WHOLE BODY VIBRATION MEASUREMENTS IN THE BRITISH COLUMBIA FORESTRY AND TRANSPORTATION INDUSTRIES

Judy Village
UBC School of Occupational and Environmental Hygiene, Judy Village & Assoc.
2220 Badger Rd, North Vancouver, BC V7G 1T1 village@interchange.ubc.ca
Jim Morrison
School of Kinesiology, Simon Fraser University, Burnaby, B.C.
Kay Teschke, Mieke Koehoorn, Yat Chow, Catherine Trask
School of Occupational and Environmental Hygiene, University of British Columbia

In a large project investigating determinants of exposure for back injuries in heavy industry in B.C., continuous full-shift measures of whole body vibration (WBV) were collected. This paper presents WBV results from 14 vehicles; 6 forestry (e.g. front-end loader, boom boat) and 8 transportation (e.g. bus, delivery truck) and compares these with the health guidance caution zone in ISO 2631-1(1997). WBV was measured in 3 axes with a Larson Davis triaxial seatpan accelerometer (SEN027) and recorded to a Larson Davis Vibration Monitor (IHVM 100). Observational data was used to select a 30-minute sample of WBV when the operator was known to be driving. Vector sum results indicate two forestry vehicles exceed the zone, suggesting health effects are likely. A further 7 vehicles (2 forestry and 5 transportation) were within the zone suggesting caution. While WBV levels were comparable to others reported in the literature, high crest factors suggest the need to evaluate vibration dose values.

Keywords: Whole body vibration, heavy equipment, health effects

LES MESURES DE VIBRATIONS GLOBALES DU CORPS DANS LES SECTEURS FORESTIER ET DE TRANSPORT EN C.-B.

Dans un vaste projet visant à connaître les déterminants de l'exposition aux lésions lombaires dans l'industrie lourde en Colombie-Britannique, on a recueilli des mesures de vibrations globales du corps sur une base continue. Cet article présente les résultats des vibrations globales du corps provenant de 14 véhicules : 6 de foresterie (p. ex., chargeur de front, remorqueur-pousseur d'allingues) et 8 de transport (p. ex., autobus, camion de livraison) et les compare avec les directives de risque pour la santé de l'ISO 2631-1 (1997). Les vibrations globales du corps ont été mesurées dans 3 axes à l'aide d'un accéléromètre pour l'assise du siège triaxial Larson Davis (SEN027), puis enregistrées sur un vibromètre Larson Davis (IHVM 100). Les données observationnelles ont été utilisées pour choisir un échantillon de 30 minutes de vibrations globales du corps au moment où l'opérateur conduisait. Les résultats de la somme vectorielle indiquent que deux véhicules de foresterie ont excédé la zone de risque, laissant supposer que des effets sur la santé sont possibles. Sept autres véhicules (2 de foresterie et 5 de transport) étaient dans les limites de la zone de mise en garde. Alors que le taux de vibrations globales du corps était comparable à d'autres taux relevés dans la documentation, des facteurs de seuil élevé suggèrent la nécessité d'évaluer les valeurs de dose de vibrations.

Mots clés : vibrations globales du corps, machinerie lourde, effets sur la santé

INTRODUCTION AND BACKGROUND

In a large project investigating the determinants of exposure for back injuries in heavy industry in British Columbia (BC), continuous direct measures of ergonomic exposure including EMG of trunk muscles, trunk posture, one-minute observational assessments, and whole body vibration (WBV) were collected for a full shift in 223 workers. Of 223 workers measured, 90 were found to operate heavy equipment. This paper presents a selection of WBV results in 14 of those workers operating a range of equipment; 6 in the forest industry (e.g. front-end loader, boom boat, logging truck) and 8 in the transportation industry (e.g. bus, delivery truck). The objective of this paper is to report WBV exposures of the 14 equipment operators while they were driving and to compare these with the health guidance caution zone in ISO 2631-1(1997).

METHODS

Whole body vibration was measured in three axes with a Larson Davis triaxial seatpan accelerometer (SEN027) and recorded to a Larson Davis Vibration Monitor (IHVM 100). The Larson Davis IHVM 100 unit averaged the incoming vibration every 1-second and this was later downloaded to a laptop computer. Data were frequency-weighted according to ISO 2631-1 (1997) for human response to WBV. Where possible, WBV was collected for the total time operating heavy equipment during one shift, therefore some records include almost seven hours of WBV data. However, since many operators were intermittently on and off the equipment during the shift, further data analysis and matching with the observational samples is required to determine actual exposure time. It can be argued that taking an average (rms) of WBV for intermittent exposures reflects the operators' "true" daily exposure to WBV. However, this would likely underestimate the WBV levels produced by the equipment and would make comparison between equipment inaccurate. Therefore, for the purpose of this study, the observational data was used to select a 30 minute sample of WBV during which the operator was known to be continuously driving. This allows comparison of the WBV of the equipment with ISO 2631 (1997) to determine likely exposure assuming 4-8 hours of driving time. Frequency weighted rms (m/s^2), instantaneous peaks, crest factors (peak/rms) and vector sums were extracted in each of the x, y and z-directions and compared to the health guidance caution zone of ISO 2631-1 (1997).

RESULTS

Equipment measured in the forest industry included front-end loaders, tractor trailers, pick-up trucks, a boom boat and a logging truck. In the transportation sector, vehicles included a bus, tractor trailers, front-end loader and delivery trucks. Table 1 presents results of WBV acceleration (rms) in each of the x, y and z-axes (m/s^2), the vector sum (based on ISO 2631-1, 1997), and the crest factor (peak/rms) in each direction. Vibration levels that are bolded represent levels within the health guidance caution zone of ISO 2631-1 (1997) in which ISO suggests caution with respect to potential health risks. The health guidance caution zone for a typical 4-8 hour work shift is between approximately 0.5 and 1.0 m/s^2. Levels starting at 0.5 m/s^2 are reported to be "fairly uncomfortable", while beyond 0.8 m/s^2 they are considered "uncomfortable" (ISO 2631-1, 1997). Levels that are bolded and underlined exceed the upper limit of the zone and ISO 2631-1 suggests that health risks, especially to the back, are likely. Exposure to WBV with crest factors beyond 9 indicate that the rms averaging method may underestimate the severity of the exposure and further assessment using the fourth power vibration dose value or ISO 2631-5 may be indicated.

Table 1. Whole body vibration measured during a 30-minute period of driving in a sample of forestry and transportation equipment operators (n=14) in British Columbia

	WBV Acceleration (rms) in m/s^2				Crest Factor (peak/rms)		
Forestry	**X**	**Y**	**Z**	**Vector Sum**	**X**	**Y**	**Z**
Truck (logging crane)	0.12	0.054	0.12	0.18	11.9	17.3	43.1
Boom boat	0.25	0.21	0.18	0.37	19.6	29.5	22.3
Tractor trailer	0.29	0.48	**0.99**	**1.1**	10.5	6.94	10.9
Front end loader	0.50	0.48	**0.61**	**0.92**	8.9	15.0	12.7
Pick-up truck	0.42	0.44	**0.80**	**1.00**	7.53	9.17	14.2
Pick-up truck	0.39	0.44	**0.76**	**0.96**	9.97	8.14	13.7
Transportation	**X**	**Y**	**Z**	**Vector Sum**	**X**	**Y**	**Z**
Bus	0.17	0.15	0.33	0.4	10.7	9.95	21.0
Truck (delivery)	0.22	0.14	**0.61**	**0.66**	9.71	9.54	29.5
Tractor trailer	0.21	0.18	0.31	0.42	17.3	10.9	70.8
Front end loader	0.34	0.32	0.40	**0.62**	12.4	11.7	25.8
Front end loader	0.33	0.32	0.31	**0.55**	10.7	16.0	17.3
Tractor trailer	0.17	0.13	**0.56**	**0.60**	13.1	10.1	6.04
Tractor trailer	0.14	0.11	0.29	0.34	25.9	26.0	80.3
Truck (disposal)	0.22	0.27	**0.67**	**0.75**	9.65	8.88	7.01

Bold: Within Health Guidance Caution Zone
Bold and Underlined: Exceeding upper limit of Health Guidance Caution Zone

As can be seen from Table 1, there was a wide range of vibration levels across the various types of equipment. In the forest industry, z-axis WBV measurements were within the health guidance caution zone for 4 of 6 types of equipment compared with 3 of 8 in transportation. When comparing vector sums, 2 measures (tractor trailer and pick-up truck) exceeded the upper limit of the zone in the forest industry and both of these were operated in rougher off-road conditions. Five of the 8 vector sum measures in transportation were within the health guidance caution zone. All equipment had crest factors exceeding 9 in at least one direction, many in all three directions. Instantaneous peaks (not shown in table 1) ranged from 0.9-7.2 m/s^2 in the x and y axis and from 3.4-23.6 m/s^2 in the z-axis.

DISCUSSION

Measures of WBV levels in this study are comparable to others who have measured similar equipment. Pope and Hansson (1992) reworked the extensive database of WBV measures collected by Dupuis and Zerlett in 1986 in order to compare average frequency weighted measures and report the following similar z-axis levels for cranes (0.15 m/s^2), trucks on paved roads (0.55 m/s^2) and on a building sites (1.05 m/s^2), loaders (0.5-2.4 m/s^2), and buses (0.4-0.8 m/s^2). In the construction sector, Cann et al. (2003) reported levels of 0.7-1.7 m/s^2 and for both loaders and dump trucks. Neither of these authors reported crest factors, although Cann et al. (2003) also calculated vibration dose values (VDVs) and reported that 8 of 14 types of equipment exceeded VDV guidelines of 8.5 m/s$^{1.75}$. Given the high crest factors in the equipment measured in this study, further analysis is needed to calculate VDVs.

ISO 2631-1 (1997) is vague about suggesting the duration of sampling and number of samples, simply stating that it should be sufficiently long to ensure reasonable statistical precision and to ensure that the vibration is typical of the exposures which are being assessed. What makes our

larger study unique is the unusually long sampling periods (up to seven hours) for WBV measurement. Most studies employ a brief sampling period often less than 10 minutes. For example, Kittusamy and Buchholz (2001) took samples ranging from 0.82 to 6.08 minutes and Cann et al. (2003) used 20 minute sampling periods. Re-analyzing our full data set using random smaller sampling periods would yield interesting perspectives on the extent of variation in WBV throughout a work day, and the minimum length and number of sampling periods necessary for appropriate characterization of workplace exposures.

While the small sample size presented here means that we cannot be sure that the vibration data is representative of the equipment or industries measured, it does give some indication of the levels of WBV to which many B.C. workers may be exposed. Given that many measures were within or above the health guidance caution zone, WBV may reasonably be considered an important risk factor in the forestry and transportation sectors. To date, Hulshof et al., (2000) report that four European countries have recognized low back pain and/or back disorders due to exposure to whole body vibration as an occupational disease (Belgium in 1978, Germany in 1993, Netherlands in 1997, and France in 1999). To our knowledge, no North American jurisdiction has followed suit. In recent reviews of WBV, authors have noted the consistency of positive associations with health effects and improvements in study design in recent years. However, there are still difficulties in ascertaining causality because of the large proportion of studies with cross-sectional design. There is also a need for improvements in case definition and in measurement of both vibration exposure and other potentially confounding or interacting exposures (Bovenzi & Hulshof, 1999; Lings & Leboeuf-Yde, 2000). One aspect of our larger study will be to ascertain the determinants of exposure from the wide variety of exposure data collected and to better understand the contribution of WBV to back injury risk. We will also be comparing direct WBV measures with observational measures and self-report measures to determine the best combination of exposure assessment strategies for larger epidemiological investigations where measurement of several hours of WBV may not be feasible on hundreds of workers.

ACKNOWLEDGEMENTS

Workers' Compensation Board of British Columbia, Finding Solutions Grant

REFERENCES

Bovenzi, M. & Hulshof, C.T.J. (1999) An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain (1986-1997). *International Archives of Occupational & Environmental Health*. 72, 351-365.

Cann, A.P., Salmoni, A.W., Vi, P., & Eger, T.R. (2003) An exploratory study of whole-body vibration exposure and dose while operating heavy equipment in the construction industry. *Applied Occupational & Environmental Hygiene.* 18, 999-1005.

Hulshof, C.T.J., Van der Laan, G.J., Braam, I.T.J. & Verbeek, J. (2000) Criteria for recognition of whole-body vibration injury as occupational disease: A review. *2nd International Conference on Whole-body Vibration Injuries*, Siena, Italy. 57-58.

International Standard Organization (ISO) 2631-1 (1997) Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration Part 1: General requirements.

Kumar Kittusamy, N. & Buchholz, B. (2001) Evaluation of excavating operations: A pilot study. *Applied Occupational & Environmental Hygiene.* 16, 23-726.

Lings S, Leboeuf-Yde C. (2000) Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992-1999. *International Archives of Occupational & Environmental Health.* 73(5), 290-7.

Pope, M.H. & Hansson, T.H. (1992) Vibration of the spine and low back pain. *Clinical Orthopaedics and Related Research*. 279, 49-57.