Evidence-Based Practice Group Answers to Clinical Questions

"Whole Body Vibration and Low Back Pain: 2nd Update"

A Rapid Systematic Review

By

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WORKING TO MAKE A DIFFERENCE

Clinical Services – Worker and Employer Services

About this report

Whole Body Vibration and Low Back Pain: 2nd Update

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About the Evidence-Based Practice Group

The Evidence-Based Practice Group was established to address the many medical and policy issues that WorkSafeBC officers deal with on a regular basis. Members apply established techniques of critical appraisal and evidence-based review of topics solicited from both WorkSafeBC staff and other interested parties such as surgeons, medical specialists, and rehabilitation providers.

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Objective

- To determine whether there is evidence to support the positive association of whole body vibration in individuals with chronic non-specific low back pain.

Introduction

- In 2001, WorkSafeBC commissioned a systematic review to investigate the causal association between low back pain and whole body vibration[1]. The findings concluded that there was insufficient evidence to conclude that WBV was causally associated with LBP in the workplace.
- An update was completed in 2008 which identified fifteen new primary studies investigating the association between WBV and LBP, but these studies did not provide new evidence that may change the conclusion of the 2001 systematic review.
- This current update seeks to update the literature from the last update in 2008 in order to investigate the causal association between WBV and LBP.

Methods

- A systematic literature search was done on January 26, 2021.
- This literature search was conducted on commercial medical literature databases, including, Medline Epub Ahead of Print®, Medline In-Process & Other Non-Indexed Citations®, Medline Daily Update® available through the Ovid® platform (1946 to November 4, 2020), Cumulative Index to Nursing and Allied Health Literature (CINAHL), available through the EBSCO® platform (Search completed November 4, 2020), PEDro (Search completed 26 January 2021), CINAHL Complete (Search completed January 26, 2021) and EBM Reviews including CENTRAL (Cochrane Database of Systematic Reviews 2005 to January 22, 2021, EBM Reviews - ACP Journal Club 1991 to January 2021, EBM Reviews - Database of Abstracts of Reviews of Effects 1st Quarter 2016, EBM Reviews - Cochrane Clinical Answers January 2021, EBM Reviews - Cochrane Central Register of Controlled Trials December 2020, EBM Reviews - Cochrane Methodology Register 3rd Quarter 2012, EBM Reviews - Health Technology Assessment 4th Quarter 2016, EBM Reviews - NHS Economic Evaluation Database 1st

Quarter 2016) available through the OVID® platform (Search completed November 10, 2020).

- The search was done by employing combinations of keywords. Full search strategies seen in Appendix 2.
- No limitations on date of publication, were implemented in any of these searches. However, publications before June 2008 were removed during the screen (i.e. Date of 1st update search).
- A manual search was also conducted on the references of the articles that were retrieved in full.
- Levels of evidence used to infer causal association in epidemiological studies relied on the Bradford-Hill framework[2]. These include consistency of association, strength of the association, dose-response, temporal relationship, and biological plausibility.

Results

- Search results:
- 661 published studies were identified through the search, 384 from MEDLINE, 211 from CINAHL, 66 from CENTRAL, and 19 from PEDRO.
- After duplicates were removed 509 published studies were identified - 384 from MEDLINE, 92 from CINAHL, and 33 from CENTRAL.
- Upon examination of the titles and abstracts of these published studies, eighty-five were thought to be relevant and were retrieved in full for further appraisal[3-87]; (60 were excluded due to incorrect population, 154 due to incorrect outcomes, twenty-five due to incorrect study design, twelve due to other reasons (eg. Not Human), 171 were pre-June 2008 and two were duplicates).
- Of the 85 studies that were retrieved in full, thirty-nine were excluded due to incorrect outcomes[3, 6, 9-14, 21, 22, 24, 27-32, 34, 35, 37, 39, 41-43, 46, 49, 52, 56, 62, 65, 71, 77, 81-87], and five due to incorrect study design[4, 23, 44, 64, 80].
- Two studies[88, 89] were included via manual search after reviewing eight relevant systematic review/meta analyses[7, 20, 38, 58, 69, 74, 75, 89] which were then excluded.
- As such, there are 31 published primary studies[5, 8, 15, 17, 19, 25, 26, 33, 36, 40, 45, 47, 48, 50, 51, 53, 55, 57, 59, 61, 63, 66-68, 70, 72, 73, 76, 78, 79, 88] that are comprised of 35 articles[5, 8, 15-19, 25, 26, 33, 36, 40, 45, 47, 48, 50, 51, 53-55, 57, 59-61, 63, 66-68, 70, 72, 73, 76, 78, 79, 88] relevant to this systematic review and are appraised and summarized below.

Study Characteristics

- A description of study characteristics of included studies is included in Table 1.

- Of the 31 primary studies, there were two case-control studies[61, 70], nineteen cross-sectional studies[5, 8, 19, 33, 40, 45, 47, 48, 53, 55, 57, 59, 63, 66-68, 73, 79, 88], one expert opinion survey[51], six prospective cohort studies[15, 17, 50, 72, 76, 78], and three retrospective cohort studies[25, 26, 36].
- Occupations of the workers varied amongst the studies: Thirteen studies were professional/commericial drivers[5, 8, 15, 17, 33, 45, 55, 57, 61, 63, 66, 67, 76], four studies included agricultural workers[25, 47, 48, 70], seven studies from the general/working population[26, 36, 51, 72, 73, 78, 88], one study from the medical field[59], four studies involved industrial workers[40, 50, 53, 79], and two studies were on mining workers[19, 68].
- Various types of lower back pain populations were examined in the included studies: 29 had chronic lower back pain[5, 15, 17, 19, 25, 33, 36, 40, 45, 47, 48, 50, 51, 53, 55, 57, 59, 61, 63, 66-68, 70, 72, 73, 76, 78, 79, 88], four had sciatica[17, 26, 40, 88], and one had dorsalgia[8].
- The exposure assessment, in this case the vibration measure used, varied greatly between studies. Calculation of exposure to vibration can determined by both the magnitude (intensity) of vibration via measurement of vibration acceleration for all three axises (x,y,z) in meters per second squared (m/s2) and the duration of the exposure (i.e. A(8)). It can also be calculated by taking the intensity of vibration as a cumulative value that increases with time (i.e. VDV) which also takes into account the peak acceleration compared to the norm. In more recent studies, vibration exposure can be quantified using daily equivalent static compression dose (Sed), the 8-h estimated daily dose of static compression dose. This approach focuses on the forces on the lumbar spine directly.
- Twelve studies used the daily vibration dose via A(8)-based estimates[5, 8, 15, 17, 33, 45, 51, 57, 61, 63, 68, 76], eight studies used daily vibration dose value, VDV(8)-based estimates of whole body vibration[8, 15, 17, 33, 47, 48, 66, 76], five studies used the daily equivalent static compression dose, Sed(8)-based estimates of WBV[8, 17, 33, 47, 48], twelve studies did not define the whole body vibration measure[19, 26, 36, 40, 50, 53, 55, 67, 70, 72, 73, 79], three studies defined use of vibration in general[59, 78, 88], and one study defined the use of tractor as a measure for vibration[25]. Furthermore, some studies used multiple vibration measures.
- Similarly, whether the exposure measure of whole body vibration was carried out via direct measurements or indirectly via questionaires/survey varied between studies. Ten primary studies measured whole body vibration directly in the population or as part of a convienience sample[5, 33, 45, 47, 48, 57, 63, 66, 70, 76], nineteen measured WBV indirectly via questionnaire/surveys[8, 19, 25, 26, 36, 40, 50, 51, 53, 55, 59, 61, 67, 68, 72, 73, 78, 79, 88], and two studies used both direct and indirect methods[15, 17].

- There was heterogeneity in the definition of the lower back pain outcome. In particular, the time period in which the LBP event occurred. Thirteen studies considered LBP events over the course of seven days[5, 15, 17, 33, 40, 45, 47, 48, 55, 57, 59, 67, 76], one study considered LBP events over the course of one month[72], twenty-two studies considered LBP events over the course of 12 months[15, 17, 19, 25, 36, 45, 47, 48, 50, 53, 57, 59, 61, 63, 66-68, 70, 76, 78, 79], three studies considered LBP events over the course of a lifetime[26, 45, 70], and three studies did not define the time period of when a LBP event occurred[51, 73, 88].

<u>Study Quality</u>

- Study quality was deemed low to low/moderate for most studies: there were no randomized controlled trials and eleven studies showed low/moderate quality[15, 17, 25, 26, 36, 50, 61, 70, 72, 76, 78] while the rest of the studies were of low study quality.
- Study quality was assessed by focusing on risk of bias in the methodology and for the exposure assessment. Overall, study quality was downgraded due to methodological limitations, and risk of bias.
- The majority of primary studies included were cross sectional in methodology *(one cannot establish a temporal association between exposure and disease with this study design)*.
- Study quality was lowered in most studies due to methodological limitations due to risk of bias. Specifically, all of the applicable studies were not able to fully control for performance bias (blinding of participants, investigator). Furthermore, the prevalance of self-reporting for both current / cumulative exposures and outcomes made it difficult for studies to control for recall/information bias.
- A few of studies specifically mentioned limitations of sample size which implied imprecision[47, 48, 57].

<u>Outcomes</u>

- A description of study outcomes of included studies is included in Table 2.
- The primary outcome of interest was chronic lower back pain.
- The majority of studies included employed self-reported LBP outcomes from questionnaires with only four studies using registry/hospital data[8, 26, 36, 88].
- In the 31 primary studies, 10 studies supported WBV association with LBP[5, 8, 15, 25, 26, 48, 50, 53, 73, 79], 12 studies did not show WBV association with LBP[17, 19, 36, 55, 57, 59, 61, 67, 68, 76, 78, 88] and 10 studies demonstrated a weak/unclear WBV association with LBP[33, 40, 45, 47, 51, 63, 66, 70, 72, 74].
- Removing lower level evidence (ie. expert opinion/cross sectional studies), four studies supported WBV association with LBP[15, 25, 26, 50], five studies did not show WBV association with LBP[17, 36, 61, 76, 78], and

two studies demonstrated WBV association with LBP only under specific conditions[70, 72].
- Of the eight systematic reviews, three studies supported WBV association with LBP[19, 69, 75], two studies did not show WBV association with LBP[7, 89], and three studies showed a weak/unclear WBV association with LBP[38, 58, 74].
- Dose Response relationship: Only four[17, 25, 45, 76] of seven studies[15, 17, 25, 45, 61, 63, 76] that found a dose-response relationship were able to determine a positive association.

Discussion

- After examining the 31 primary studies, while several had at a weak positive association between whole body vibration and LBP, only 10 of 31 studies showed a significant positive association.
- There was no standard in the methods of assessing exposure (vibration frequency/duration/intensity), and there were inconsistent definitions of outcomes (ascertainment of chronic pain).
- Given the differences in the how vibration exposure was measured, there was no standard or consistency of the ascertainment of measurement of WBV. Furthermore, several studies did not even define the whole body vibration measurement.
- The definition of what constituted a low back pain event varied within the studies. Studies used questionnaires (including self-reporting), and clinician examination to determine LBP. The range in which a LBP event could be considered varied greatly with some studies asking if a LBP event happened over the last 7 days, and others asking if a LBP event happened over the course of the preceeding 12 months.
- Several primary studies also suggested that there may also be causal relationship between WBV and low back pain. While this was beyond the scope of our objective, we investigated this using Bradford-Hill criteria of causality.
- However, none of the included primary studies had strong evidence to support a causal relationship of whole body vibration with LBP.
- In terms of the use of Bradford-Hill Criteria to determine causality:
    1. Consistency of Association: Only 10/31 studies showed a clear association of whole-body vibration and chronic non-specific lower back pain. When limiting to higher levels of evidence, the association was still mixed (4/11).
    2. Temporality: Over 60% of the studies were cross-sectional in nature. This design is limited in its ability to show causality as it is not a time-dependent construct as causality would infer[90]. Several authors from the primary studies above did point out that this was

a limitation to determining causality. Future research should include the use of prospective cohort studies in order to determine if there is a causal effect.

3. Dose Response relationship: Four of seven studies found a dose response relationship. However, these four relationships were demonstrated in studies with cross-sectional designs that contained a number of design flaws that made the results inconclusive in terms of interpretation.
4. Experiment: None of primary studies reviewed suggested any physiological process as to how whole body vibration could be said to be causative of lower back pain.
5. Heterogeneity in both the exposure (whole body vibration) and outcome (chronic non-specific lower back pain) assessment also effected the ability to determine causality.
6. Exposure assessment varied in measure, frequency and duration. Twelve of thirty-one studies used direct measurement of whole body vibration while the other studies used self-reported measures of WBV although two of the direct measurement studies extrapolated a full day of vibration from a 10 min sample[15, 17]. Of the ten remaining studies, only one study was not a cross-sectional study and did suggest an association with WBV and non-specifc LBP[70]. While frequency and duration of the vibration can be determined on a daily vibration dose it is difficult to account for cumulative exposure of WBV without relying on self-reported outcomes.

- When assessing the eight identified systematic reviews, the results for an association between whole body vibration and chronic lower back pain were mixed. The one systematic review that did not include cross-sectional studies found that exposure to vibration was not found to be predictive of LBP in the occupational population[89].
- Confounding variables were quite pronounced in these primary studies. Often occupations with WBV exposure will also be exposed to other possible physical risk factors for LBP (i.e. heavy lifting, bending, turning). Furthermore, psychological factors such as workplace stress and job satisfaction have been shown to be associated with LBP[91]. However, only twelve studies had accounted for these psychological factors[15, 16, 25, 45, 47, 50, 61, 63, 67, 72, 76, 79].
- This systematic review strictly looked at chronic lower back pain and sciatica. Chronic pain in other areas of the body should be examined in further systematic review studies. Furthermore, the causality of other lower back pain disorders such were not examined.

Summary

- At present, there is insufficient high quality evidence study to strongly support positive association of whole-body vibration with low back pain, and change the conclusions of the 2001 systematic review on the same topic.
- While there is evidence that suggests some association of lower back pain associated with whole-body vibration, it cannot be determined whether the data was clinically relevant as the majority of the studies were cross-sectional in nature.
- There was heterogeneity in the methods of assessing exposure (vibration frequency/duration/intensity), and inconsistent definitions of outcomes (ascertainment of chronic pain).
- While attempts were made to control for some confounding variables, often occupations with WBV exposure will also be exposed to other possible physical risk factors (i.e. heavy lifting, bending, and turning) and psychological factors for lower back pain.
- In conclusion, the likely explanation is that multiple risk factors, both occupational and non-occupational, factor in the etiology of chronic non-specific lower back pain.

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Primary Study *(additional articles)*	**n**	**Population**	**Experimental Group (n)**	**Measure of Vibration Assessment**	**Type of Pain Outcome**	**Duration of Outcome Assessment**
Awang Lukman et al., 2019	118	Cross-Sectional	Commercial vehicle drivers	Av(8), Az(8)	LBP	LBP event within the last 7 days
Bakker et al., 2009		Systematic Review		WBV	LBP	
Barrero et al., 2019	2302	Cross-Sectional	Heavy equipment vehicle operators (Mining)	A(8), VDV(8), Sed(8)	Dorsalgia related absence	LBP outcome measured monthly or 4 years
Bovenzi et al., 2009 *Bovenzi et al., 2010*	202	Prospective cohort	Professional drivers	A(8)max, VDV(8)max, VDV(8)sum	LBP	LBP event within the last 7 days and 12-month LBP
Bovenzi et al., 2015a *Bovenzi et al., 2015b*	537	Prospective cohort	Professional drivers	A(8)max, VDV(8)max, S(ed), Risk Factor	LBP, sciatia	LBP within the last 7 days and 12-month LBP
BurströM et al., 2017	1323	Cross-Sectional	Mine workers	WBV	LBP	12-month LBP
Burstrom et al., 2015		Systematic Review			LBP, sciatia	
Essien et al., 2016	1149	Retrospective Cohort	Farmers	Tractor operation	LBD	12-month LBP
Euro et al., 2019	1196	Retrospective Cohort	Finns aged 30 to 59 who had participated in a national health examination survey in 1978-8	WBV	Sciatia	Lifetime (no time limit)
Kim et al., 2016	96	Cross-Sectional	Professional truck drivers	A(8), VDV(8), Sed(8)	LBP	LBP event within the last 7 days
Kuijer et al., 2015	4068	Retrospective Cohort	Dutch workers	WBV	LBP	12-month LBP (annual incidence)
Kwaku Essien et al., 2018		Systematic Review			LBP	

Landsbergis et al., 2020	4816	Cross-Sectional	Railroad maintenance-of-way (MOW) workers	WBV	LBP, sciatica	LBP event within the last 7 days
McBride et al., 2014	1032	Cross-Sectional	Locomotive engineers	Ax, Ay, Az, Aw(t)	LBP	LBP in the last 7 days, 12-month LBP, lifetime
Milosavljevic et al., 2010	12	Cross-Sectional	New Zealand farmers	VDVx, VDVy, VDVz, VDVdrt, Sed	LBP	LBP in the last 7 days and 12-month LBP
Milosavljevic et al., 2012	131	Cross-Sectional/ Retrospective study	New Zealand farmers and rural workers	VDVz (daily), VDVz (1 h), Sed(daily), and Sed(1 h)	LBP	LBP in the last 7 days and 12-month LBP
Miranda et al., 2008	2256	Prospective cohort	Finnish industrial workers	WBV	LBP	12 month LBP (7 days)
Morgan et al., 2014	74	Expert Opinion Survey	Academic experts in ergonomics, human response to whole-body vibration, and agricultural operators	A(8)	LBP	NR
Murtezani et al., 2010 *Murtezani et al., 2011*	489	Cross-Sectional	Power plant workers	WBV	LBP	12-month LBP
Nazerian et al., 2020	384	Cross-Sectional	Heavy truck drivers	WBV	LBP	LBP in the last 7 days and 12-month LBP
Noorloos et al., 2008	30	Cross-Sectional	Occupational drivers	A(8)	LBP	LBP in the last 7 days and 12-month LBP
Okada et al., 2013		Systematic Review			LBP	
Oliveira Dantas et al., 2015	387	Cross-Sectional	Dentists	Use of vibrating tool	LBP	LBP in the last 7 days and 12-month LBP
Palmer et al., 2008 *Palmer et al., 2012*	1072	Case-Control	Professional drivers	A(8)	LBP	12-month LBP (had to have held job for at least 12 months)

Raffler et al., 2017	102	Cross-Sectional	Occupational drivers	A(8)	LBP	12 m-LBP: pain or discomfort, sick leave due to LBP in the previous 12 months.
Rozali et al., 2009	159	Cross-Sectional	Military Armoured Vehicle Drivers	eVDV	LBP	12-month LBP
Saberi et al., 2009	514	Cross-Sectional	LBP/sciatica patients	Vibratory Job	LBP, sciatica	Nucleus pulposus herniation (main cause of radicular pain)
Sekkay et al., 2018	249	Cross-Sectional	Industrial gas delivery truck drivers	WBV	LBP	LBP in the last 7 days and 12-month LBP
Skandfer et al., 2014	3530	Cross-Sectional	Mine workers	A(8)rms	LBP	12-month LBP
Solecki et al., 2014	138	Case-Control	Agricultural workers		LBP	12-month LBP, lifetime , permenant pain,short pain episodes, acute pain, chronic pain
Solecki et al., 2011		Systematic Review			LBP	
Sterud et al., 2013	12500	Prospective cohort	Working population	WBV	LBP	1-month LBP
Stoyneva et al., 2010	33	Cross-Sectional	Patients with hand-arm vibration syndrome / whole-body vibration syndrome	WBV	LBP	NR
Swain et al., 2020		Systematic Review			LBP	
Swedish Council on Health Technology et al., 2014		Systematic Review			Sciatia	
Taylor et al., 2014		Systematic Review			LBP	
Tiemessen et al., 2008	229	Prospective cohort	Professional drivers	Av(8), Amax(8), VDVv, VDVmax	LBP	LBP in the last 7 days and 12-month LBP, Driving-related

						LBP, LBP intensity, LBP disability
van Oostrom et al., 2012	4738	Prospective cohort	General Population	Mechanical Vibration	LBP	12-month LBP
Vandergrift et al., 2012	1181	Cross-Sectional	Automobile manufacturing workers	WBV	LBP	12-month LBP (3 times or last more than week)

Table 1. Description of study characteristics. Abbreviations: A(8), weighted root mean square acceleration; Amax(8) Maximum rms over 8 h, Ax, A(8)-based estimates of WBV for the x axis; Ay, A(8)-based estimates of WBV for the y axis; Az, A(8)-based estimates of WBV for the z axis, Av(8) Current rms over 8 h; Chronic Lower Back Pain (CLBP), eVDV, mean estimated vibration dose value; Sed, the daily equivalentstatic compression dose, Sed(8)-based estimates of WBV; VDV, daily vibration dose value, VDV(8),VDV(8)-based estimates of WBV;

Primary Study *(additional articles)*	**n**	**Study Type**	**Population/age**	**Outcome Association**
Awang Lukman et al., 2019	118	Cross-Sectional	Commercial vehicle drivers	**(+).** The prevalence of LBP was significantly higher among drivers who were exposed to daily vibration Az(8) at 0.25m·s−2 rms and above, compared to those exposed to Az(8) for less than 0.25m·s−2 rms (prevalence odds ratio [POR] = 2.97, 95% confidence interval [CI] [1.30, 6.76]). Av(8) at 0.29m·s−2 rms or more, compared to those exposed to Av(8) less than 0.29m·s−2 rms (POR = 2.79, 95% CI [1.24, 6.34])
Bakker et al., 2009		Systematic Review		**(-).** Systematic Review. 6 studies reporting on the effect of WBV. One study reported a decreased risk for LBP for riding a forklift truck for more than 10 hours per week. Another study described an increased risk for driving a car 10 to 14 hours, and 15 to 19 hours per week. They found no-associations with the development of LBP and driving a car in the lower, or higher ranked categories. Four other studies reported no statistically significant associations.
Barrero et al., 2019	2302	Cross-Sectional	Heavy equipment vehicle operators (Mining)	**(+).** Estimated WBV exposure metrics were positively and significantly associated with back pain-related work absence. HRs ranged from 2.03 (95% CI 1.69 to 2.44) to 12.39 (95% CI 8.94 to 17.18) for a 0.21 m/s2 increase in the A(8)-based exposures; from 1.03 (95% CI 1.02 to 1.04) to 1.18 (95% CI 1.16 to 1.20) for a 1.72 m/s1.75 increase in VDV(8)-based exposures; and from 1.04 (95% CI 1.03 to 1.05) to 1.07 (95% CI 1.06 to 1.08)
Bovenzi et al., 2009 *Bovenzi et al., 2010*	202	Prospective cohort	Professional drivers	**(+).** After adjusting for age at entry and survey time (standard model), drivers of earth-moving machines and fork-lift trucks (Groups A and B) reported disability in the lower back more frequently than drivers employed in public utilities
Bovenzi et al., 2015a *Bovenzi et al., 2015b*	537	Prospective cohort	Professional drivers	**(-).** Sciatic pain in the last 7 days and the previous 12 months were significantly associated with measures of both daily vibration exposure (A(8)max and VDVmax but not after adjusted for individual- and work-related risk factors. After adjustment for potential confounders, the measures of internal lumbar load calculated according to ISO/WD 2631-5 (2013) were better predictors of the occurrence of sciatic pain than those of daily vibration exposure established by the EU Directive on mechanical vibration. Significant trends of increasing occurrence of sciatic pain with the increase of dose measures were observed for daily compressive dose and risk factor but not for A(8)max or VDVmax.

BurströM et al., 2017	1323	Cross-Sectional	Mine workers	**(-).** The daily driving of mining vehicles had no significant association with the risk of LBP symptoms for 12 months (aOR 1.16 (0.92–1.46)) or previous month (aOR 1.26 (0.97–1.64)). Female drivers indicated a higher prevalence of symptoms as compared to male drivers. Drivers in the Nordic mines reported fewer symptoms than non-drivers (aOR 0.92 (0.54–1.57)), while for Russian mine workers the results were the opposite of that. (aOR (1.51 (1.09–2.09))
Burstrom et al., 2015		Systematic Review		**(+).** Among the included studies, comparisons between exposed and unexposed groups were conducted in 15 studies for LBP and 9 studies for sciatica. For the LBP outcome, the pooled estimate had an odds ratio of 2.17 (95 % CI 1.61–2.91) and the heterogeneity was 85 % ($p < 0.01$). The results for the sciatica outcome gave a pooled odds ratio of 1.92 (95 % CI 1.38–2.67) and a heterogeneity of 70 % ($p < 0.01$).
Essien et al., 2016	1149	Retrospective Cohort	Farmers	**(+).** Adjusted for age, education, and gender, LBDs were associated with tractor operation for 1 to 150 hours/year (Relative Risk [RR] 1.23, 95%CI 1.05 to 1.44), 151 to 400 hours/year (RR 1.32, 95%CI 114 to 1.54) and 401þ hours/year (RR 1.34, 95%CI 1.15 to 1.56). For combine and ATV use, no significant relationship was found after accounting for potential confounders for either ‘‘Any back symptoms’’ or ‘Interrupting back symptoms
Euro et al., 2019	1196	Retrospective Cohort	Finns aged 30 to 59 who had participated in a national health examination survey in 1978-8	**(+).** After adjustment for confounders, sedentary work involving exposure to whole-body vibration (HR 1.61; 0.95–2.72) predicted sciatica. Individuals of normal weight who were exposed to vibration were not at an increased risk (HR 0.93 (0.44–1.97)) compared to obese individuals (HR 3.50 (1.44–8.46)).
Kim et al., 2016	96	Cross-Sectional	Professional truck drivers	**(Unclear).** This study indicates that the predominant-axis A(8) or vector sum A(8) may have a stronger link to musculoskeletal (LBP) and other adverse health outcomes than the impulsive VDV(8) or Sed(8) measures. Even though we noted the possible relationships between lower WBV exposures and lower LBP, this result cannot be interpreted as a causal relationship because these results are based on the cross-sectional analysis with an assumption that drivers have experienced the current WBV exposures throughout their career
Kuijer et al., 2015	4068	Retrospective Cohort	Dutch workers	**(-).** The number of notified cases of nLPB as an occupational disease attributed to whole body vibration is low with less than 1% (0.8% (SD 0.1)) of all cases in the Netherlands. An explanation is that other work-related risk factors for nLBP such as lifting are more frequently occurring, more visible and have a higher attributable risk than WBV. However, continuing attention for WBV remains warranted given a higher percentage of cases with sick leave of more than 2 weeks (35% of the

				cases of nLBP due to WBV were associated with a sick leave of more than 2 weeks.)
Kwaku Essien et al., 2018		Systematic Review		**(Unclear).** Four studies showed no association between WBV and LBDs, four a positive association, and three results were mixed depending on the exposure/outcome measure. Conclusion: A firm conclusion is difficult due to heterogeneity in, LBDs definition, type of farm commodity, study design, and statistical strategy. Direct comparisons and synthesis were not possible.
Landsbergis et al., 2020	4816	Cross-Sectional	Railroad maintenance-of-way (MOW) workers	**(Unclear).** Back pain radiating below the knee (sciatica indicator) was associated with high-vibration vehicle use greater than 0.4 and less than 1.9 years (aPR = 1.58, 95% CI: 1.15-2.18). Compared with respondents with 0 years of full-time equivalent use, respondents with >1.9 years had an elevated risk of neck and knee pain but not back pain (aPR = 1.43, 95% CI: 0.90-2.28). No elevated risk of back pain with 0 to 0.4 years either (aPR = 1.30, 95% CI: 0.95-1.7).
McBride et al., 2014	1032	Cross-Sectional	Locomotive engineers	**(Unclear).** Engineers experienced more frequent low back; odds ratios (OR) of 1.77 (95% confidence interval [CI]: 1.19–2.64) but not more severe (OR 1.28 (0.89–1.84)) or longer duration (OR 1.36 (0.95–1.95)); Cumulative Exposure to Vibration and LBP: Frequency of LBP of 3+ times a year was statistically significant at a cumulative exposure of 6.3–12.4 year m2/s4 (OR 2.41 1.00–5.79) but not >12.4 or continuous. Severity of LBP of 50+ on VAS was statistically significant at a cumulative exposure of > 12.4 only (OR 1.62 1.05–2.52) but not continuous exposure (OR 1.01 0.99–1.03). Prolonged length of LBP of 7+ days was statistically significant at a cumulative exposure of > 12.4 only (OR 1.62 1.06–2.49) but not continuous exposure (OR 1.02 1.00–1.04).
Milosavljevic et al., 2010	12	Cross-Sectional	New Zealand farmers	**(+).** Low back pain was the most commonly reported complaint for both 7-day (50%) and 12-month prevalence (67%),
Milosavljevic et al., 2012	131	Cross-Sectional/ Retrospective study	New Zealand farmers and rural workers	**(Unclear).** Bivariate logistic regression (LBP yes/no) for the four primary vibration and shock variables of VDVz(daily), VDVz(1 h), Sed(daily), and Sed(1 h) that none had an acceptable association with 12- month prevalence of LBP. Sed(1h) was the closest with (OR 1.24, P= 0.092). When multivariate analysis was completed using a combined model of Sed 1 h, occupational status and percentage time on a farm track link exposure to mechanical shock with 12-month LBP (OR 1.45 (1.09-1.93); P = 0.011).
Miranda et al., 2008	2256	Prospective cohort	Finnish industrial workers	**(+).** WBV predicted LBP in forest workers <40 (OR 2.0 (1.4-2.9), and 40-50 (OR 1.5 (1 0-2.2)), and 50+(OR 1.7 (1.1- 2.6)) whene adjusted for gender and age but not for 50+ when adjusted for gender and age, Physical exerciseBMI, smoking, heavy lifting, awkward postures 1.2 (0.8-1.8)

Morgan et al., 2014	74	Expert Opinion Survey	Academic experts in ergonomics, human response to whole-body vibration, and agricultural operators	**(Unclear).** Only 85% (n=11) of vibration experts (VE) questioned considered this risk to be present. Of the postural experts (PE), only 65% considered this impact, and in contrast the majority of operator experts (OE) (45%) did not consider WBV to be a causal factor in the development of LBP.
Murtezani et al., 2010 *Murtezani et al., 2011*	489	Cross-Sectional	Power plant workers	**(+).** One of the main risk factors for long-term sickness absence due to LBP among production workers were eexposure to whole-body vibration (OR = 1.75, 95% CI = 1.04– 2.95). There is insufficient evidence for vibration as a predictive factor because only one study (Steenstra et al, 2015) found a significant effect of this factor for duration on sick leave. Driving a vehicle might be correlated with this factor, but was only a predictive factor if driving took more than 75% of the working day.
Nazerian et al., 2020	384	Cross-Sectional	Heavy truck drivers	**(-).** There was not enough evidence to reveal any association between hours of exposure and lower back discomfort. (p = 0.300).
Noorloos et al., 2008	30	Cross-Sectional	Occupational drivers	**(-).** No association between exposure to WBV and LBP in the last 7 days (OR 0.33; 95% CI: 0.94–1.15) neither for LBP in the last 12 months (OR 0.46; 95% CI: 0.15–1.39). Exposure to WBV in this study does not seem to be associated with the onset of LBP.
Okada et al., 2013		Systematic Review		**(Unclear).** There is no study that confirms the dose-response relationship of low-level exposure, which is the basis of the Japan Society for Occupational Health41) that the provisional standard value should be lowered to 0.35 m / s2.
Oliveira Dantas et al., 2015	387	Cross-Sectional	Dentists	**(-).** There was no association between musculoskeletal complaints in the lower back and use of vibrating tool (High exposure 85/198 (prevalence ratio (PR) 1.126 (0.942-1.345)) in dentists
Palmer et al., 2008 *Palmer et al., 2012*	1072	Case-Control	Professional drivers	**(-).** In stepwise regression analysis, whole body vibration of profession driving for ≥3 hours was not significant risk factor of LBP for being a case of LBP (OR 1.8 (0.8–4.1)) or a severe case of LBP (OR 2.3 (0.8–6.5)
Raffler et al., 2017	102	Cross-Sectional	Occupational drivers	**(Unclear).** In terms of WBV exposure, the only significant association is observed between the ten-fold daily vibration exposure A(8) × 10 and 12 m-LBP: odds ratio (OR) is 1.33 (95 % confidence interval 1.03–1.72; $p < 0.05$).
Rozali et al., 2009	159	Cross-Sectional	Military Armoured Vehicle Drivers	**(Unclear).** Logistic regression analysis revealed that WBV exposure at X-axis (OR 1.94, 95% CI 1.02–3.69) were significant risk factors to LBP. WBV exposure at Y-axis (OR 1.01(0.59-1.73)) and Z-axis (OR 0.95(0.77-1.17)). There was also a significant difference in the WBV (eVDV) at the sum of all axes (XYZ) between the respondents with LBP and the respondents without LBP ($p<0.05$, difference=3.562, 95% CI 0.37-6.75). This showed that the armoured vehicle drivers who complained of LBP

				were exposed to higher WBV at X-axis, Zaxis and sum of all axes (XYZ) for an eight-hour daily exposure as compared to the armoured vehicle drivers who did not complain of LBP
Saberi et al., 2009	514	Cross-Sectional	LBP/sciatica patients	**(-).** There was no any significant correlation between NP degeneration without dislodgement and risk factors such vibration, neither in upper nor in lower lumbar levels.
Sekkay et al., 2018	249	Cross-Sectional	Industrial gas delivery truck drivers	**(-).** In picking-up and delivering gas cylinder (P&D) drivers muscularskelatal pain in any body area was strongly associated with ""Whole-body vibration" (OR=5.48, p=0.018), but not specifically back pain
Skandfer et al., 2014	3530	Cross-Sectional	Mine workers	**(-).** Wet clothing, cold working conditions, heavy lifting, previous work as a driver and driving certain vehicles were associated with LBP, but vehicles with WBV levels above action value were not
Solecki et al., 2014	138	Case-Control	Agricultural workers	**(Unclear).** The frequency of back pains experienced by farmers during the entire period of occupational activity increases with a growing dose of whole body vibration (p = 0.005). In the incidence of chronic pain an upward tendency was observed (statistically insignificant).
Solecki et al., 2011		Systematic Review		**(+).** Research indicates the incidence of back pain among tractor drivers (exhibited on vibration WBV) is significantly higher than in the control group (Odds ratios of the studies vary from (1.3–3.2).
Sterud et al., 2013	12500	Prospective cohort	Working population	**(Unclear).** The risk for LBP was associated with whole body vibration(OR 1.60 (1.11 to 2.29)) when adjusted for LBP at T1, gender, age.but in a second model adjusted for education, occupation, psychological distress and work-related mechanical and/or psychosocial exposures yielding a 10% change of OR, the LBP were not significant (OR (1.31 (0.90 to 1.91))
Stoyneva et al., 2010	33	Cross-Sectional	Patients with hand-arm vibration syndrome / whole-body vibration syndrome	**(+).** A statistically significant increase of relative risk of the following alterations was found in the WBVS patients: degenerative alterations of the lumbar spine: RR 2.49; 95% CI (1.55 - 3.99), lumbosacral radicular syndromes: RR 8.53; 95% CI (3.73 - 19.52). Concomitant low back pain syndromes were found in 15% of vibration disease patients
Swain et al., 2020		Systematic Review		**(Unclear).** Whole body vibration Effect estimate for systematic reviews: 1.39(1.24,1.55) to 2.3(1.8,2.9) in 4 of 12 meta analyses. type of evidence available was predominantly (23/27 studies) cross-sectional. Overall, metaanalyses demonstrated association, with evidence for a dose response relationship. However, systematic reviews only looking at prospective studies were less clear and did not strongly support temporality with weak or no evidence.
Swedish Council on Health		Systematic Review		**(+).** Those who work in forward bent postures or are exposed to whole body vibration in their work develop more symptoms of sciatica than others.

Technology et al., 2014				
Taylor et al., 2014		Systematic Review		**(-).** Exposure to vibration were not found to be predictive of LBP in the occupational population
Tiemessen et al., 2008	229	Prospective cohort	Professional drivers	**(-).** The associations between the various WBV daily exposure measures (daily driving time, Av(8), Adom(8), VDVv and VDVdom) and the outcomes 12-month LBP and driving-related LBP showed that no significant associations were found in the daily exposure measures and 12-month LBP
van Oostrom et al., 2012	4738	Prospective cohort	General Population	**(-).** Mechanical vibration (PR 1.04, 95% CI 1.01 to 1.08) were not associated with Incident Chronic LBP at t 3 Among Those Without Chronic LBP at t 1 and t 2 and persistence of Chronic LBP at t 3 Among those With Chronic LBP at t 1 and/or t 2
Vandergrift et al., 2012	1181	Cross-Sectional	Automobile manufacturing workers	**(+).** Whole body vibration (PR 1.04, 95% CI 1.01 to 1.08) were each associated cross-sectionally with LBP

Table 2. Description of causation outcomes due to whole body vibration for chronic lower back pain.

Appendix 1

WorkSafeBC - Evidence-Based Practice Group Levels of Evidence (adapted from 1,2,3,4)

1	Evidence from at least 1 properly randomized controlled trial (RCT) or systematic review of RCTs.
2	Evidence from well-designed controlled trials without randomization or systematic reviews of observational studies.
3	Evidence from well-designed cohort or case-control analytic studies, preferably from more than 1 centre or research group.
4	Evidence from comparisons between times or places with or without the intervention. Dramatic results in uncontrolled experiments could also be included here.
5	Opinions of respected authorities, based on clinical experience, descriptive studies or reports of expert committees.

References

1. Canadian Task Force on the Periodic Health Examination: The periodic health examination. CMAJ. 1979;121:1193-1254.

2. Houston TP, Elster AB, Davis RM et al. The US Preventive Services Task Force Guide to Clinical Preventive Services, Second Edition. AMA Council on Scientific Affairs. American Journal of Preventive Medicine. May 1998;14(4):374-376.

3. Scottish Intercollegiate Guidelines Network (2001). SIGN 50: a guideline developers' handbook. SIGN. Edinburgh.

4. Canadian Task Force on Preventive Health Care. New grades for recommendations from the Canadian Task Force on Preventive Health Care. CMAJ. Aug 5, 2003;169(3):207-208.

Appendix 2

Search 1. Search strategy for MEDLINE (via OVID)

1	exp vibration/	25332
2	whole-body vibration.mp.	2072
3	wbv.mp.	1348
4	occupational vibration.mp.	57
5	or/1-4	26116
6	dorsalgia.tw,kf.	103
7	exp Back Pain/	39804
8	backache.tw,kf.	3722
9	((lumb* adj pain) or (back adj pain)).tw,kf.	51344
10	coccyx.tw,kf.	901
11	coccydynia.tw,kf.	159
12	sciatic*.tw,kf.	30180
13	sciatic neuropathy/	2053
14	spondylosis.tw,kf.	3639
15	spondylolisthesis.tw,kf.	5486
16	degenerative disc disease*.tw,kf.	2246
17	(disc adj degeneration).tw,kf.	5161
18	(disc adj prolapse).tw,kf.	731
19	(disc adj herniation).tw,kf.	7134
20	(failed adj back).tw,kf.	1171
21	lumbago.tw,kf.	1385
22	exp Spondylosis/	7676
23	or/6-22	115023
24	5 and 23	420
25	(animals not (humans and animals)).sh.	4746711
26	24 not 25	384

Search 2. Search strategy for CINAHL (via EBSCO)

1	(MH "Vibration")	4,009
2	"whole-body vibration"	1,038
3	"wbv"	529
4	"occupational vibration"	6
5	S1 or S2 or S3 or S4	4,180
6	"dorsalgia"	30
7	(MH "Back Pain+")	31,626
8	(MH "Low Back Pain")	20,407
9	"backache" or back pain	41,117
10	lumb* W1 pain	1,032
11	lumb* N5 pain	3,282
12	S6 or S7 or S8 or S9 or S10 or S11	42,286
13	(MH "Coccyx")	254
14	(MH "Sciatica")	1,761
15	"sciatic*"	5,430
16	"coccyx"	369
17	"coccydynia"	104
18	(MH "Lumbar Vertebrae")	17,903
19	lumb* N2 vertebra*	18,695
20	S13 or S14 or S15 or S16 or S17 or S18 or S19	24,062
21	(MH "Thoracic Vertebrae")	6,521
22	(MH "Spondylolisthesis") OR (MH "Spondylolysis")	1,852
23	"lumbago"	16,301
24	S21 or S22 or S23	24,349
25	S12 or S20 or S24	64,015
26	S5 AND S25	213
27	(MH "Animals")	90,008
28	S26 NOT S27	211

Search 3. Search strategy for CENTRAL (via OVID)

1	exp vibration/	14778
2	whole-body vibration.mp.	1249
3	wbv.mp.	696
4	occupational vibration.mp.	1
5	or/1-4	1964
6	dorsalgia.tw,kf.	142
7	exp Back Pain/	5221
8	backache.tw,kf.	494
9	((lumb* adj pain) or (back adj pain)).tw,kf.	14778
10	coccyx.tw,kf.	99
11	coccydynia.tw,kf.	70
12	sciatic*.tw,kf.	2174
13	sciatic neuropathy/	7
14	spondylosis.tw,kf.	792
15	spondylolisthesis.tw,kf.	769
16	degenerative disc disease*.tw,kf.	551
17	(disc adj degeneration).tw,kf.	360
18	(disc adj prolapse).tw,kf.	133
19	(disc adj herniation).tw,kf.	1422
20	(failed adj back).tw,kf.	307
21	lumbago.tw,kf.	301
22	exp Spondylosis/	378
23	or/6-22	20125
24	5 and 23	66
25	(animals not (humans and animals)).sh.	21
26	24 not 25	66

Search 4. Search strategy for PEDRO

Last searched 26 January 2021
Abstract and title: Vibration AND
Problem: pain AND
Body Part: lumbar spine, sacroiliac joint or pelv

Results: 19 hits