the design process and potentially creating new computer input device design standards to further promote effective ergonomics and health across specific subpopulations, including youth and smaller statured users (e.g. females and non-Caucasian populations). We are able to provide company leaders with data-driven design recommendations to advance the field of computer ergonomics.

How does this project fit into the work of your organization?

Our research team works towards advancing the science of ergonomics and human factors through field and laboratory exposure assessment investigations with the goal of protecting working populations from the onset and development of preventable work-related musculoskeletal disorders. This project's long-term goal is to improve the health and well-being of semi- truck drivers in the Transportation, Warehouse, and Utilities sectors though whole body vibration (WBV) exposure reduction, is directly in line with our mission and has grown from previous exposure assessment research and fills a specific Washington State need.

Current engineering approaches to reduce truck drivers' exposures to whole body vibration rely on passive suspension systems for both the semi-truck cab and the driver's seat suspension. These seat suspensions employ mainly pneumatic and hydraulic components to attenuate the transmission of vibration from the floor of the cab to the seat of the driver; however, as our preliminary and past studies have demonstrated these technologies do not have the frequency response (ability to react in a rapid manner) to reduce WBV exposures (Johnson and Blood, 2011).

Recently, active vibration cancelling semi-truck seats, which use linear electromagnetic actuators and actively counteract vehicle vibrations transmitted to the driver through the truck floor, have become commercially available. Due to far greater fidelity in frequency response (faster response times), these electromagnetic, active vibration cancelling (EAVC) seats are far superior to their pneumatic and/or hydraulic passive and active vibration cancelling counterparts. As demonstrated in our preliminary work (Johnson and Blood, 2011), the EAVC systems reduced average vibration exposures by up to 50% compared to the conventional passive, air-suspension seats that are supplied as standard equipment in most semi-trucks. However, to determine whether the EAVC seat suspension system is a viable intervention for reducing WBV exposures and improving the low back health of semi-truck drivers, we proposed a randomized controlled trial comparing the current technology, passive air-suspension truck driver seats and the new technology active suspension truck driver seats.

Partners

Brief history of organization

The Washington Trucking Associations (WTA) is a nonprofit corporation established in 1922 by a group of truck owners for the purpose of protecting and promoting the interests of all segments of Washington's trucking industry.

Brief Statement of organization's vision/mission

The WTA is the Washington trucking industry's information center and spokesperson; providing services tailored to its trucking industry members and keeping them informed. The mission of WTA is to promote a favorable and profitable operating climate for your trucking business, as well as maintaining close contacts with government agencies, the legislature and other organizations directly or indirectly related to your business. Progressive legislation is indispensable to the welfare of the trucking industry. The WTA utilizes the united power of its membership to support legislation that would benefit the trucking industry.

Their contribution to the project

The WTA has substantial knowledge of the day-to-day operations and challenges, as well as the economic realities, faced by its industry owners and truck drivers. They not only assisted with recruitment of the companies that participated in our study, but their collaboration also helped the researchers approach the trucker drivers in a culturally competent and appropriate manner.

Collaborator

Brief history of organization

Harvard School of Public Health traces its roots to public health activism at the beginning of the last century, a time of energetic social reform. HSPH began as the Harvard-MIT School of Health Officers, founded in 1913 as the first professional training program of public health in America. The partnership offered courses in preventive medicine at Harvard Medical School, sanitary engineering at Harvard University and allied subjects at MIT. In 1922, the School split off from MIT, helped by a sizeable grant from the Rockefeller Foundation. From the start, faculty were expected to commit themselves to research as well as teaching. In 1946, no longer affiliated with the medical school, HSPH became an independent, degree-granting body.

Brief Statement of organization's vision/mission

The overarching mission of Harvard School of Public Health is to advance the public's health through learning, discovery, and communication. To pursue this mission, the School produces knowledge through research, reproduces knowledge through higher education, and translates knowledge into evidence that can be communicated to the public, policy makers, and practitioners to advance the health of populations.

Their contribution to the project

Our collaborator, Dr. Jack Dennerlein who now has his primary appointment at Northeastern University and a secondary appoint at Harvard University has significant skills in the work-role functional survey data and the musculoskeletal pain surveys and participated in the creation, administration and analysis of survey data, and provided and will continue to provide additional expert oversight in the preparation of manuscripts, reports, and dissemination of results.

Abstract: Present a short overview of the nature and scope of the project and major findings (less than half a page).
Previous epidemiological studies have shown that exposure to whole body vibration (WBV) is a leading risk factor for occupational low back pain (LBP) in professional vehicle operators. LBP is the most common cause of persistent disability claims and continues to be the leading cause of morbidity and lost productivity in the workplace. Therefore, this study characterized WBV exposures during regular truck driving and evaluated an engineering seating intervention designed to reduce WBV exposures. Using a prospective, longitudinal study design with 60 professional truck drivers including 20 control group participants (used their existing old seat), 20 placebo group participants (received and used a new air-suspension seat) and 20 intervention group participants (received and used a new active-suspension seat), WBV exposures, LBP and low back function data were collected over five specific time points over a 12 month period: 1) one month prior to the intervention, 2) post-intervention, 3) 3-months post-intervention, 6-months post-intervention and 12-months post intervention. The results showed greater reduction in the WBV exposures in the truck drivers using the active suspension seats compared to the truck drivers using the air-suspension seats. This greater reduction in WBV exposures with the active suspension seats was also reflected by relatively greater improvement on LBP outcomes in the intervention group (truck drivers with the active suspension seats). The findings indicate that the proposed seating intervention (active suspension seats) can be beneficial to reduce WBV exposures and potentially improve the LBP for professional truck drivers.

Purpose of Project: Describe what the project was intended to accomplish.
Truck drivers suffer from numerous health issues, predominantly musculoskeletal disorders (MSDs) in the low back. These MSDs have been strongly associated with exposure to whole body vibration (WBV). This proposal will determine if reducing WBV exposure will improve the health and safety of trucker drivers in Washington State and the throughout United States.

Statement and Evidence of the Results:

Provide a clear statement of the results of the project include major findings and outcomes and provide evidence of how well the results met or fulfilled the intended objectives of the project.

1. The truck drivers in the intervention group (received the active suspension seats) showed significantly greater reduction in WBV exposures as compared to the placebo (received new air-suspension seats) and control (received no new seats) groups (Appendix A).
2. The truck drivers in the intervention group experienced greater improvement in LBP as compared to the control and placebo groups (Appendix B).
3. The study showed that the group mean vector sum WBV exposures were at or above International Standards Organization (ISO) and European Union (EU) action limits for the control and placebo groups whereas all the vector sum WBV exposures were below these action limits for the intervention group (Appendix C).

Measures to Judge Success:

If relevant, state what measures or procedures were taken to judge whether/ how well the objectives were met and whether the project or some other qualified outside specialist conducted an evaluation.

The success of the project will be evaluated via dissemination including scientific regional and national conferences, and peer-review journal articles. The peer-review process during journal submission will extensively evaluate the success of the projects in an objective manner. Currently, several peer-review journal papers from this project are under preparation.

Relevant Processes and Lessons Learned:

Specify all relevant processes, impact or other evaluation information which would be useful to others seeking to replicate, implement, or build on previous work

AND

Provide information on lessons learned through the implementation of your project. Include both positive and negative lessons. This may be helpful to other organizations interested in implementing a similar project.

Relevant processes, impact, or other evaluation information

- First randomized controlled trial study to evaluate a WBV engineering (seating) intervention

As there have been no systematic, long-term studies evaluating WBV interventions, measuring WBV exposures over time, and/or characterizing the subsequent health effects (e.g. changes in low back pain and/or low back function) in professional vehicle operators, it is still unclear whether reduced WBV exposures can improve work-related musculoskeletal disorders, especially low back pain. Therefore, this randomized controlled longitudinal trial evaluated the WBV attenuation performance of two different types of seat suspension for one year as described in Figure 1.

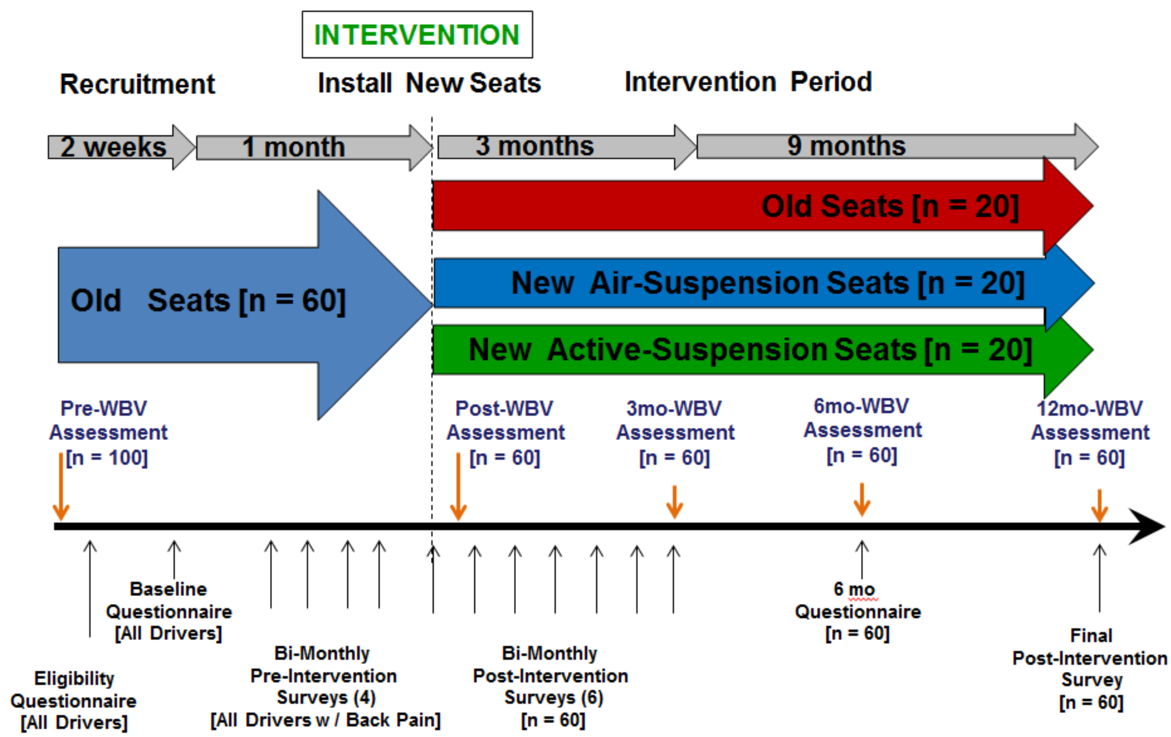

Figure 1. Study design.

-Subject recruitment

A total of 60 professional long-haul truck drivers from five different companies participated for this randomized controlled trial designed to evaluate different seat suspension systems. All the participating drivers were regional or line-haul drivers, meaning that they spent the majority of their day behind the wheel driving. In addition, all recruited drivers were classified as "no-touch" drivers which implies they primarily did not handle or lift cargo unless absolutely necessary. The experimental protocol was approved by the University's Human Subject Committee and all subjects gave their informed consent prior to their participation in the study.

- WBV exposure data collection and analysis (pre, 0, 3, 6, 12 months)

Prior to the data collection, accelerometer calibration was verified using a vibration calibrator (VC21; Metra Mess- and Frequenztechnik; Radebeul, Germany) with vibration magnitudes of 1, 2, 5, and 10 m/s2 (root mean square) at vibration frequencies of 15.92, 80, and 159.2 Hz. The accelerometer calibrations and measured outputs were verified using a data logger (HVM 100; Larson Davis; Depew, NY, USA).

Per ISO 2631-1 standards, a tri-axial seat-pad accelerometer (Model 356B40; PCB Piezotronics; Depew, NY) was mounted on the driver's seat and either an identical tri-axial or single axis (z-axis) accelerometer (Model 352C33; PCB Piezotronics; Depew, NY) was magnetically mounted to the floor of the truck cab beneath the driver's seat (Figure 2). Raw un-weighted acceleration data were collected at 1,280 Hz using either a four or eight channel data recorder (Model DA-20 or DA-40; Rion Co. LTD; Tokyo, Japan) during the subjects' full work shift (8-12 hours). Vehicle speed and location were simultaneously recorded at 1 Hz using a GPS logger (Model DG-100; GlobalSat; Chino, CA).

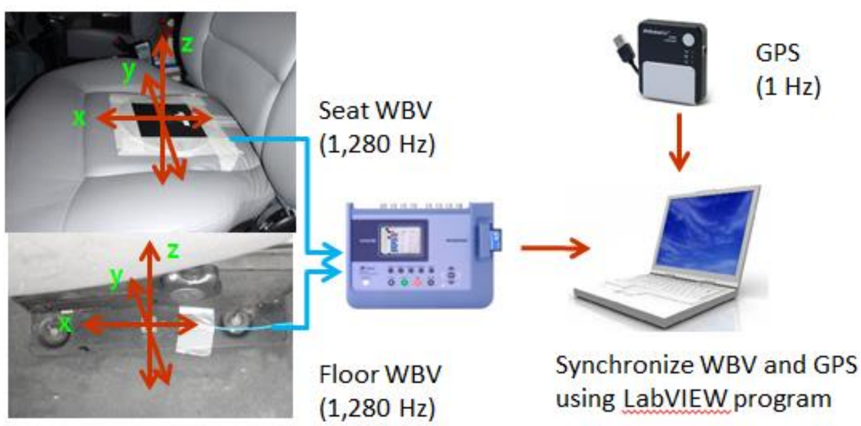

Figure 2. Data acquisition system

After the data collection, a LabVIEW program (v2012; National Instruments; Austin, TX) was used to parse the acceleration data based on GPS coordinates and then calculate the WBV exposure parameters per International Standards Organazation (ISO) 2631-1 and 2631-5 standards. Both continuous (ISO 2631-1) and impulsive (ISO 2631-5) WBV exposure parameters calculated using a LabVIEW program (Blood et al., 2010 and 2011, Thamsuwan et al, 2013) included:

ISO 2631-1 parameters

- Root mean square (r.m.s) weighted average acceleration (A_w) calculated at the floor and at the seat pan (m/s^2) during the full work shift:

$$A_w = \sqrt{\frac{1}{T}\int_0^T a_w^2(t)dt} \quad (1)$$

$where$
$a_w(t)$: $instantaneous\ frequency - weighted\ acceleration\ at\ time, t;$
T: $the\ duration\ of\ the\ measurement, in\ seconds.$

- Vibration dose value (VDV), which is more sensitive to impulsive vibration and reflects the total, as opposed to average vibration, over the measurement period at the seat pan and floor of the trucks (m/s$^{1.75}$):

$$VDV = \left[\int_0^T a_w^4(t)dt\right]^{\frac{1}{4}} \quad (2)$$

- Maximum transient vibration value (MTVV), the highest magnitude of the instantaneous frequency-weighted acceleration, $a_w(t_0)$ during the measurement period (T):

$$MTVV = \max[a_w(t_0)] \quad (3)$$

$$a_w(t_0) = \sqrt{\frac{1}{\tau}\int_{-\infty}^{t_0} a_w^2(t)\exp\left(\frac{t-t_0}{\tau}\right)dt}$$

$where$
$a_w(t)$: $instantaneous\ frequency - weighted\ acceleration\ at\ time, t;$
τ: $the\ integration\ time\ for\ running\ average;$
t: $the\ time\ (integration\ variable);$
t_0: $the\ time\ of\ observation\ (instantaneous\ time).$

ISO 2631-5 parameters

- Acceleration dose value (D_k) in m/s^2:

$$D_k = \left[\sum_i A_{ik}^6\right]^{\frac{1}{6}} \quad (4)$$

$where$
A_{ik}: $the\ i^{th}\ peak\ of\ the\ response\ acceleration\ (a_{ik}(t));$
k: $x, y, or\ z.$

- Average daily dose value (D_{kd}) to which a truck driver will be exposed (m/s^2):

$$D_{kd} = D_k\left(\frac{t_d}{t_m}\right)^{\frac{1}{6}} \quad (5)$$

$where$
D_k: $acceleration\ dose\ value\ in\ equation\ (4)$
t_d: $the\ duration\ of\ the\ daily\ exposure;$
t_m: $the\ period\ over\ which\ D_k\ has\ been\ measured.$

All the parameters (A_w, VDV, D_k, S_{ed}) were normalized to reflect 8 hours of driving exposure (e.g. $A_w(8), VDV(8), D_k(8)$. Finally, seat effective amplitude transmissibility (SEAT) factors were calculated on A_w, VDV and D_k to determine how well the seats attenuate the vibration transmitted to the seat base from the floor as shown in equation (6).

$$SEAT\ (\%) = \frac{parameter\ value_{seat}}{parameter\ value_{floor}} \times 100 \quad (6)$$

The statistical analysis was conducted in JMP Statistical Discovery Software (Version 9; SAS

Institute; Cary, SC). A *mixed* model with *restricted maximum likelihood estimation* (REML) was used to determine whether there were differences in WBV attenuation between the seats over time. In the model, subject was included as a random effect; seat type and measurement time were treated as fixed effects. When statistical significance was found, *Tukey post hoc* multiple pairwise comparisons were carried to specify where the differences came from. Significance was noted when Type I error is less than 0.05.

- Pain data collection and analysis

To evaluate the long-term effect of the seat intervention on musculoskeletal outcomes, comprehensive pain data were collected using standardized and validated questionnaires (Table 1). The comprehensive surveys included baseline (pre-intervention) questionnaires and post-intervention follow-up questionnaires at 3, 6, and 12 months. The questionnaires were designed to evaluate LBP intensity and frequency, LBP disability index, other musculoskeletal health outcomes, work function, job characteristics, and individual characteristics (Table 1).

Table 1. Standardized questionnaires.

Outcomes	Methods	Source
LBP intensity	Nordic questionnaire	Kuorinka et al. 1987
LBP frequency	Oswestry questionnaire	VIBVRISK 2007
LBP effects on personal and working life	Oswestry LBP disability index	Fairbank & Pynsent 2000
Other musculoskeletal health outcome	10-point standardized and modified Nordic questionnaire	Vibration Injury Network 2001 Dennerlein et al. 2012
Work function	Work limitation questionnaire	Lerner et al. 2001
Job characteristics	Structured questionnaire	Dennerlein et al. 2012
Individual characteristics	Structured questionnaire	Ware 1993

In addition, pain data were also collected via 4 weekly pre-intervention (1 month) and 6 semi-monthly post-intervention questionnaires (3 months) to evaluate the short-term effects of the seat interventions on musculoskeletal outcomes.

Because this study was longitudinal, it was inevitable to have missing measurements and responses in the data we collected. To minimize the potential for any misleading results due to the missing values, a mixed statistical model, which is known to be one of the most effective statistical models for dealing with missing data, was used to analyze the pain data. Results were considered statistically significant when p-values were less than 0.05.

- Impact

The findings obtained from this randomized controlled trial will provide evidence-based approaches to reduce WBV vibration and therefore reduce occupational LBP for the transportation sector and long haul truckers. Because of the huge public health burden associated with low back pain, the potential social and economic benefit associated with reducing low back pain has the potential to be quite large (Rauser et al. 2008). The demonstrated effect will provide credence to the trucking industry to seek effective ways to reduce whole body vibration beyond the traditional approaches. The results can also have implications beyond semi-trucks. Such technology could yield positive effects in other large occupational populations including city and coach bus drivers, garbage collectors, and other professional drivers.

Lessons learned

- Positive

a) The collected GPS data were extremely useful for us to identify standardized road segments. By comparing the WBV exposure data between the study exposure groups from the standardized road segments, we were able to reduce variability and confounding effects (e.g. different speed, road surface roughness and types of road) when comparing the WBV exposures between the seats. The GPS data also enabled us to systematically compare the WBV exposures by speed and location.

b) Building good relationships with truck drivers and dispatchers were extremely helpful for us to facilitate the exposure measurement, seating intervention, and survey administration.

c) It was very important for the research group to minimize possible interference with truck driver's work and their schedule during data collection.

- Negative (Potential improvement for future studies)

a) As stated in the project proposal, participation drop out is inevitable in any longitudinal study. In this study, the dropout rate (~35%) was higher than what we expected due to various reasons including truck driver's health problems, personal seat preference, and truck break down.

b) The sample size of 60 participants was selected in order not to exceed the grant budget limit. However, given the higher dropout rate in trucking industry, a larger sample size would be beneficial to increase the statistical power to detect differences in LBP between the groups.

c) As stated in the study limitations in the proposal, the active suspension seat is available from only one manufacturer. Truck drivers who previously owned National seats preferred the seat tops manufactured by National. Having different seat tops available to drivers in the active suspension seats would reduce the dropout rate because the active seat top is very different from the National seat top.

Product Dissemination:

Outline of how the products of the project have been shared or made transferrable.

2 conference proceedings were published and presented:
- American Conference on Human Vibration 2014, Guelph, Ontario, CA.
- Association of Canadian Ergonomists 44th Annual Conference 2013, Whistler, BC., CA.

5 peer-review journal articles are currently under preparation

Feedback:

Provide feedback from relevant professionals, stakeholder groups, participants, and/ or independent evaluator on the project.

Dissemination and feedback is ongoing which will include further disseminating results to our grant partner, the Washington Truckin Association (WTA) as well as presenting results at the Washington Govenor's Industrial Safety & Health Conference.

Project's Promotion of Prevention: Explain how the results or outcomes of this project promote the prevention of workplace injuries, illnesses, and fatalities?
Previous epidemiological and physiological studies have shown that the occupational WBV exposure is strongly associated with LBP. Numerous truck drivers are suffering from various health problems among which LBP is the most common, costly work-related injury. Therefore, the study determined the reduced WBV via seat intervention could reduce LBP outcomes. The fundamental assumption of the study was the less exposures the less injuries.

Uses: How might the products of your project be used within the target industry at the end of your project? Is there potential for the product of the project to be used in other industries or with different target audiences?
The results will provide an evidence-based engineering intervention to reduce WBV vibration and therefore reduce occupational LBP for the transportation sector and long haul truckers. Because of the huge public health burden of low back pain the potential social and economic benefit can be large (Rauser et al. 2008). The demonstrated effects of our grant results showed that reducing WBV exposures lowered LBP. This demonstrates that seating interventions which substantially reduce WBV exposure may reduce back pain and potentially the morbidity and long-term direct and indirect costs. The results can also have implications beyond semi-trucks. Such seating technologies which reduce WBV exposures could yield positive effects in other large occupational populations including city and coach bus drivers, garbage collectors, and other professional drivers such as agricultural tractor drivers and mining equipment operators. Indeed, based on the lessons learned from this project, we were funded and are currently conducting similar studies in larger scale (NIOSH R01 OH010097-01A2) and in different industries such as surface mining (Alpha Foundation) and agriculture industry (NIOSH R21: pending).

Additional Information

<table>
<tr><td colspan="2">Project Type
☐ Best Practice
☐ Technical Innovation
☐ Training and Education Development
☐ Event
☐ Intervention
☒ Research
☐ Other (Explain):</td><td rowspan="3"><u>Industry Classification</u> (check industry(s) this project reached directly)
☐ 11 Agriculture, Forestry, Fishing and Hunting
☐ 21 Mining
☐ 22 Utilities
☐ 23 Construction
☐ 31-33 Manufacturing
☐ 42 Wholesale Trade
☐ 44-45 Retail Trade
☒ 48-49 Transportation and Warehousing
☐ 51 Information
☐ 52 Finance and Insurance
☐ 53 Real Estate and Rental and Leasing
☐ 54 Professional, Scientific, and Technical Services
☐ 55 Management of Companies and Enterprises
☐ 56 Administrative and Support and Waste Management and Remediation Services
☐ 61 Educational Services
☐ 62 Health Care and Social Assistance
☐ 71 Arts, Entertainment, and Recreation
☐ 72 Accommodation and Food Services
☐ 81 Other Services (except Public Administration)
☐ 92 Public Administration</td></tr>
<tr><td colspan="2">Target Audience: Trucking industry, Drivers, truck and seat manufacturers, practitioners, and researchers.</td></tr>
<tr><td colspan="2">Languages: English</td></tr>
<tr><td colspan="2">Please provide the following information - -
(information may not apply to all projects)</td><td rowspan="6">List, by number above, industries that project products could potentially be applied to.
11, 21, and 23</td></tr>
<tr><td># classes/events:</td><td></td></tr>
<tr><td># hours trained</td><td></td></tr>
<tr><td># companies participating in project</td><td>4</td></tr>
<tr><td># students under 18</td><td></td></tr>
<tr><td># workers</td><td>60</td></tr>
<tr><td># companies represented</td><td></td><td rowspan="3">Potential impact (in number of persons or companies) after life of project?</td></tr>
<tr><td># reached (if awareness activities)</td><td></td></tr>
<tr><td>Total reached</td><td></td></tr>
<tr><td colspan="3">Have there been requests for project products from external sources?
If Yes, please indicate sources of requests:</td></tr>
</table>

PART II

Financial Information
Budget Summary

Project Title:	Randomized Controlled Trial of a Whole Body Vibration Intervention in Truck Drivers		
Project #:	2011WH00171	**Report Date:**	10/0/2014
Contact Person:	William Pickert	**Contact #:**	206-616-0545
Start Date:	02/01/2012	**Completion Date:**	6/30/2014

1.	**Total original budget for the project**	$ 253,525
2.	**Total original SHIP Grant Award**	$ 253,525
3.	**Total of SHIP Funds Used**	$ 253,525
4.	**Budget Modifications (= or - if applicable)**	$ 0
5.	**Total In-kind contributions**	$ 65,900
6.	**Total Expenditures (lines 2+4+5)**	$ 319,425

Instructions:
- Complete the Supplemental Schedule (Budget) form first (on the next page).
- The final report must include all expenditures from date of completion of interim report through termination date of grant.
- Indicate period covered by report by specifying the inclusive dates.
- Report and itemize all expenditures during specified reporting period per the attached supplemental schedule.
- Forms must be signed by authorized person (see last page).
- Forward one copy of the report to Arlene Hallom, SHIP Project Manager at PO Box 44612, Olympia, WA 98504-4612

PART II *(Continued)*

Financial Information
Supplemental Schedules (Budget)

Project Title:	Randomized Controlled Trial of a Whole Body Vibration Intervention in Truck Drivers		
Project #:	2011WH00171	**Report Date:**	10/08/2014
Contact Person:	William Pickert	**Contact #:**	206-616-0545
Total Awarded:	$253,525		

ITEMIZED BUDGET: How were SHIP award funds used to achieve the purpose of your project?

	Budgeted for Project	Amount Paid Out	Difference
A. PERSONNEL	$92,321	$126,470.17	$-34,149.17

Explanation for Difference and other relevant information: New personnel, Monica Zigman, on project whose pay rates were higher than Visiting Scientist Patrik Rynell who they replaced. Jeong Ho Kim assisted on the project and his salary was also higher. Increases in UW fringe benefits rate. Project personnel completed work that was originally to be done by the subcontractor so that resulted in more effort.

	Budgeted for Project	Amount Paid Out	Difference
B. SUBCONTRACTOR	$60,000	$23,303	$36,697

Explanation for Difference and other relevant information: Project personnel completed several task that were originally part of the scope of work for the subcontract.

	Budgeted for Project	Amount Paid Out	Difference
C. TRAVEL	$8,338	$11,630.78	$-3,292.78

Explanation for Difference and other relevant information: More travel to study sites was required than was anticipated in the original budget request.

	Budgeted for Project	Amount Paid Out	Difference
D. SUPPLIES	$69,250	$73,982.36	$-4,732.36

Explanation for Difference and other relevant information: Prices for the passive suspension seats turned out to be less than budgeted. The cost saving was used to supplement salaries.

	Budgeted for Project	Amount Paid Out	Difference
E. PUBLICATIONS	$3,750	$0	$3,750

Explanation for Difference and other relevant information: The data analysis ran until the end of the grant as a result we could not hire someone to develop a website and paper develop the pamphlets as outlines in the original proposal. The difference was used to supplement salaries.

	Budgeted for Project	Amount Paid Out	Difference
F. OTHER	$19,866	$18,138.69	$1727.31

Explanation for Difference and other relevant information: UW's indirect cost rate went down slightly during the project period.

	Budgeted for Project	Amount Paid Out	Difference
Total Direct Costs	$233,659	$235,386.31	$1,727.31
	Budgeted for Project	Amount Paid Out	Difference
Total Indirect Costs	$19,866	$18,138.69	$1,727.31
	Budgeted for Project	Amount Paid Out	Difference
Total SHIP Budget	$253,525	$253,525	$0

	Budgeted for Project	Amount Paid Out	Difference
G. In-kind	$65,900	$65,900	$0
Explanation for Difference and other relevant information:			

I hereby certify that the expenditures listed on this report were made with my approval:

10/8/14

Date | Signature of Project Manager

Part III
Attachments:

Appendix A. Whole body vibration exposure comparisons between the three study groups. Control refers to the truck drivers who kept their existing seats (n = 12), Placebo refers to the truck drivers receiving new, current technology, passive, air-suspension seats (n = 20). Intervention refers to the groups of truck drivers that received the new technology, active-suspension truck driver seats (n = 20).

As shown in the right side of Figure 3, over time and compared to the control and placebo groups, the active suspension seats (intervention) showed greater reduction (46%) in z-axis (up-and-down) WBV weighted average vibration (A(8)) although there were no differences in the floor-measured WBV exposures (left side of Figure 3). However, the time-dependent changes in the vibration does values (VDV(8)) between the groups were relatively small.

Seat effective amplitude transmissibility (SEAT) ratios were calculated for A(8) and VDV(8) to determine how well the seats attenuated the vehicle transmitted vibration. The SEAT ratio is the seat-measured vibration divided by the floor-measured vibration of the vehicle. (Figure 4). The results showed that the intervention seat had better WBV attenuation performance when compared to the other seats.

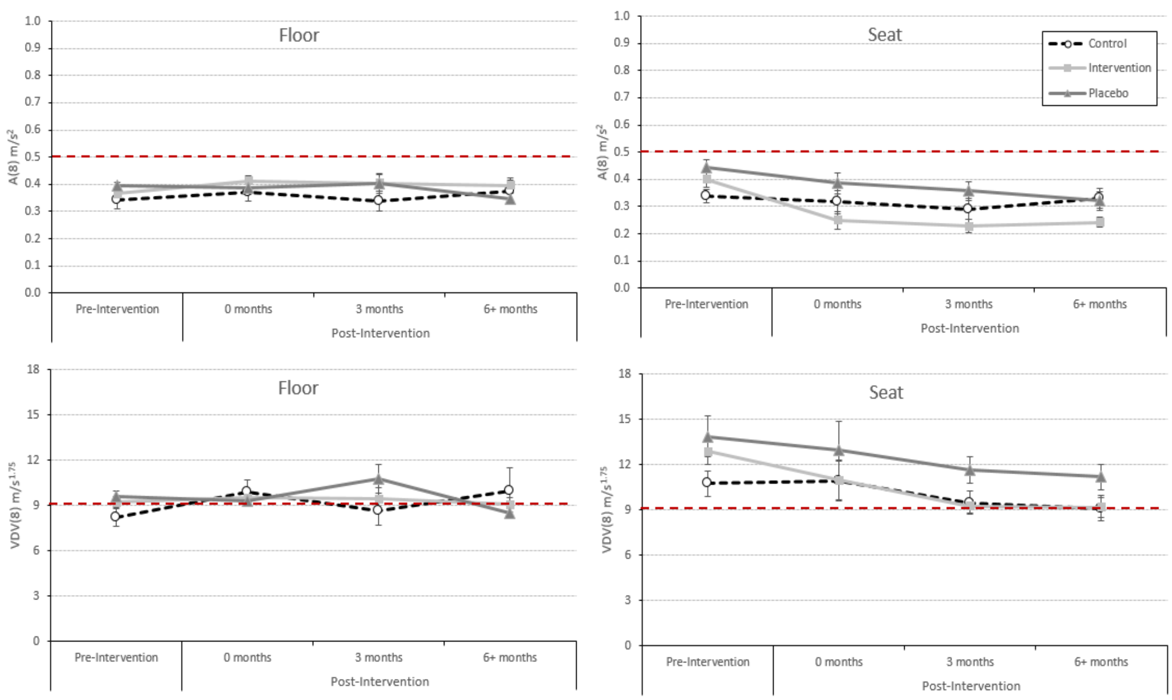

Figure 3. Comparison of the daily average weighted vibration (A(8)) and daily Vibration Dose Values (VDV(8)) between the three study groups over time. The red dotted lines represent the ISO and EU action limits, 0.5 m/s^2 for A(8) and 9.1 $m/s^{1.75}$ for VDV(8), for exposure to WBV. Note that pre-intervention WBV measurements are based on the original air suspension seats and not from the seats installed or used after the intervention. Due to the substantial number of study dropouts, subject turnover and new trucks, 12 month values are not presented.

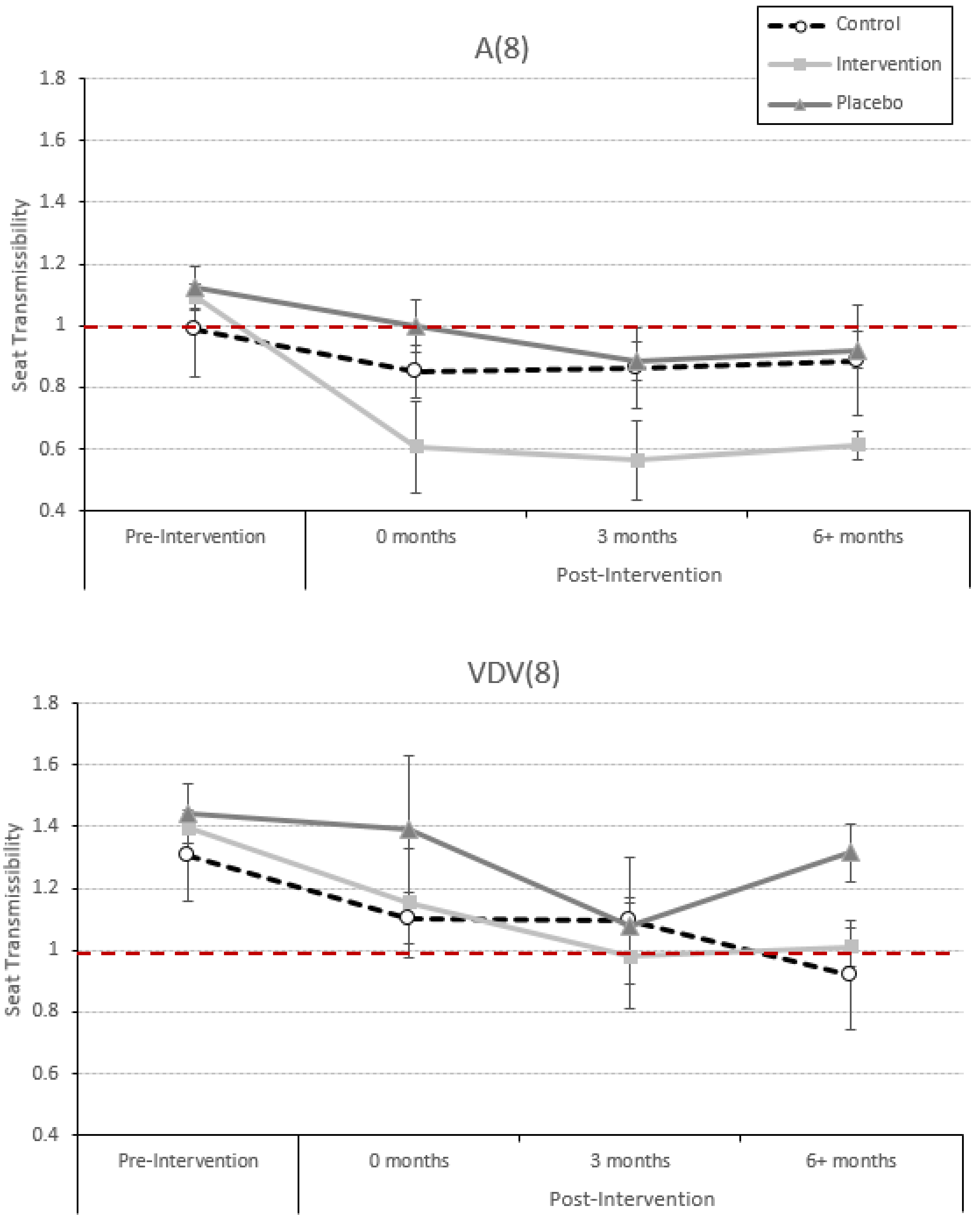

Figure 4. Comparison of Seat Transmissibility (%) between the groups based on the daily average weighted vibration (A(8)) and daily vibration dose value (VDV(8)). Values above the red dotted line indicates that the seat is amplifying rather than attenuating the floor-transmitted vibration.

Appendix B. Low back pain outcome comparisons

As shown in Figure 5, the truck drivers in the intervention group experienced greater improvement in LBP as compared to the other groups. The LBP reduction in the intervention group (active suspension seat) was approximately 30% of the mean baseline measures. This change may be clinically meaningful as previous studies suggested that clinical important differences should be at least 25% changes in the mean baseline.

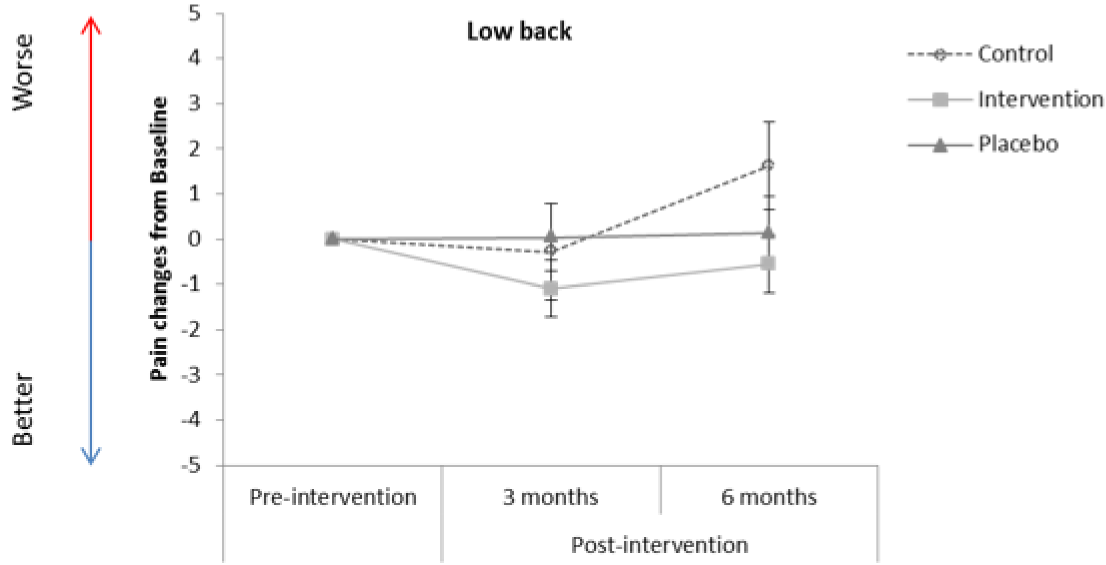

Figure 5. Comparisons of low back pain scores between the subjects when grouped by seat type. The positive numbers indicates increase in pain intensity whereas the negative numbers implies improvements in LBP.

Appendix C. Vector sum measures of WBV exposures

The study showed that the seat-measured A(8) vector sum WBV exposures were at or above ISO and EU action limits for the non-intervention groups whereas all the vector sum WBV exposures were below these action limits for the intervention group. All vector sum VDV(8) exposures were above ISO and EU action limits.

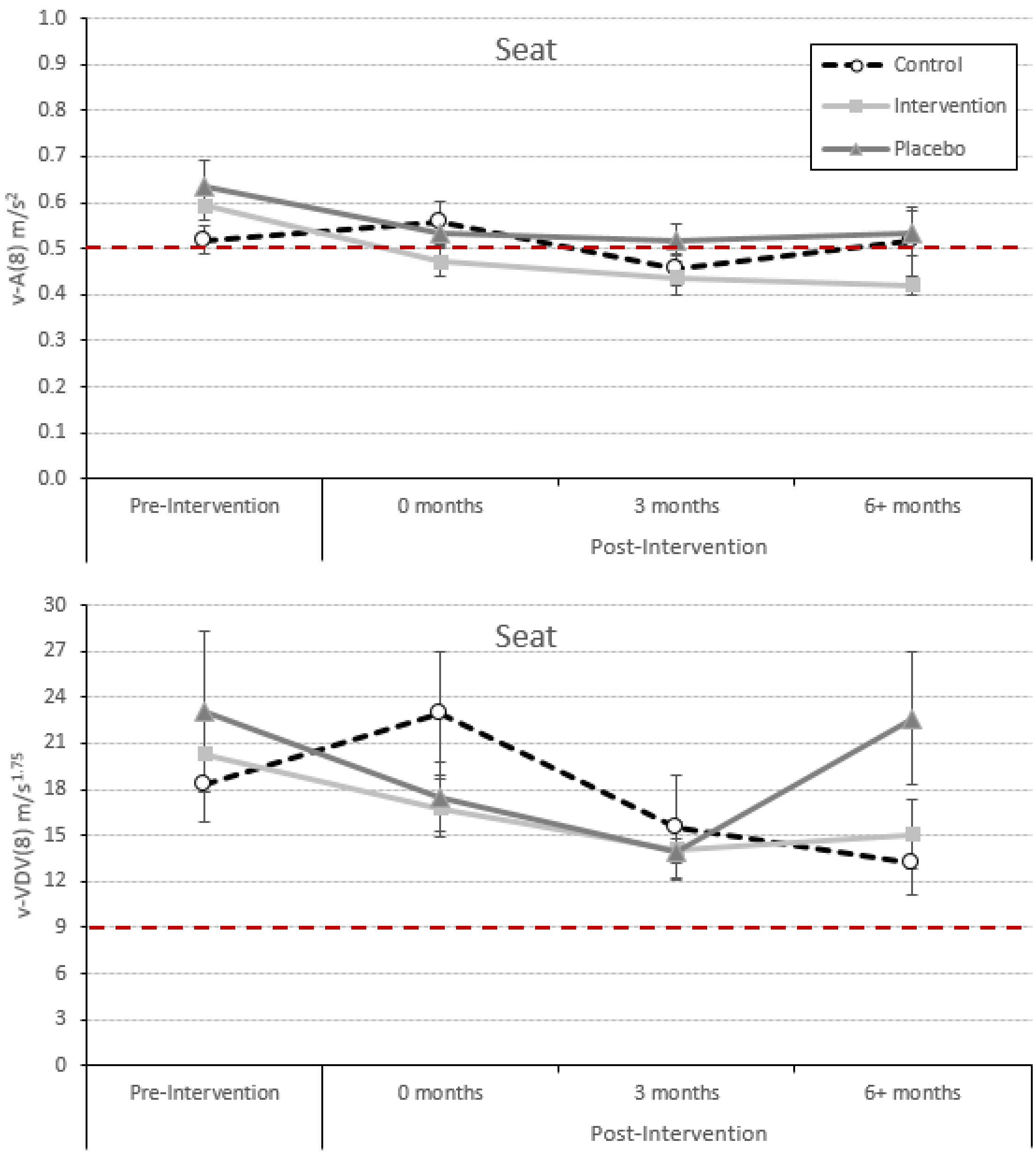

Figure 6. Comparison of the vector sum daily average weighted vibration (vA(8)) and daily vibration base values (vVDV(8)) between the seats over time. The red dotted line stands for the ISO action limits 0.5 m/s^2 for A(8) and 9.1 $m/s^{1.75}$ for VDV(8).