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Effect Of Forklift Operation On Lower Back Pain – An Evidence-Based Approach

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ABSTRACT

Numerous reviews have been conducted on the relationship between working as heavy equipment operator and musculoskeletal disorders. These reviews were qualitative in nature and did not include the ingredients of an evidence-based approach. This research deals with a critical appraisal and meta analysis designed to provide an answer to the relationship of whole-body vibration (WBV) and postures with lower back pain among heavy equipment operators (chapter 2). Chapter 3 deals with an evidence-based approach designed to provide an answer to the relationship of WBV and postures with lower back pain among heavy equipment operators, and identify mechanisms to minimize the risk of lower back pain among forklift operators. The published articles were obtained from a search of electronic databases and bibliographies of identified articles. The critical appraisal was conducted using an Epidemiological Appraisal Instrument. The meta-analysis method was conducted using statistical techniques employing fixed-effect and random-effect models.

Eighteen observational articles in chapter two and six observational articles in chapter three, satisfied the inclusion criteria adopted in this research. The methodological qualities of the published studies ranged from marginal to average. In chapter two the meta-relative risk was 2.2 and 2.1 in chapter three. The meta-analysis results shows that heavy equipment and forklift operators are at more than twice the risk of lower back pain of those workers not exposed to operate heavy equipment or forklift. Some of the factors that influenced vibration

in forklift equipment are: seat, speed, floor surface, and tires. Also awkward postures and static postures are affected by: seat, time seated, and the task performed. There appears to be a certain degree of evidence for a causal relationship between working as heavy equipment or forklift operators and lower back disorders. The reported findings point to an urgent need for improved ergonomic design of heavy equipment vehicles. The significance of this study is that a systematic approach to evidence-based decision making is likely to improve the occupational safety and health programs of heavy equipment operators.

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**I DEDICATE THIS WORK TO MY WIFE ROSA, MY SON
HERIBERTO, AND MY DAUGHTER ALANIS.**

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CHAPTER ONE

INTRODUCTION

Heavy equipment may be defined as vehicles used to execute specialized, heavy-duty tasks such as engineering and construction activities (Wikipedia, 2005). Typical heavy equipment include back hoe loader, bulldozer, combat engineering vehicle, compactor, crane, drag line, excavator, feller buncher, forklift, forwarder, fresno scraper, front loader, grader, harvester, paver, rock-truck, scraper, skid loader, and tractor. The operation of a heavy equipment vehicle may expose its operator to multiple ergonomic risk factors, including static and awkward work postures (e.g., trunk and neck twisting, stooping, deep sideway trunk-bending), whole-body vibration, shock (also called jarring and jolting), physical work demands (e.g., walking, pulling, lifting), climatic conditions (e.g., heat, cold), and psychosocial factors (e.g., job satisfaction) (Brendstrup and Biering-Sorensen, 1987; Bongers et al. 1988; Troup, 1978). These ergonomic risk factors are known to be associated with musculoskeletal disorders.

The present study consisted of two parts. Chapter two deals with this issue among heavy equipment operators and seeks an answer to the following question: “Are whole-body vibration/shock and working postures associated with lower back and neck pain among heavy equipment operators (i.e., forklift, crane, tractor, and earth moving equipment) while accounting for individual (i.e., age, gender, prior history of back or neck disorders) and occupational confounders (i.e., material handling, climatic conditions, psychosocial conditions)?”. Chapter

three deals with the forklift operation and seeks an answer to the following question: *“Is there a relationship between whole-body vibration and postures with lower back pain among forklift operators? And if a relationship exists, Is there any mechanisms to minimize the risk of lower back pain among forklift operators?”*

Though numerous reviews have been published on the subject (see table 2-1 for a summary of sample reviews), the great majority of these reviews was qualitative in nature and did not include the ingredients of an evidence-based methodology. Rosenberg and Donald (1995) described an evidence-based approach as a process consisting of four steps: (1) formulation of a clear ergonomic question from a user's problem (in this case heavy equipment operator); (2) search the literature for relevant literature; (3) critical appraisal of the evidence for its validity and usefulness; and (4) implement useful findings in ergonomic practice. Therefore, this research deals with the use of an evidence-based approach to provide an answer to the aforementioned questions.

CHAPTER TWO

The Impact Of Operating Heavy Equipment Vehicles On Lower Back

SUMMARY

Background – Numerous reviews have been conducted on the relationship between working as a heavy equipment operator and musculoskeletal disorders. These reviews were qualitative in nature and did not include the ingredients of an evidence-based approach.

Objective – This research deals with a critical appraisal and meta analysis designed to provide an answer to the health effects of heavy equipment vehicle operation.

Methods – The published articles were obtained from a search of electronic databases and bibliographies of identified articles. The critical appraisal was conducted using an Epidemiological Appraisal Instrument. The meta-analysis methods was conducted using statistical techniques employing fixed-effect and random-effect models.

Results – Eighteen observational articles satisfied the inclusion criteria adopted in this research. The methodological qualities of the published studies ranged from marginal to average. The meta-relative risk was 2.21 indicating that operators exposed to driving heavy equipment are at more than twice the risk of those workers not exposed to driving heavy equipment.

Conclusions – There appears to be a certain degree of evidence for a causal relationship between working as a heavy equipment operator and lower back/neck health outcomes. Prospective cohort studies are urgently needed to confirm our evidence-based methodology and the biological plausibility should be further explored.

Significance – The reported findings point to the urgent need of improved ergonomic design of heavy equipment vehicles.

INTRODUCTION

Heavy equipment may be defined as vehicles used to execute specialized, heavy-duty tasks such as engineering and construction activities (Wikipedia, 2005). Typical heavy equipment includes back hoe loader, bulldozer, combat engineering vehicle, compactor, crane, drag line, excavator, feller buncher, forklift, forwarder, fresno scraper, front loader, grader, harvester, paver, rock-truck, scraper, skid loader, and tractor. The operation of a heavy equipment vehicle may expose its operator to multiple ergonomic risk factors, including static work postures (e.g., trunk and neck twisting, stooping, deep sideways trunk-bending), whole-body vibration, shock (also called jarring and jolting), physical work demands (e.g., walking, pulling, lifting), climatic conditions (e.g., heat, cold), and psychosocial factors (e.g., job satisfaction) (Brendstrup and Biering-Sorensen, 1987; Bongers et al. 1988; Troup, 1978). These ergonomic risk factors are known to be associated with musculoskeletal disorders. This research deals with this issue among heavy equipment operators and seeks an answer to the following question: “Are whole-body vibration/shock and working postures

associated with lower back and neck pain among heavy equipment operators (i.e., forklift, crane, tractor, and earth moving equipment) while accounting for individual (i.e., age, gender, prior history of back or neck disorders) and occupational confounders (i.e., material handling, climatic conditions, psychosocial conditions)?”.

Numerous reviews have been published on the subject (see table 1 for a summary of sample reviews). The great majority of these reviews were qualitative in nature and did not include the ingredients of an evidence-based methodology. Rosenberg and Donald (1995) described an evidence-based approach as a process consisting of four steps: (1) formulation of a clear ergonomic question from a user’s problem (in this case heavy equipment operator); (2) search the literature for relevant literature; (3) critical appraisal of the evidence for its validity and usefulness; and (4) implement useful findings in ergonomics practice. Most of the reviews cited in Table 1, although not explicitly designed to answer the question raised in this research, did not include a critical appraisal of the published studies. This paper deals with a critical appraisal and meta analysis designed to provide an answer to the aforementioned question.

METHODS

Search Strategy and Inclusion Criteria

In this critical appraisal the target population is heavy equipment operators and the outcome of interest is lower back and neck disorders. Observational studies were considered including retrospective/prospective cohort incidence, case-control, proportional hazards, and cross-sectional. Initially, there was no

restriction on the exposure variable collected from the target population other than at least one year in service as heavy equipment operators, then vibration and postures were added.

Publications were retrieved by a search of electronic databases including PubMed, NIOSHTIC, and NIOSHTIC-2 (up to May 2005) using the following keywords: (a) forklift/fork-lift and back/neck pain; (b) tractor and back/neck pain; (c) crane and back/neck pain; (d) earth movers; (e) operating engineers and back/neck pain. In addition to the electronic search, bibliographies in identified papers were reviewed for additional studies.

The search was restricted to reports published in English, abstracts and reviews were not included. Studies were excluded if these did not present basic data that are usable in the derivation of the meta-analysis risk. If there was more than one article dealing with the same or overlapping population, preference was given to the article providing frequency measures similar to those used in articles by different authors.

Data Extraction

From all the included studies, the following items were documented: location (US versus non-US), study design, study period, number of exposed group(s), exposure variable, outcome (e.g., prevalence or incidence). The data were extracted from each article by one reviewer and was verified by another reviewer. Discrepancies identified by the second reviewer were resolved between both reviewers in a consensus meeting.

Quality Assessment

The methodological quality of all the studies that entered the review was assessed by means of the 'Epidemiological Appraisal Instrument or EAI developed by Genaidy (2005). The EAI consists of 43 questions grouped into five scales: (1) reporting (17 items); (2) subject selection (7 items); (3) measurement quality (10 items); (4) data analysis (7 items); and (5) generalization of results (2 items). Every item in the EAI was rated for a given study using one of the following options: (1) "not applicable" (not included in score calculation); (2) "Yes" (2 points); (3) "Partial" (1 point); (4) "No" (0 point); and "Unable to determine" (0 point). The final score for each scale was taken as the average of the values recorded for each item. Four members of our research team conducted the critical appraisal independently. The results of the evaluations were compared, and areas of disagreement were discussed and resolved in a follow-up session.

It should be noted that each article was critically appraised for the research question formulated in this research. It was not evaluated on the basis of the aims cited in each individual article. This practice should be the base in systematic reviews dealing with critical appraisals in order to compare the included studies on equal basis. As such, the quality of the studies were compared with respect to the research question in this paper.

Statistical Methods for Meta-Analysis

Reviewed articles were subjected to a meta-analysis to estimate an overall odds ratio on lower back and neck pain among heavy equipment operators (meta-odds ratio). The confidence limit method was used to calculate the meta-odds ratio and 95% confidence limits (Elwood, 2000). This necessitated the extraction of

the total number of subjects participating in the exposed and non-exposed groups and the prevalence rates from each individual study. As such, an odds ratio and the corresponding 95% confidence limits were computed for each study, and were consequently used in the calculation of the overall odds ratio. The “LOGISTIC” procedure of the Statistical Analysis Software (SAS) was used to calculate the odds and 95% confidence limits for each study.

Traditionally, a fixed effect model is used if there is no heterogeneity among the studies. If it exists, a random-effects model is preferred. A statistical test of the homogeneity assumption for the fixed-effect approach is given by $Q = \sum_{i=1}^n W_i * \{\log(OR_i) - \log(mOR)\}^2$ where, OR_i and mOR are the relative risk for a given study and the meta-relative risk, respectively. The hypothesis would be rejected if Q exceeds $\chi^2_{n-1, \alpha}$ and the random-effects model is used with a different study weight (W_i^*) that further accounts for the inter-study variation in effect size (Petitti, 2000). The weighing factor W_i^* in the DerSimonian and Laird random-effects model is

$$W_i^* = \frac{1}{\left[D + \left(\frac{1}{w_i} \right) \right]}$$

where, W_i is the statistical weight for a given study for the fixed-effect model and is equal to $(1/SE_i^2)$ with SE_i being the standard error for a given study, and,

$$D = \frac{[Q - (n - 1)] * \sum_{i=1}^n W_i}{\left(\sum_{i=1}^n W_i \right)^2 - \sum_{i=1}^n W_i^2}.$$

It should be noted that D is set to 0 if $Q < n-1$. We validated our random-effects model against data provided in Petitti (2000). In this study, we adopted an $\alpha \leq 10\%$ or less for declaring heterogeneity (Greenland, 1987).

We were interested to determine whether the overall quality index may change the results obtained for the meta-odds ratio. The weight is the overall quality index multiplied by the inverse of the variance.

RESULTS

Identification of studies

The search of computerized databases identified a total of 187 peer-reviewed articles from PubMed, NIOSHTIC, and NIOSHTIC-2. Table 2-2 provides a summary of the process search consisting of four steps. Upon review of published articles, additional studies were excluded because of, among other things, overlapping population, no specification of vehicle type, lack of data, type of study design (i.e., intervention) and type of outcome (other than musculoskeletal disorders) (Riihimaki et al., 1989; Shinozaki et al., 2001; Franzini and Benedyk, 1996; Van Poppel et al., 1998; Issever et al., 2003; Spear et al., 1976; Futatsuka et al., 1998; Nakata et al., 1987; Holmström and Engholm, 2003; Järvholm et al., 2004; Sjaastad and Bakketeig, 2002; Toren et al., 2002).

After applying all exclusion criteria, a total of 18 studies were identified from electronic search of databases and bibliographies of published articles. Of

those articles, there were thirteen cross-sectional studies with the exception of one study possessing hybrid design (Schwarze et al., 1998). The remaining articles were cohort articles (Viikari-Juntura et al., 1994; Riihimaki et al., 1994; Tola et al., 1988; Bongers et al., 1988; Boshuizen et al., 1990a). The first three studies were based on the same population but they differed in terms of the reported outcome measures (i.e., neck, both neck and shoulder, sciatic pain). It should also be noted that the five cohort studies were also based on the same populations used in the cross-sectional studies. Therefore, the critical appraisal reported in a subsequent section was only based on the cross-sectional investigations. Three of the thirteen studies examined more than one type of vehicle. For example, Bovenzi et al. (2002) studied the health effects of forklift and crane operators.

Description of Evidence

Table 2-3 displays the description of evidence for the thirteen cross-sectional studies in terms of exposure, outcome, study design, study population, and main results. The highlights of this evidence are:

- (1) The number of studies for forklift operators (n=6) was twice the number of studies for either crane, tractor or earth moving operators (n=3).
- (2) All studies had cross-sectional design except that by Schwarze et al. (1998) which was hybrid (cross-sectional with prospective cohort component).
- (3) Three studies measured whole-body vibration and postural loading as exposures (Hoy et al., 2005; Bovenzi et al., 2002; Bovenzi and Betta, 1994). Six investigations examined whole-body vibration as exposure (Schwarze et

al., 1998; Miyashita et al., 1992; Boshuizen et al., 1992; Kumar et al., 1999; Dupuis and Zerlett, 1987). Occupation was adopted as the exposure variable in Brendstrup and Biering-Sorensen (1987), Burdorf et al. (1993), and Burdorf and Zondervan (1990).

- (4) Lower back pain was investigated as an outcome in all studies. Neck pain was only measured in Dupuis and Zerlett (1987) and Zimmermann et al. (1997).
- (5) Associations with lower back pain demonstrated that 4 in 6 studies had significant relationship at the 5% level for forklift operators, 2 in 3 studies for crane operators, all 3 studies for tractor operators, and 1 in 3 studies for earth moving operators (see tables 5 through 8, respectively).
- (6) All studies but one (Zimmermann et al. 1997) had control groups.
- (7) All studies came from different parts of the world: UK (1), Italy (2), Germany (2), Netherlands (4), Japan (1), US (1), Sweden (1), and India (1). As such most studies came from Italy, Germany and Netherlands.
- (8) Three studies examined two of the four groups reported in this research (Bovenzi et al., 2002; Schwarze et al., 1998; Miyashita et al., 1992). No one study examined all the covariates/confounders cited in our research question (Table 2-4). Bovenzi et al. (2002), Boshuizen et al. (1992), Bovenzi and Betta (1994) were the only studies who seriously accounted for the majority of confounders/covariates. The measurements of these confounders, however, were not detailed enough and did not account for all of its elements such as psychosocial factors.

Table 2-5 summarizes the description of evidence for the prospective (Viikari-Juntura et al., 1994; Riihimäki et al., 1994; Tola et al., 1988) and retrospective (Bongers et al., 1988; Boshuizen et al., 1990a) cohort studies. These cohort investigations were from Finland and Netherlands, respectively. They were based on moderately-sized populations and adequate follow-up periods (adjusted at a minimum for age). The findings demonstrated that the association measures of lower back and neck disorders were significantly associated with the task of operating heavy equipment machinery

Critical Appraisal of Study Quality

The studies identified from the literature search were subjected to a rigorous critical appraisal using an Epidemiological Appraisal Instrument. Each study was evaluated separately by four assessors (AG, HB, TR, MM). There after, a consensus was established through follow-up meetings. The differences among the assessors stemmed directly from the research question outlined in the introduction. The research question was based on expert knowledge (AG, TW) and information extracted from the published literature. As such, each study was not evaluated based on its own objectives. Indeed, it reflects its methodological quality and the knowledge gap with respect to the research question established in this report.

An overall appraisal of the studies suggests that the quality of individual studies range from marginal (0.5 on 0-2 scale) to average (1.0 on 0-2 scale) (Figure 2-1). Figure 2-2 provides a summary of the different methodological qualities for each study. The following can be deduced:

- (a) Studies scored average in reporting the different elements of methodological qualities.
- (b) There was a variance in the subject selection criteria among the studies. About one-third of the studies did an average job, with the remaining two-thirds roughly split between marginal and poor scores.
- (c) The majority of the studies were uniformly marginal in terms of measurement quality with the remainder scoring somewhat poor.
- (d) The data analysis methods were widely scattered between poor and average scores. This was greatly impacted by the lack of consideration for some important individual and environmental covariates/confounders.
- (e) The generalization of the studies is greatly in question. This may be attributed in part to the lack of information about the participation rate. In addition, the criteria for sample size calculations were not reported.

Figure 2-3 provides a closer look at the measurement quality of individual studies. Investigators paid more attention to the exposure and outcome methods. Still, the quality of these methods centered around marginal values. The blinding procedures were not discussed. Therefore, it was not possible to determine if investigators considered these principles in the conduct of their studies. Moreover, the investigators did not pay attention to the reporting of the observation period across the groups and the subject population.

Figure 2-4 summarizes the methodological qualities of study description and execution across all individual investigations. The overall quality was, on average, marginal. The reporting index was the highest, scoring average values.

The subject selection and data analysis methods were, on average, marginal. Measurement quality was somewhat poor and study generalization was in question. There was a wide variance among the studies in terms of quality attributes.

Meta Relative Risk

Tables 2-6 through 2-9 provides documentation of the meta analysis details conducted for operators of forklifts, cranes, tractors, and earth moving machinery respectively. Results of the fixed-effect and random-effect models are presented for each group. Heterogeneity was found for all groups except forklift operators. Therefore, the random-effects models were used for crane, tractor, and earth moving operators. The fixed-effect model will be applied for forklift operators. The meta-relative risk for the different groups was as follows from highest to lowest:

- (1) Tractor – 2.983 (95% CI 1.595-5.582)
- (2) Forklift – 2.077 (95% CI 1.645-2.624)
- (3) Crane – 1.854 (95% CI 0.893-3.848)
- (4) Earth Moving – 1.839 (95% CI 0.897-3.773)

The overall estimate was only significant at the 5% level for the forklift and tractor operators.

Table 2-10 displays the meta-analysis details for heavy equipment operators across all studies. Because heterogeneity was present across the studies, the meta-relative for the random-effects model was adopted and was equal to 2.209 (95% CI 1.706-2.861). This was significant at the 5% level. These results suggest that there is a significant association between lower back pain

and heavy equipment operators. This association was based on 3151 exposed operators and 1728 controls and crude estimates not accounting for potential confounders/covariates.

Accounting for the overall study quality slightly improved the results (Table 2-11). The meta-relative risk increased to 2.32 relative to the 2.21 obtained without incorporating the study quality.

DISCUSSION

As pointed out in the introduction, numerous reviews have been reported in the published literature on the relationship between musculoskeletal disorders and risk factors among heavy equipment operators. These reviews were largely qualitative and lacked the rigorous methodology of an evidence-based approach. This research was conducted to fill in this gap by conducting a meta-analysis and a critical appraisal of the published literature to examine the association between lower-back /neck pain and operators of heavy equipment. Across all studies, a crude meta-relative risk was 2.2 suggesting that operators of heavy equipment are at more than twice the risk of acquiring lower back pain than controls who do not operate heavy equipment. This primary finding is discussed in the following sections from different angles.

Critical appraisal of reported studies

The methodological qualities of the published studies ranged from marginal to average. Although there was a wide variance among the studies in terms of quality, attributes, the subject and data analysis methods were marginal and

measurement quality was somewhat poor, As such, study generalization is in question.

The evidence was mostly based on cross-sectional designs and non-US studies. In addition lower-back outcomes were only examined among heavy equipment operators. Musculoskeletal outcomes should be examined in other body regions such as the neck and shoulders.

Association between lower back pain and types of heavy equipment

The meta-analysis results suggest that the meta-odds ratio for tractor drivers was almost 3.0 and that for forklift operators was 2.0. This may be explained in part by the intensity of steady-state whole-body vibration and level of mechanical shock induced while driving the vehicle. To illustrate this point, the studies by Bovenzi et al. (2002) and Bovenzi and Betta (1994) are compared. These studies had similar methods and procedures. Both studies had a cross-sectional design with both exposed and non-exposed groups. The exposure variables were whole-body vibration and posture. Among other types of outcomes, lower back pain in the last 12 months was measured. The odds ratio for lower back pain was 2.39 (95% CI 1.57-3.66) and 1.42 (95% CI 1.13-1.78) for tractor and forklift operators, respectively, and were adjusted for several covariates. The weighted rms acceleration for forklifts was 0.90 m/s^2 with 0.77 standard deviation (Bovenzi et al., 2002). The mean value of rms acceleration was 1.97 m/s^2 for tractors (Bovenzi and Betta, 1994). The vector sum averaged 1.22 m/s^2 (range 0.89-1.47 m/s^2) when measurements were performed on tractors towing loaded trailers on

farm tracks at 6 km/h, and 0.86 m/s^2 (range $0.52\text{-}1.21 \text{ m/s}^2$) when the tractors traveled at full speed on asphalt roads.

Results of the meta-analysis further indicated that the meta odds ratio was slightly higher for forklift operators than crane operators. These findings may be supported by the exposure data summarized in table 2-12. The frequency weighted rms and cumulative vibration exposure was higher for forklifts than cranes. On average, the frequency weighted rms for tractors was the highest, followed by that for forklift, then cranes.

The aforementioned results suggest that the steady state whole-body vibration may not account for its full association with lower back pain. It is possible that this may be attributed to the mechanical shocks induced during rough rides and high accelerations. Sandover (1998) suggested that mechanical shocks are short duration (20-50 ms), high acceleration (e.g., weighted rms values over 4 s of up to 5.8 m/s^2 and unweighted peak values of at least 20 m/s^2 vibration). He further indicated, without direct proof, that mechanical shocks have a greater influence on both human health and subjective discomfort than the long term rms approach.

In conclusion, the aforementioned results suggest that epidemiologically mechanical shocks may be a potential contributor to the onset of lower back pain. Both steady state and transitory vibration should be simultaneously measured in health studies of heavy equipment in order to determine their relative contribution to lower back risk. It is of utmost importance to conduct full exposure assessment of both types to better understand the health risks at hand.

Association between lower back pain and vibration and postural load exposure variables

Heavy equipment operators may be exposed to a number of ergonomic risk factors. Among the most important are vibration and posture. Only two studies examined the joint effect of vibration and postural load on lower back pain. Table 2-13 presents the odds ratio for lower back pain as a function of postural load or cumulative vibration exposure (adjusted for age). These results suggest that lower back pain increases with an increase in vibration load or postural load. The combined effect of both exposure variables is displayed in Table 2-14. The joint effect is clearly demonstrated. It should be noted that it is our assumption that the vibration load consists of both the steady state and transitory components as previously mentioned.

Causal Relationship

In light of the evidence presented in this research, one should ask whether working as a heavy equipment operator is causally related to lower back and neck outcomes. The bulk of the evidence is presented for lower back pain and is discussed with respect to several criteria of causality (Teschke et al., 1999):

- (a) consistency of association – is the association found repeatedly in studies of different populations, in different conditions, with different designs?;
- (b) strength of association – how high is the risk in exposed populations compared to unexposed populations? Is the risk high enough to exclude chance or confounding as possible explanations;
- (c) dose-response – does the effect increase in a predictable way, as the exposure intensity, duration, or dose (intensity times duration) increase?

- (d) temporal relationship – does the effect appear after the exposure? Is there usually an induction period between first exposure and disease onset, and if so, is the timing of the disease plausible in relation to the exposure
- (e) plausibility – is the association plausible given the science and clinical knowledge about the disease?

Table 2-10 suggests that the relationships reported are elevated (i.e., relative risk > 1) and are fairly consistent in 14 out of 15 study groups. The meta-relative risk was considered high with overall risk being greater than 1.0. In many studies, some covariates and confounders were accounted for. As such, it appears that the association may not be due to chance. This is further supported by our earlier discussions on the different types of vehicles and role of exposure loads such as vibration and postural loading. For example, the meta-relative risk for tractor operators was higher than that for forklift operators. Therefore, the transitory whole-body vibration may play a potential role in harmful effect in addition to those induced by the steady-state whole-body vibration and postural loading.

Few investigators researched the dose-response relationships between exposure variables and musculoskeletal disorders. Table 2-15 provides a summary of data from the published literature. A general trend cannot be deduced from the data presented because of the limited range of exposure data. In few instances, there was a larger increase in the point estimate with an increase in the duration of exposure.

Limited evidence is obtained from prospective and retrospective cohort studies. Studies from Finland and Netherlands consistently report elevated risks for lower back and neck outcomes among heavy equipment operators, particularly for severe outcomes.

The aforementioned discussion suggests that there was a certain degree of causal relationship between working as a heavy equipment operator and lower back outcome. This is further supported by comparison of the vehicle vibration levels to the whole body vibration standard of the International Standards Organization (ISO 2631-1.2, 1997) (See Tables 2-16 and 2-17). In many instances, the ISO standard values have been exceeded.

Table 2-1. Summary of sample review articles

Source	Objective	Epidemiological Appraisal of Methodological Quality	Meta-Analysis	Assessment for Causal Evidence
Ramos Vieira and Kumar (2004)	Review of working postures	No	No	No
Kittusamy and Buchholz (2004)	Review of whole-body vibration and postural load among operating engineers.	No	No	No
Walker-Bone and Palmer (2002)	Review of musculoskeletal disorders among farmers and farm workers	No	No	No
Stayner (2001)	Review of health effects of whole-body vibration and shock	No	No	No
Mehta and Tewari (2000)	Review of seating discomfort among tractors operators	No	No	No
Teschke et al. (1999)	Epidemiological evidence for whole-body vibration and lower back disorders among heavy equipment operators	No	No	Yes
Lings and Leboeuf-Yde (2000)	Review of relationship between whole-body vibration and lower back pain	Yes	No	No
Bovenzi and Hulshof (1999)	Epidemiological evidence linking whole-body vibration to lower back pain	Yes	Yes	No
Sandover (1998)	Review of literature and expert evaluation of high acceleration events	No	No	No
Magnusson and Pope (1998)	Review of relationship between working postures and musculoskeletal disorders among drivers	No	No	No

Table 2-1. Cont'd

Source	Objective	Epidemiological Appraisal of Methodological Quality	Meta-Analysis	Assessment for Causal Evidence
Pope et al. (1998)	Assessment of possible mechanisms leading to lower back pain due to whole-body vibration	No	No	No
Wilder et al. (1996)	Assessment of solutions to reductions of lower back pain associated with whole-body vibration	No	No	No
Wilder and Pope (1996)	Review of relationship between lower back pain and whole-body vibration	No	No	No
Pope et al. (1995)	Review of whole-body vibration and lower back pain	No	No	No
Boshuizen et al. (1990)	Review of studies conducted by the authors linking vibration to lower back pain	No	No	No
Sandover (1988)	Review of spinal behavior under shock and vibration	No	No	No
Helmkamp et al. (1984)	Review of whole-body vibration	No	No	No
Hagberg (1984)	Assessment of potential pathophysiological pathways leading to neck and shoulder disorders due to working postures	No	No	No
Troup (1978)	Review of factors leading to lower back pain	No	No	No

Table 2-2. Summary of steps involved in electronic search of databases

Step 1. Number of abstracts obtained for each database with corresponding keywords			
Keyword	Databases		
	PubMed	NIOSHTIC	NIOSHTIC-2
Fork-lift and neck/back pain	4	1	0
Forklift and vibration	6	10	1
Fork-lift and vibration	5	8	0
Tractor and neck/low back	12	11	2
Tractor and neck/back pain	15	14	2
Crane and neck/low back	12	19	2
Crane and neck/back pain	16	14	0
Earth movers	3	6	2
Operating engineers and neck/back pain	9	0	0
Operating engineers and neck/low back	8	1	2

Step 2. Number of abstracts obtained for each type of equipment across all databases	
Type of Equipment	Number of Abstracts
Forklift	35
Crane	63
Tractor	56
Earth movers	11
Operating engineers	20

Step 3. Number of abstracts obtained for each type of equipment after elimination of duplication	
Type of Equipment	Number of Abstracts
Forklift	32
Crane	33
Tractor	32
Earth movers	11
Operating engineers	12

Step 4. Number of studies obtained for each type of equipment after applying inclusion criteria and adding relevant articles from bibliographies included in identified articles and reviews

Type of Equipment	Number of Studies
Forklift	6
Crane	3
Tractor	3
Earth movers	4
Operating engineers	1

Note: The total number of studies are 13 but three of the studies included more than one type of equipment.

Inclusion Criteria

- 1 English
- 2 Peer review ed journal
- 3 Full text (no abstract)
- 4 Epidemiological study
- 5 Vibration, postures, and/or occupation as exposures variables

Table 2-3. Summary of description of evidence for cross-sectional studies

Type of Equipment	Source	Description
Forklift	Hoy et al. (2005)	
	<i>Exposure</i>	Whole-body vibration and postural load among forklift operators
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross-sectional
	<i>Study population</i>	23 forklift operators
		23 workers from other departments who did not drive vehicles at work (control group)
	<i>Main results</i>	Paper mill company in the UK
		Lower back pain in last 12 months was significantly more prevalent among drivers than
		12-month prevalence for forklift group (65%)
		12-month prevalence for controls (35%)
		Odds ratio for forklift operators 3.52 (95% CI 1.04-11.83) (not adjusted for confounders)
	Bovenzi et al. (2002)	
	<i>Exposure</i>	Whole-body vibration and postural load among forklift, crane, and straddle carrier
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross-sectional
	<i>Study population</i>	88 forklift drivers
		85 straddle carrier operators
		46 crane operators
		85 maintenance workers (control group)
	<i>Main results</i>	Transportation company in Northern Italy
		Whole-body vibration and postural loading were significantly associated with lower back pain
		12-month prevalence ratio for forklift operators: 1.42 (95% CI 1.13-1.78) (adjusted for covariates)
		12 month LBP prevalence ratio for crane operators 0.96 (95% CI 0.68-1.35) (adjusted for covariates)
	Schwarze et al. (1998)	
	<i>Exposure</i>	Whole-body vibration among forklift, and earth moving machinery operators
	<i>Outcome</i>	Physician diagnosed "lumber syndrome"
	<i>Study design</i>	Cross-sectional
	<i>Study population</i>	159 forklift operators
		64 truck drivers

Table 2-3. Cont'd

Type of Equipment	Source	Description
	<i>Main results</i>	165 operators of earth moving machinery operators 65 controls (workers in same companies not exposed to whole body vibration) Workers from more than 30 companies in Germany Prevalence of lumbar syndrome among forklift operators (0.65), earth moving machinery operators (0.60), and controls (0.58)
	Miyashita et al. (1992)	
	<i>Exposure</i>	Whole body vibration among workers (forklift and earth moving machinery operators)
	<i>Outcome</i>	Low back pain
	<i>Study design</i>	Cross-sectional
	<i>Study population</i>	184 power shovel operators 127 bulldozer operators 44 forklift operators 85 office workers (control group) Construction workers from different companies in Japan
	<i>Main results</i>	Lower back pain was only significantly higher among forklift operators 12-month prevalence for forklift operators (50%), bulldozer operators (36%), and controls (27%)
	Boshuizen et al. (1992)	
	<i>Exposure</i>	Whole body vibration among forklift operators
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross-sectional
	<i>Study population</i>	242 drivers 210 referent workers (workers from the same companies who were not exposed to whole-body vibration) Workers drawn from six ship companies in the Rotterdam harbor (Netherlands)
	<i>Main results</i>	Lower back pain significantly higher among exposure group Overall 12-month odds ratio 2.2 (90% CI 1.03-4.7) (adjusted for confounders)
	Brendstrup and Biering-Sorensen (1987)	
	<i>Exposure</i>	Occupation as exposure (forklift operators)

Table 2-3. Cont'd

Type of Equipment	Source	Description
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross sectional
	<i>Study population</i>	240 male forklift operators from 13 companies in Copenhagen
		Control group from Copenhagen County (399 working men)
	<i>Main results</i>	Forklift operators had significantly higher lower back pain than controls
		12-month prevalence for exposure and control groups are 0.65 and 0.47, respectively
Cranes	Bovenzi et al. (2002)	See forklift equipment
	Burdorf et al. (1993)	
	<i>Exposure</i>	Occupation as exposure
	<i>Outcome</i>	Low back pain
	<i>Study design</i>	Cross sectional
	<i>Study population</i>	94 crane operators
		95 straddle carrier drivers
		86 office workers (control group)
	<i>Main results</i>	Males working for a large transportation company in the Port of Rotterdam.
		12-month prevalence among crane operators (50 %) and office workers (34%)
		Odds ratio for newly developed cases of lower back pain in the current job was 3.29
		(1.52-7.12) among crane operators
	Burdorf and Zondervan (1990)	
	<i>Exposure</i>	Occupation as exposure
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross sectional
	<i>Study population</i>	33 crane operators
		30 crane helpers, general operators, maintenance workers (control group)
		Workers employed in a steel factory in the Netherlands
	<i>Main results</i>	12-month prevalence of LBP among crane operators (61%) and controls (27%)
		LBP odds ratio equaling 3.6(1.2-10.6) (adjusted for confounders)

Table 2-3. Cont'd

Type of Equipment	Source	Description
Tractors	Kumar et al. (1999)	
	<i>Exposure</i>	Whole-body vibration among tractor driving farmers
	<i>Outcome</i>	Lower back pain and pathologic changes in the lower back
	<i>Study design</i>	Cross sectional
	<i>Study population</i>	50 tractor driving farmers
		50 non-tractor driving farmers (control group)
		Selected from two villages in the Sonipat District, Haryana, India
		Prevalence of reported back symptoms higher in tractor driving farmers (56%) as compared to non tractor driving farmers (32%)
	<i>Main results</i>	Degenerative changes in the back similar for both groups
	Bovenzi and Betta (1994)	
	<i>Exposure</i>	Whole-body vibration and postural load among tractor drivers
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross sectional
	<i>Study population</i>	1155 tractor drivers
		220 office workers (control group)
		Drivers from Trentino-Alto Adige, Italy
	<i>Main results</i>	12 month prevalence among tractor drivers (71.7%) and controls (36.8%)
		12 month odds ratio for tractor operators 2.39 (1.57-3.66) (adjusted for covariates)
	Boshuizen et al. (1990a)	
	<i>Exposure</i>	Whole-body vibration in agricultural tractor drivers
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross sectional
	<i>Study population</i>	450 tractor drivers
		110 non exposed workers (control group)
	<i>Main results</i>	Prevalence of lower back pain among tractor drivers (38.1%) and control group (19.1%) for a vibration dose > 5 years
		Odds ratio 2.8 (90% CI 1.64-5.0) (vibration dose > 5years m^2s^4)

Table 2-3. Cont'd

Type of Equipment	Source	Description
Earth Movers	Schwarze et al. (1998)	See forklift equipment
	Miyashita et al. (1992)	See forklift equipment
	Dupuis & Zerlett (1987)	Whole-body vibration in earth-mover operators
	<i>Exposure</i>	Various back symptoms including discomfort and lumbar syndrome
	<i>Outcome</i>	Cross sectional
	<i>Study design</i>	352 earth-moving machine operators (at least 3 yr exposure)
	<i>Study population</i>	315 controls (not exposed to vibration)
		Workers drawn for Germany
	<i>Main results</i>	Prevalence for earth-moving machinery operators (0.69) and controls (0.42)
Operating Engineers	Zimmermann et al. (1997)	Occupation as construction operating engineers
	<i>Exposure</i>	Various musculoskeletal disorders
	<i>Outcome</i>	Cross sectional
	<i>Study design</i>	410 operating engineers, part of a union in Iowa
	<i>Study population</i>	The job factors perceived almost problematic were: working in the same position for long periods and bending and twisting the back.
	<i>Main results</i>	

Table 2-4. Summary of potential confounders/covariates in different studies

Source	Confounders/Covariates
Hoy et al. (2005)	Exercise habit, lifting during work, job satisfaction and smoking.
Bovenzi et al. (2002)	Body mass index, smoking, mental stress on current job and back trauma.
Schwarze et al. (1998)	Body mass index, prior spinal injuries, heavy lifting, load to the spine by leisure activities, and age.
Miyashita et al. (1992)	None reported.
Boshuizen et al. (1992)	Age, experienced mental stress, number of years lifting greater than 10 kg more than 25 times a day while twisting the spine, number of times per day lifting a weight of 10 kg or more with a twisted spine, body height, smoking, percent of time looking backward, and number of hours sitting uninterrupted.
Brendstrup and Biering- Sorensen (1987)	Age, length of employment, and daily driving hours.
Burdorf et al. (1993)	History of heavy physical work, exposure to whole-body vibration, history of work requiring prolonged sitting, cold and draught in current job, working under severe pressure and job satisfaction in the current job.
Burdorf and Zondervan (1990)	Age, height, weight, heavy physical work, and frequent lifting.
Kumar et al. (1999)	Exposed and non-exposed groups are matched for age, gender, ethnic group, land-holding, and work routine.
Bovenzi and Betta (1994)	Age, body mass index, education, sports activity, car driving, marital status, mental stress, climatic conditions, back trauma, and postural load.
Boshuizen et al. (1990a)	Age, height, smoker/non-smoker, twisting, lifting, experienced mental workload, and employing company.
Dupuis and Zerlett (1987)	None reported.
Zimmermann et al. (1997)	None reported.

Table 2-5. Summary of description of evidence for prospective and retrospective cohort studies

Type of Equipment	Source	Description
Machine Operators	Viikari-Juntura et al. (1994)	Occupation as exposure (machine operators)
	<i>Exposure</i>	Neck pain
	<i>Outcome</i>	Prospective cohort
	<i>Study design</i> <i>Study population</i>	688 machine operators - earthmovers and longshoremen specialized in motorized stevedoring (at beginning of study) 553 carpenters (at beginning of study) 591 office workers - control group (at beginning of study) All workers from Finland
	<i>Main results</i>	12-month prevalence of severe neck pain (> 30 days) in machine operators and controls were 28% and 9%, respectively 12-month prevalence of severe neck pain after three yr follow-up were 40% and 12%, respectively Odds ratio for machine operators vs. office workers (95% CI) in terms of change in severe neck pain over 3 yr follow-up 4.2 (2.0-9.0)
	Riihimäki et al. (1994)	Occupation as exposure (machine operators)
	<i>Exposure</i>	Sciatic pain
	<i>Outcome</i>	Prospective cohort
	<i>Study design</i> <i>Study population</i>	688 machine operators - earthmovers and longshoremen specialized in motorized stevedoring (at beginning of study) 553 carpenters (at beginning of study) 591 office workers - control group (at beginning of study)
	<i>Main results</i>	Rate ratios of 3-year cumulative incidence of mild and severe sciatic pain (95% CI) were 2.90 (1.22-6.90) and 5.58 (2.27-13.8), respectively
	Tola et al. (1988)	Overlapping population with Viikari-Juntura et al. (1994). The only difference is the outcome (combined neck and shoulder)
Cranes	Bongers et al. (1988)	Crane operators exposed to vibration
	<i>Exposure</i>	Back disability defined according to International Disease Classification
	<i>Outcome</i> <i>Study design</i>	Retrospective cohort (10 year follow up)

Table 2-5. Cont'd

Type of Equipment	Source	Description
	<i>Study population</i>	743 crane operators (at beginning of study) 662 floor workers (control group) (at beginning of study)
	<i>Main results</i>	Workers from Netherlands Incidence density ratio (per 100 person years) for disability due to degeneration of intervertebral disc 2.95 (90% CI, 1.20-7.25) (adjusted for age and work shift) Incidence density ratio for disability due to displacement of intervertebral disc 1.41 (90% CI, 0.58-3.42)
Tractors	Boshuizen et al. (1990c)	
	<i>Exposure</i>	Tractor operators exposed to vibration
	<i>Outcome</i>	Back disability defined according to International Disease Classification
	<i>Study design</i>	Retrospective (11 year follow up)
	<i>Study population</i>	689 tractor operators (at beginning of study) 109 workers (control group) (at beginning of study)
	<i>Main results</i>	Workers from Netherlands Age adjusted incidence density ratio of intervertebral disc disorders (90%CI) 3.1 (1.16-8.3)

Table 2-6. Meta analysis for lower back pain among forklift operators

Study # (i)	Sample Size for Exposed Group (Prevalence)	Sample Size for Non- Exposed Group (Prevalence)	Odds Ratio (OR)	Ln (OR)	95% CL Lower	95% CL Upper	Variance	Weight (w 1)	Weight (w 1) ²	w 1 ln OR	Heterogeneity	D	Weight (w 2)
1	23(0.652)	23(0.348)	3.516	1.257	1.045	11.831	0.383	2.610	6.810	3.281	0.723		2.569
2	88(0.78)	85(0.52)	3.384	1.219	1.745	6.563	0.114	8.758	76.700	10.676	2.085		8.314
3	159(0.65)	65(0.54)	1.577	0.456	0.877	2.833	0.090	11.158	124.493	5.083	0.847		10.447
4	44(0.50)	44(0.27)	2.667	0.981	1.097	6.484	0.205	4.868	23.694	4.775	0.304	0.006	4.727
5	196(0.41)	107(0.31)	1.546	0.436	0.938	2.548	0.065	15.386	236.739	6.703	1.343		14.067
6	169(0.65)	399(0.47)	2.135	0.758	1.471	3.098	0.036	27.682	766.313	20.996	0.021		23.685
Total	679.00	723.00						70.461	1234.749	51.514	5.323		63.809

Summary Ln OR = $\sum(w_i \ln OR_i) / \sum(w_i)$	0.731
Summary OR = $\exp(\ln OR)$	2.077
95% CI for Summary OR = $\exp(\ln OR \pm 1.96 * ((1/\sum w_i)^{0.5}))$	1.645 2.624
α level for Homogeneity Test	0.378

Study #

1. Hoy et al. (2005)
2. Bovenzi et al. (2002)
3. Shw arze et al. (1998)
4. Miyashita et al. (1992)
5. Boshuizen et al. (1992)
6. Bendstrup and Biering-Sorensen (1987)

Table 2-8. Meta analysis for lower back pain among tractor operators

Study # (i)	Sample Size for Exposed Group (Prevalence)	Sample Size for Non- Exposed Group (Prevalence)	Odds Ratio (OR)	Ln (OR)	95% CL Lower	95% CL Upper	Variance	Weight (w 1)	Weight (w 1) ²	w 1 ln OR	Heterogeneity	D	Weight (w 2)
1	50(0.560)	50(0.320)	2.704	0.995	1.197	6.112	0.173	5.785	33.464	5.754	0.421		2.493
2	1155(0.861)	220(0.573)	4.639	1.534	3.386	6.357	0.026	38.753	1501.800	59.467	2.822	0.228	3.935
3	450(0.311)	110(0.191)	1.914	0.649	1.143	3.205	0.069	14.454	208.919	9.383	5.475		3.361
Total	1655	380						58.992	1744.183	74.604	8.718		9.789

Summary Ln OR = $\sum(w_i^* \ln OR_i) / \sum(w_i)$

Summary OR = $\exp(\ln OR)$ =

95% CI for Summary OR = $\exp(\ln OR \pm 1.96 * ((1/\sum w_i)^{0.5}))$ =

α level for Homogeneity Test

Summary LnOR_{bl}

Summary OR_{bl}

95% CI for Summary OR_{bl}

1.265

3.542

2.744

4.572

0.013

1.093

2.983

1.595

5.582

Study #

1. Kumar et al. (1999)
2. Bovenzi and Betta (1994)
3. Boshuizen et al. (1990a)

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Table 2-9. Meta analysis for lower back pain among earth moving operators

Study # (i)	Sample Size for Exposed Group (Prevalence)	Sample Size for Non- Exposed Group (Prevalence)	Odds Ratio (OR)	Ln (OR)	95% CL Lower	95% CL Upper	Variance	Weight (w 1)	Weight (w 1) ²	w 1 ln OR	Heterogeneity	D	Weight (w 2)
1	165(.600)	65(0.580)	1.066	0.064	0.595	1.91	0.089	11.298	127.653	0.722	6.864		2.450
2	127(0.362)	44(0.250)	1.703	0.532	0.787	3.687	0.155	6.447	41.566	3.432	0.623	0.320	2.106
3	352(0.688)	315(0.416)	3.09	1.128	2.248	4.245	0.026	37.958	1440.804	42.823	3.079		2.890
Total	644	424						55.703	1610.023	46.978	10.567		7.447
<div>Summary Ln OR = $\sum(w_i \ln OR_i) / \sum(w_i)$0.843</div> <div>Summary OR = $\exp(\ln OR)$ =2.324</div> <div>95% CI for Summary OR = $\exp(\ln OR \pm 1.96 * ((1/\sum w_i)^{0.5}))$ =1.7873.022</div> <div>α level for Homogeneity Test0.005</div> <div>Summary LnOR₉₅0.609</div> <div>Summary OR₉₅1.839</div> <div>95% CI for Summary OR₉₅0.8973.773</div>													

Study #

- 1. Schw arze et al. (1998)
- 2. Miyashita et al. (1992)
- 3. Dupuis and Zerlett (1987)

Table 2-10. Meta analysis for lower back pain among all operators – without study quality

Table 10. Meta Analysis for lower back pain among all operators - without study quality													
Study # (i)	Sample Size for Exposed Group (Prevalence)	Sample Size for Non- Exposed Group (Prevalence)	Odds Ratio (OR)	Ln (OR)	95% CL Lower	95% CL Upper	Variance	Weight (w 1)	Weight (w 1)²	w 1 ln OR	Heterogeneity	D	Weight (w 2)
1	23(0.652)	23(0.348)	3.516	1.257	1.045	11.831	0.383	2.610	6.810	3.281	0.343		1.855
2	88(0.78)	85(0.52)	3.384	1.219	1.745	6.563	0.114	8.758	76.700	10.676	0.920		3.702
3	159(0.65)	65(0.54)	1.577	0.456	0.877	2.833	0.090	11.158	124.493	5.083	2.155		4.073
4	44(0.50)	44(0.27)	2.667	0.981	1.097	6.484	0.205	4.868	23.694	4.775	0.036		2.767
5	196(0.41)	107(0.31)	1.546	0.436	0.938	2.548	0.065	15.386	236.739	6.703	3.247		4.527
6	169(0.65)	399(0.47)	2.135	0.758	1.471	3.098	0.036	27.682	766.313	20.996	0.516		5.207
7	46(0.522)	85(0.529)	0.970	-0.030	0.473	1.989	0.134	7.448	55.468	-0.227	6.379		3.446
8	94(0.500)	86(0.337)	1.965	0.675	1.08	3.591	0.094	10.592	112.187	7.155	0.510	0.156	3.995
9	33(0.606)	30(0.267)	4.231	1.442	1.453	12.3	0.297	3.363	11.309	4.851	1.008		2.206
10	50(0.560)	50(0.320)	2.704	0.995	1.197	6.112	0.173	5.785	33.464	5.754	0.058		3.042
11	1155(0.861)	220(0.573)	4.639	1.534	3.386	6.357	0.026	38.753	1501.800	59.467	15.847		5.503
12	450(0.311)	110(0.191)	1.914	0.649	1.143	3.205	0.069	14.454	208.919	9.383	0.873		4.442
13	165(.0600)	65(0.580)	1.066	0.064	0.595	1.91	0.089	11.298	127.653	0.722	7.804		4.091
14	127(0.362)	44(0.250)	1.703	0.532	0.787	3.687	0.155	6.447	41.566	3.432	0.848		3.215
15	352(0.688)	315(0.416)	3.09	1.128	2.248	4.245	0.026	37.958	1440.804	42.823	2.063		5.487
Total	3151	1728						206.559	4767.918	184.875	42.607		57.558

Summary Ln OR = $\sum(w_i \ln OR_i) / \sum(w_i)$	0.895
Summary OR = $\exp(\ln OR)$	2.447
95% CI for Summary OR = $\exp(\ln OR \pm 1.96 * ((1/\sum w_i)^{0.5}))$	2.135 2.805
α level for Homogeneity Test	0.000
Summary LnOR _{adj}	0.793
Summary OR _{adj}	2.209
95% CI for Summary OR _{adj}	1.706 2.861

Study #

- Hoy et al. (2005)
- Bovenzi et al. (2002)
- Shw arze et al. (1998)
- Miyashita et al. (1992)
- Boshuizen et al. (1992)
- Bendstrup and Biering-Sorensen (1987)
- Bovenzi et al. (2002)
- Burdorf and Zondervan (1990)
- Kumar et al. (1999)
- Bovenzi and Betta (1994)
- Boshuizen et al. (1990)
- Schw arze et al. (1998)
- Miyashita et al. (1992)
- Dupuis and Zerlett (1987)

Table 2-11. Meta analysis for lower back pain among all operators – with study quality

Study # (i)	Sample Size for Exposed Group (Prevalence)	Sample Size for Non- Exposed Group (Prevalence)	Odds Ratio (OR)	Ln (OR)	95% CL Lower	95% CL Upper	Variance	Weight (w1)	Study Quality	Weight (w1a)	Weight (w1a) ²	w1a ln OR	Heterogeneity	D	Weight (w2)
1	23(0.652)	23(0.348)	3.516	1.257	1.045	11.831	0.383	2.610	0.33334	0.870	0.757	1.094	0.136		0.854
2	88(0.78)	85(0.52)	3.384	1.219	1.745	6.563	0.114	8.758	0.47143	4.129	17.046	5.033	0.527		3.803
3	159(0.65)	65(0.54)	1.577	0.456	0.877	2.833	0.090	11.158	0.47059	5.251	27.570	2.392	0.866		4.736
4	44(0.50)	44(0.27)	2.667	0.981	1.097	6.484	0.205	4.868	0.25	1.217	1.481	1.194	0.017		1.187
5	196(0.41)	107(0.31)	1.546	0.436	0.938	2.548	0.065	15.386	0.25	3.847	14.796	1.676	0.698		3.563
6	169(0.65)	399(0.47)	2.135	0.758	1.471	3.098	0.036	27.682	0.3125	8.651	74.835	6.561	0.092		7.336
7	46(0.522)	85(0.529)	0.970	-0.030	0.473	1.989	0.134	7.448	0.33334	2.483	6.163	-0.076	1.976		2.361
8	94(0.500)	86(0.337)	1.965	0.675	1.08	3.591	0.094	10.592	0.37143	3.934	15.477	2.657	0.136	0.021	3.638
9	33(0.606)	30(0.267)	4.231	1.442	1.453	12.3	0.297	3.363	0.25	0.841	0.707	1.213	0.284		0.826
10	50(0.560)	50(0.320)	2.704	0.995	1.197	6.112	0.173	5.785	0.29167	1.687	2.847	1.678	0.030		1.630
11	1155(0.861)	220(0.573)	4.639	1.534	3.386	6.357	0.026	38.753	0.36111	13.994	195.835	21.474	6.335		10.849
12	450(0.311)	110(0.191)	1.914	0.649	1.143	3.205	0.069	14.454	0.28205	4.077	16.620	2.647	0.184		3.759
13	165(0.600)	65(0.580)	1.066	0.064	0.595	1.91	0.089	11.298	0.47059	5.317	28.269	0.340	3.384		4.789
14	127(0.362)	44(0.250)	1.703	0.532	0.787	3.687	0.155	6.447	0.25	1.612	2.598	0.858	0.175		1.560
15	352(0.688)	315(0.416)	3.09	1.128	2.248	4.245	0.026	37.958	0.11429	4.338	18.818	4.894	0.308		3.980
Total	3151	1728						206.559	4.812	62.246	423.820	53.635	15.149		54.871

Summary Ln OR = $\sum(w_i \ln OR_i) / \sum(w_i) =$			0.862
Summary OR = $\exp(\ln OR) =$			2.367
95% CI for Summary OR = $\exp(\ln OR \pm 1.96 * (1/\sum w_i)^{0.5})) =$			1.846 3.035
α level for Homogeneity Test			0.368
Summary LnOR _{adj}	0.839		
Summary OR _{adj}	2.315		
95% CI for Summary OR _{adj}		1.777	3.016

Study #

- Hoy et al. (2005)
- Bovenzi et al. (2002)
- Shw arze et al. (1998)
- Myashita et al. (1992)
- Boshuizen et al. (1992)
- Bendstrup and Biering-Sorensen (1987)
- Bovenzi et al. (2002)
- Burdorf et al. (1993)
- Burdorf and Zondervan (1990)
- Kumar et al. (1999)
- Bovenzi and Betta (1994)
- Boshuizen et al. (1990)
- Schw arze et al. (1998)
- Myashita et al. (1992)
- Dupuis and Zerlett (1987)

Table 2-12. Summary of vibration measurements

Source	Equipment	Frequency-weighted root-mean-square accelerations (m/s ²) Mean (SD)	Cumulative vibration exposure (yr m ² /s ⁴) Mean(SD)
Bovenzi et al. (2002)	Forklift	0.90 (0.77)	9.2 (12.2)
	Mobile Cranes	0.53 (0.27)	2.0 (2.2)
	Overhead Cranes	0.22 (0.12)	
Schwarze et al. (1998)	Forklift	0.45 (0.18)	12.8 (7.7)
	Earth Moving Machinery	0.67 (0.30)	20.1 (9.8)
Boshuizen et al. (1992)	Small Forklift	0.80	4.2 (5.8)
	Large Forklift	0.79	2.7 (3.5)
Burdorf et al. (1993)	Crane	0.31	-
Bovenzi and Betta (1994)	Tractors	1.07 (range: 0.52-1.47)	-
Boshuizen et al. (1990)	Tractor in the field	0.60	-
	Tractor on the road	1.10	-

Note:

SD - Standard deviation

Table 2-13. Main effects of vibration and postural load on lower back pain (adjusted for age)

Exposure Variable	Bovenzi et al. (2002)	Bovenzi and Betta (1994)
Postural Load		
Mild	1.0	1.0
Moderate	1.37 (0.92-2.02)	1.54 (0.80-2.95)
Hard	1.79 (1.23-2.66)	2.19 (1.19-4.03)
Very Hard	2.03 (1.41-2.93)	3.27 (1.80-5.96)
Cumulative Vibration exposure ($\text{yr m}^2/\text{s}^4$)		
0	1.0	-
<1	1.22 (0.92-1.61)	-
1-4	1.08 (0.82-1.43)	-
>4	1.35 (1.06-1.72)	-
0	-	1.0
<15	-	1.69 (1.10-2.59)
15-30	-	2.34 (1.52-3.58)
>30	-	2.63 (1.70-4.05)

Table 2-14. Odds ratio for combined effect of vibration and postural load (Bovenzi and Betta, 1994)

Total Vibration Dose (yr m ² /s ⁴)	Postural Load			
	Mild	Moderate	Hard	Very Hard
5	1.29	1.79	2.5	3.48
10	1.41	1.96	2.73	3.79
20	1.55	2.15	2.99	4.16
30	1.63	2.27	3.16	4.39
40	1.70	2.36	3.29	4.58

Note:

- Analysis is made with reference to control subjects exposed to mild postural load and unexposed to vibration.
- Odds ratio is adjusted for age and several other confounders

Table 2-15. Summary of dose-response data for lower back pain (odds ratio and 95% CI)

Source	Type of Equipment	Outcome	Description of Dose-Response Data	
Bovenzi et al. (2002)	Straddle carriers, fork-lift trucks, and freight-container tractors	Lower back pain	Equivalent Vibration Magnitude (m/s ² rms)	
			< 0.46	0.46-0.79 > 0.79
			1.04 (0.82-1.33)	1.11 (0.89-1.38) 1.24 (1.01-1.53)
			Cumulative Vibration Exposure (year m ² /s ⁴)	
			< 1	1-4 > 4
			1.07 (0.83-1.39)	0.99 (0.76-1.28) 1.27 (1.02-1.58)
			Duration of exposure (driving years)	
			1-6	6-12 >12
			1.25 (0.98-1.59)	1.11 (0.85-1.45) 1.27 (1.04-1.56)
Bovenzi and Betta (1994)	Tractors	Lower back pain	Equivalent Vibration Magnitude (m/s ² rms)	
			0.5-1.0	1.0-1.25 > 1.25
			2.39 (1.52-3.76)	2.87 (1.83-4.49) 2.29 (1.43-3.68)
			Total Vibration Dose (years m ² /s ⁴)	
			<15	15-30 >30
			2.33 (1.48-3.67)	3.04 (1.92-4.82) 2.36 (1.48-3.74)
			Duration of exposure (driving years)	
			5-15	16-25 > 25
			2.65 (1.68-4.18)	2.31 (1.46-3.64) 2.74 (1.69-4.45)
Boshuizen et al. (1990)	Tractors	Lower back pain	Equivalent Vibration Magnitude (m/s ² rms)	
			0.3-0.55	0.55-0.7 0.7-0.9 > 0.9
			1.98 (0.97-4.0)	1.66 (0.82-3.4) 2.10 (1.07-4.1) 1.38 (0.52-3.7)

Table 2-15. Cont'd

Source	Type of Equipment	Outcome	Description of Dose-Response Data		
			Vibration Dose (years m ² /s ⁴)		
			0-2.5	2.5-5	> 5
			1.80 (1.11-2.9)	1.78 (1.04-3.1)	2.8 (1.64-5.0)
			Years of full time exposure		
			0-5	5-10	> 10
			2.44 (0.84-7.1)	2.5 (0.85-7.6)	3.6 (1.21-11)
Boshuizen et al. (1990)	Tractors		Total Vibration Dose (year m ² /s ⁴)		
			0-0.5	0.5-2.5	2.5-5.0 > 5.0
			1	4.1 (0.53-10)	11 (1.7-267) 7.2 (0.92-179)
Bongers et al. (1988)	Cranes	Disorders of the intervertebral disc	Years of exposure		
			≤4	5-9	10-14 15-19 ≥20
			1.41	2.03	3.99* 3.13 16.9
			2.95*	3.81**	5.77** 4.99** 5.73**
		All intervertebral disc disorders	2.00*	2.74**	4.90** 4.45** 6.84**

Note:

Odds ratio for lower back pain with 95% confidence intervals for all studies except Bongers et al. (1988) and Boshuizen et al. (1990)

Incidence density ratio per 100 person years for Bongers et al. (1988) and Boshuizen et al. (1990)

* Significant at the 5% level

** Significant at the 1% level

Table 2-16. Levels of exposure to whole body vibration

Author (Year)	Industry;	Measurement	Vehicle Types	Vehicle Specifics
	Study Conditions;	Location;		
	Study Objectives	Device Type;		
		Sample Duration		
Hoy et al. (2005)	Paper mill company;	At seat;	Forklifts	Forklift
	Normal operating conditions;	Tri-axial accelerometer;		
	Health study	Sampling duration approx. 5 min		
Bovenzi et al. (2002)	Port machinery; Normal working conditions; Health study	"In agreement with ISO 2631 guidelines"	Forklift, mobile cranes, and overhead cranes	Forklift Mobile cranes Overhead cranes
Kumar et al. (1999)	Tractors; Normal operating conditions; Health study	At seat; Tri-axial accelerometer; Sampling duration NR	Tractors	Tractors
Schwarze et al. (1998)	Different vehicles; Normal working conditions; Health study	Measurement location NR; Device Type NR; Sampling duration NR	Forklift and earth moving machinery	Forklift Earth moving machinery

Bovenzi and Betta, (1994)	Tractors; Normal operating conditions; Health study	At seat; Tri-axial accelerometer; Sampling duration NR	Low-power tractors (45-85 hp)	Fiat (50-70 hp) n = 14 Ford (45-60 hp) n = 23 Fendt (58-64 hp) n = 9 International (58 hp) n = 2 Lamborghini (65-80 hp) n = 2 Massey Ferguson (50-85 hp) n = 3
Burdorf et al. (1993)	Large transport company; Normal working conditions; Health study	Measurement location NR; Vibration meter and piezoelectric accelerometer; Sampling duration approx. 5 min	Cranes	Crane n = 20
Boshuizen et al. (1992)	Heavy equipment; Normal working conditions; Health study	At seat; Tri-axial accelerometer; Sampling duration approx. 5 min	Forklifts and freight tractor	Small forklift Large forklift Freight container tractor
Boshuizen et al. (1990)	Agricultural vehicles; Normal working conditions; Health study	Measurement location NR; Tri-axial accelerometer; Sampling duration NR	Tractors	Tractor in field Tractor on the road

EL - Exposure Level (Exposure Limit applies to situations where the health and safety of the worker, such as back injuries and injuries to internal organs, is of concern.)

FDP - Fatigue Decreased Proficiency Level (Fatigue Decreased Proficiency Boundary is applied to the situations where maintaining operator efficiency of a vehicle is of concern, such as situations where operators are required to work with safe manipulation of controls or to read the gauges accurately.)

Crest Factor - the ratio of the peak value to the r.m.s acceleration ($a_{\text{peak}}/a_{\text{r.m.s}}$)

Table 16: Cont'd

Author (Year)	Vibration Exposure Levels (Exposure in Root Mean Square m/s^2 unless otherwise specified)	Dominant Vibration Frequencies (Hz)	Compliance with ISO 2631 (EL, FDP)
Hoy et al. (2005)	x-axis 0.31(SD - 0.072) y-axis 0.29 (SD - 0.089) z-axis 0.57 (SD - 0.124)	5 - 7 Hz	Measured values were below the EU Physical Agents Directive on Vibration Exposure action level Of 0.5 m/s^2 , but not the z axis
Bovenzi et al. (2002)	$a_{\text{vector sum}} = 0.90 \text{ m/s}^2$ $a_{\text{vector sum}} = 0.53 \text{ m/s}^2$ $a_{\text{vector sum}} = 0.22 \text{ m/s}^2$	2 - 5 Hz (z-axis) NR 1.25 - 4 Hz (x and z-axis)	
Kumar et al. (1999)	NR	7 Hz	Measured values exceeded FDP 4 hour limit;
Schwarze et al. (1998)	$a^* = 0.45 \text{ m/s}^2$ $a^* = 0.67 \text{ m/s}^2$	NR	NR

Bovenzi and Betta, (1994)	$a_{\text{vector sum}} = 1.24$ (mean, range 0.58-2.00) $a_{\text{vector sum}} = 0.96$ (mean, range 0.36-2.03) $a_{\text{vector sum}} = 0.89$ (mean, range 0.53-1.25) $a_{\text{vector sum}} = 1.08$ (mean, range 0.85-1.30) $a_{\text{vector sum}} = 1.05$ (mean, range 0.86-1.25) $a_{\text{vector sum}} = 1.41$ (mean, range 0.84-1.82)	2.5 - 4 Hz	For estimated daily average exposure (2.5 hours), mean value (1.1 m/s ²) of frequency weighted acceleration is below EL (1.4 m/s ²)
<hr/>			
Burdorf et al. (1993)	$a_{\text{vector sum}} = 0.31$ m/s ²	NR	NR
<hr/>			
Boshuizen et al. (1992)	$a_{\text{vector sum}} = 0.80$ m/s ² $a_{\text{vector sum}} = 0.79$ m/s ² $a_{\text{vector sum}} = 1.04$ m/s ²	3.15 Hz 2.5 Hz 1.6, 2.5 Hz	Acceleration levels for forklifts exceeded FDP 4 hour limit; levels for tractor exceeded 2.5 hour limit
<hr/>			
Boshuizen et al. (1990)	$a^{**} = 0.60$ m/s ² $a^{**} = 1.10$ m/s ²	NR	NR
<hr/>			
EL - Exposure Level (Exposure Limit applies to situations where the health and safety of the worker, such as back injuries and injuries to internal organs, is of concern.)			
FDP - Fatigue Decreased Proficiency Level (Fatigue Decreased Proficiency Boundary is applied to the situations where maintaining operator efficiency of a vehicle is of concern, such as situations where operators are required to work with safe manipulation of controls or to read the gauges accurately.)			
Crest Factor - the ratio of the peak value to the r.m.s acceleration ($a_{\text{peak}}/a_{\text{r.m.s}}$)			

Table 16: Cont'd

Author (Year)	Peak Exposure or Crest Factors (CF) (CF = $a_{\text{peak}}/a_{\text{rms}}$)	Jolts and Shocks	Determinants of Vibration Exposure (other than vehicle type)
Hoy et al. (2005)	Peak x-axis 3.35(SD - 0.848) y-axis 3.37 (SD - 1.186) z-axis 13.53 (SD - 6.351)	NR	NR
	Crest Factor x-axis 11.08(SD - 2.252) y-axis 12.01 (SD - 4.507) z-axis 26.54 (SD - 17.228)		
Bovenzi et al. (2002)	NR	NR	NR
Kumar et al. (1999)	NR	NR	NR
Schwarze et al. (1998)	NR	NR	NR

Bovenzi and Betta, (1994)	NR	NR	NR
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Burdorf et al. (1993)	NR	NR	NR
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Boshuizen et al. (1992)	Crest factor all above 6.	NR	NR
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Boshuizen et al. (1990)	NR	NR	NR
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EL - Exposure Level (Exposure Limit applies to situations where the health and safety of the worker, such as back injuries and injuries to internal organs, is of concern.)

FDP - Fatigue Decreased Proficiency Level (Fatigue Decreased Proficiency Boundary is applied to the situations where maintaining operator efficiency of a vehicle is of concern, such as situations where operators are required to work with safe manipulation of controls or to read the gauges accurately.)

Crest Factor - the ratio of the peak value to the r.m.s acceleration ($a_{peak}/a_{r.m.s}$)

Table 2-17. Exposure levels and compliance with ISO comfort zones

Study	Vehicle Type	Vibration Exposure Levels				Compliance with ISO 2631 Comfort Zone					
		x-axis	y-axis	z-axis		Less than 0.315 m/s ² not uncomfortable	0.315 m/s ² to 0.63 m/s ² a little uncomfortable	0.5 m/s ² to 1 m/s ² fairly uncomfortable	0.8 m/s ² to 1.6 m/s ² uncomfortable	1.25 m/s ² to 2.5m/s ² very uncomfortable	Greater than 2 m/s ² extremely uncomfortable
Hoy ⁱ (2005)	Forklift	Mean	0.31	0.29	0.57	0.7107				X	
Bovenzi ⁱⁱ (2002)	Forklift	Mean	0.18	0.35	0.64	0.7513			X		
	Mobile Cranes	Mean	0.37	0.21	0.32	0.5324			X		
	Overhead Cranes	Mean	0.11	0.07	0.11	0.1706	X				
Schw arze ⁱⁱⁱ (1998)	Forklift	Mean	0.45								
	Heavy machinery	Mean	0.67								
Bovenzi ^{iv} (1994)	Tractors	Mean	1.07						X		X
Burdorf ⁱⁱ (1993)	Crane	Mean	0.15	0.11	0.17	0.252	X				
Boshuizen ⁱ (1992)	Small Forklift	Mean	0.55	0.37	0.44	0.7956			X		
	Large Forklift	Mean	0.43	0.29	0.59	0.7856			X		
Boshuizen ^{vi} (1990)	Tractor in the fields	Mean	0.6						X		
	Tractor on the road	Mean	1.1						X		
	Bulldozer	Mean	0.6						X		
	Excavator	Mean	0.4				X				
	Shovel	Mean	1.1						X		
Dupuis ^{vii} (1987)	Forklift	Mean	0.4-2.0				X		X		X
	Agricultural tractors	Mean	0.4-1.25				X		X		X
	Excavators	Mean	0.3-1.3			X	X		X		X

Notes

i-Mean acceleration (RMS) (m/s²)

ii-Frequency-weighted root mean square (RMS) (m/s²)

iii-Frequency-weighted energy-equivalent acceleration (m/s²)

iv-Peak acceleration all directions (Hz)

v-Vector sum of frequency-weighted acceleration (RMS) (m/s²)

vi-Equivalent vibration magnitude (m/s²)

vii-Weighted root mean square (RMS) (m/s²)

Figure 2-1. Overall critical appraisal for individual studies (Heavy Equipment)

Figure2-2. Detailed critical appraisal for individual studies (Heavy Equipment)

Figure 2-3. Critical appraisal of measurement quality of individual studies (Heavy Equipment)

Figure 2-4. Detailed critical appraisal across all studies (Heavy Equipment)

CHAPTER THREE

Effect Of Forklift Operation On Lower Back Pain – An Evidence-Based Approach

SUMMARY

Background – Most studies on the occupational hazards associated with forklift operation have examined risks of fatalities and traumatic injuries. Few studies have examined the magnitude of risk of lower back pain. We adopted an evidence-based approach to examine the relationship between forklift operation and lower back pain.

Objective – This research deals with an evidence-based approach designed to examine if there is a relationship between whole-body vibration and postures with lower back pain among forklift operators and to offer some recommendations to minimize the risk of lower back pain.

Methods – To accomplish the study goal, an evidence based approach was adopted from evidence-based medicine. The basic steps of this evidence based approach were the following: 1) formulation of a clear research question from a worker occupational problem; 2) search the literature for the best evidence with which to answer the question; 3) critically appraise the evidence; and 4) implementation of useful findings in occupational health and safety practices. In addition, meta-relative risk was calculated and the biological plausibility between WBV and posture with lower back pain was investigated.

Results – Six observational articles satisfied the inclusion criteria adopted in this research. The methodological qualities of the published studies ranged from marginal to average. The meta-relative risk was 2.1 indicating that operators exposed to driving heavy equipment are at more than twice the risk of those not exposed to driving heavy equipment. There are biologic mechanisms by which WBV and postures could develop lower back pain. Some of the work environment that influenced vibration are: seat, speed, track, and tyres. Awkward postures and static postures are affected by: cab design, seat, time spend seated, and the task performed.

Conclusions – Lessons for occupational safety and health engineering can be learned from an evidence-based evaluation. While evidence is limited for many occupational safety and health interventions, yet approaches should be based on the best possible science, be multidisciplinary, and center on sound planning and evaluation methods.

Significance – A systematic approach to evidence-based decision making is likely to improve the occupational safety and health programs for forklift operators.

INTRODUCTION

Heavy equipment operators are exposed to a variety of hazards that may lead to health problems. Research on these occupations has focused mainly on fatalities and traumatic injuries. However there is growing evidence that these operators may be at increased risk of additional health problems. This results in workers suffering as well as lower productivity and profits for companies using heavy

equipment. In particular, there appears to be a certain degree of evidence for a causal relationship between working as heavy equipment operator and lower back outcome. A meta-analysis to estimate an overall odds ratio on lower back pain among heavy equipment operators (meta-odds ratio) was applied to chosen epidemiological studies. The meta-relative risk obtained was 2.21 indicating that operators exposed to driving heavy equipment are at more than twice the risk of those not exposed to driving heavy equipment. Some of the health hazards among operators of heavy equipment are: whole body vibration (steady state and/or transient) and awkward postures (including static sitting, trunk twisting and bending, neck flexion and rotation) (see figure 3-1).

Heavy equipment operation covers a wide range of activities including: crane and tower operators, excavating and loading machine and dragline operators, operating engineers and other construction equipment operators (including: motor graders, bulldozers, scrapers, compressors, pumps, derricks, shovels, tractors, and front-end loaders) and industrial trucks (including forklifts) and tractor operators. Forklifts in particular are extremely useful vehicles for a wide variety of industrial operations and an estimated 1.2 million workers operate as many as 800,000 forklifts in the US alone (Waters et al. 2005). These vehicles are relatively small but powerful equipment capable of lifting heavy loads. At the same time, this equipment is versatile and can be used for a variety of different tasks depending on the attachment used, for example: forks, container spreaders, drum clamps, bale clamps, roll clamps, etc. During the course of performing different tasks the forklift drivers are exposed to some conditions that

could increase the risk for contacting low back pain. Some of the conditions that the forklift drivers face includes: static sedentary position, twisting of the trunk in relation to the pelvis, deep sideways trunk bending and whole body vibration (WBV).

Some studies have investigated the relationship between heavy equipment operation (WBV and postures) and musculoskeletal disorders (e.g. lower back pain). But these studies do not take in consideration important aspects such as: critical appraisal of the evidence, meta-analysis, and biological plausibility. To examine the relationship between WBV and postures with lower back pain among forklift operators an evidence-based approach could be appropriate. An evidence-based approach is a procedure that is used to gather useful findings and propose practical guidelines and is adopted from the evidence-based medicine practice. Evidence-based medicine is defined as “the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients” (Sackett et al. 1996). Therefore, in terms of occupational safety and health engineering an evidence-based approach could be defined as the process of systematically finding, appraising, and using research findings as the basis for the identification, improvement, and maintenance of the well being characteristics of individuals in the occupational environment. The term evidence involves the available body of facts or information indicating whether a belief or proposition is true or valid. For engineers or researchers this evidence are often obtained by quantitative data (epidemiologic) and qualitative data. The evidence based approach adopted in

this research consists mainly of the following four steps (Rosenberg and Donald 1995):

- 1) Formulation of a clear research question from a worker occupational problem
- 2) Search the literature for the best evidence with which to answer the question
- 3) Critically appraise the evidence
- 4) Implementation of useful findings in occupational health and safety practices

The useful findings obtained through the use of an evidence based approach in this research could be used to develop practical ergonomic guidelines for the control of low back pain among forklift operators. The use of evidence based approach is important because it provides insurance that decision making is based on scientific evidence. Therefore the purpose of this study was to use an evidence-based approach adopted from evidence-based medicine to examine if there is any relationship between whole-body vibration and postures with lower back pain among forklift operators and then if a relationship exists, to develop some recommendations to minimize any risk of developing lower back pain.

FORMULATION OF A CLEAR RESEARCH QUESTION

The question is based in an occupational issue for which more information is needed and the population of interest in this research was forklift operators. The research question in this study is: *Is there a relationship between whole-body*

vibration and postures with low back pain among forklift operators? And if a relationship exist, Is there any mechanisms to minimize the risk of lower back pain among forklift operators?

SEARCHING THE LITERATURE AND DESCRIPTION OF EVIDENCE

Searching strategy

The practice of evidence-based research requires that the investigator search the published literature employing the best available databases and using relevant keywords. The best available databases will depend on the research question. The following databases were very helpful in obtaining evidence for the present research question: Ergo Abstracts, PubMed, Medline, OSHLINE, NIOSHTIC, NIOSHTIC-2, HSELINE, CISILO, Canadiana and Health and Safety. The search strategy on this study was divided in two parts. One search was dedicated to epidemiological studies examining the relationship between forklift operators and lower back pain. To these studies a critical appraisal was applied to evaluate the quality of the evidence, plus the data was used to obtain a meta-relative risk. For the epidemiological studies reviewed, an inclusion and exclusion criteria was developed so only the most relevant studies were included. The second search was dedicated to examine the biological plausibility between WBV and/or postures with lower back pain among forklift operators.

Description of evidence

Considering the research question and after a comprehensive search on the databases, a total of 6 epidemiological studies were found that meet the inclusion criteria (Hoy et al. 2005, Bovenzi et al. 2002, Schwarze et al. 1998,

Miyashita et al. 1992, Boshuizen et al. 1992, Bendstrup and Biering-Sorensen 1987). The following inclusion criteria were used: type of equipment – forklift; exposure variable – whole-body vibration and/or posture; outcome variable – low back pain; type of study – observational studies (retrospective and prospective cohort, case control, cross-sectional); language – English; source – peer reviewed journal and full text (no abstracts).

Table 3-1 shows a summary of each study included in this research. As shown in table 3-1 all the studies are cross-sectional design except the one by Schwarze et al. (1998) which was cross-sectional with a prospective cohort component. None of the studies were conducted in US. The main outcome variable is low back pain in all studies. In terms of the exposure variable, two studies examined whole-body vibration and postural load (Hoy et al. 2005, Bovenzi et al. 2002), three studies examined whole-body vibration (Schwarze et al. 1998, Miyashita et al. 1992, Boshuizen et al. 1992), and one study examined occupation (forklift operator) (Bendstrup and Biering-Sorensen 1987). Four of the six studies show significant relationship between forklift operators and low back pain at the 5% level.

CRITICAL APPRAISAL OF THE EVIDENCE

Critical Appraisal

It is necessary to take in consideration sound epidemiological principles to evaluate the quality of the evidence. Therefore the quality of the evidence was assessed using a critical appraisal tool developed by Genaidy (Genaidy 2004). The appraisal tool covers the following epidemiological aspects (see appendix):

1. Study description - Study description evaluates if the different elements of the study are clearly described (hypothesis, exposure/intervention, outcome, study design, study population, covariates and confounders, statistical tests, and results).
2. Study execution - Study execution is a detailed evaluation of the methodological quality characteristics (subject/record selection, observation quality, data analysis, and generalization of results).

Each of these items were evaluated as follows: yes (2 points), partial (1 point), no or unable to determine (0 points). The evaluators were blinded to the source of information (e.g. author, journal, etc.). The results of these evaluations were compared and discussed until an agreement was reached. The final score for each element was taken as the average of the values obtained for each item.

The quality of the evidence was evaluated taking in consideration sound epidemiological principles using a critical appraisal instrument. Blinded to the source of information each study was evaluated by four assessors individually. Then, for each study, all 43 items covered in the appraisal tool were discussed between all assessors until an agreement was reached. Figures 3-2 to 3-4 shows the results from the critical appraisal, and the findings are summarized bellow:

1. The overall study quality (all 43 items) range from marginal (0.5) to average (1.0) within a 0 – 2 scale. The studies by Bovenzi et al. (2002) and Schwarze et al. (1998) attained the highest in terms of overall quality.

2. The reporting the elements (17 items) of methodological quality, the studies scored about average (1.0).
3. The subject selection criteria (7 items) were scored average (1.0) by three studies and poor (0) by two studies.
4. The measurement quality criteria (10 items) were scored about marginal (0.5) by five studies and poor (0) by one study.
5. The data analysis criteria (7 items) were scored average (1.0) by one study, marginal (0.5) by two studies, and poor (0) by three studies.
6. The generalization criteria (2 items) were scored poor (0) in all the studies. This could be due to the fact that there is limited, if none, information about the participation rate and that the criteria for sample size calculations were not reported.
7. The measurement quality of individual studies is divided on the following criteria: observation period, outcome, blinding, and exposure (Figure 4). All the studies scored poor (0) for observation period and blinding. For exposure and outcome criteria the studies scored a little over marginal (0.5).

Meta-analysis

To determine an overall estimate for the odds ratio of lower back pain among forklift operators a meta-analysis of the reviewed articles was performed. For each study the number of subjects participating in the exposure and control groups, and the prevalence rate were collected. Using this data extracted from

the studies and the “LOGISTIC” procedure of the statistical analysis software (SAS), the odds ratio and the 95% confidence limits were calculated for each study. The confidence limit method was used to calculate the meta-relative risk and 95% confidence intervals (Elwood 2000). Then a new calculation of the meta-relative risk was obtained applying the overall quality index of the studies.

The meta-relative risks of lower back pain among forklift operators obtained by meta-analysis are shown in table 3-2 and 3-3. The fixed effect model was applied because heterogeneity was not found between the studies. Heterogeneity would be found if an α of 0.1 (10%) or less were obtained. The meta-relative risk among forklift operators was 2.1 and 95% confidence interval (CI) 1.645-2.624 and was significant at the 5% level (table 2). This result shows that forklift operators were 2.1 times more likely to develop low back pain than workers that do not operate forklifts. If the overall quality index is taken into account the meta-relative risk obtained was unchanged 2.1 (2.115; 95% CI: 1.417-3.156) (table 3).

BIOLOGICAL PLAUSIBILITY

The epidemiological evidence shows that there is strong association between forklift operation and lower back pain. And this association is consistent among studies evaluated. This observed association is more believable if there is a known biologic mechanism by which the exposure could develop a disease. The possible main factors that expose forklift operators at risk of developing lower back pain are whole-body vibration and postures. Therefore the next two

sections are dedicated to examine the biological plausibility between whole-body vibration and/or postures with lower back pain.

Whole-body vibration

An operator is exposed to whole-body vibration transmitted from a vibrating seat. But also they are exposed to local vibration of the head from the head rest, the hands from the steering wheel, and the feet from the floor panel. The dominant vibration transmitted through the seat of vehicles in general is often at frequencies below 20 Hz (Griffin 1990), and 4 to 12 Hz in forklifts. Typical whole-body vibration exposure levels of heavy vehicle drivers are in the range 0.4 to 2.0 m/s² with a mean value of 0.7 m/s² in the vertical axis. Vibration measurement according to ISO 2631-1 showed that vibration magnitude ranged from 0.79 to 1.04 m/s² in forklift-trucks (Bovenzi and Hulshof 1999). The permissible 8-hour and 12-hour average vibration exposures levels for the International Standard ISO 2631 are the following:

Exposure Duration	Likely Health Risk	Caution Zone	Comfort Level
8-hours	0.8 m/s ²	0.5 m/s ²	0.315 m/s ²
12-hours	0.7 m/s ²	0.4 m/s ²	0.315 m/s ²

Some of the biological mechanisms that deal with the relationship between vibration and lower back pain have been examined in different studies and the results are outlined below:

1. The resonance of the human spinal system occurs most often within the band 4.5 – 5.5 Hz (Pope et al. 1998).

2. Biodynamic investigations have shown that the response of the human body to vibration is frequency dependent. If vibration occurs at a frequency that is identical to the natural frequency period of body tissue, resonance can occur and this resonance can lead to large internal stresses and strain (Wilder et al. 1996).
3. Vibration exposure (5 Hz) increase the rate of development of fatigue in the erector spinae muscles in a seated person, compared to the same conditions without vibration (Pope et al. 1998).
4. WBV exposure increase produces vascular changes that could result in nutritional compromise of the tissues around the spine. This results in muscle fatigue and the discs compression. The discs are less capable of absorbing and distributing load (Pope et al. 1998). So the spine is not in condition to sustain loads such as heavy lifting or unexpected vertical or horizontal shocks (Wilder et al 1996).
5. Significant ($p < 0.0005$) height loss (discs compression) resulted from vibration and static posture, and was greater when exposed to vibration than when not (Pope et al. 1998).
6. Inclination of backrest (110° and 120° angles) resulted in significant less height loss than upright unsupported sitting (Pope et al. 1998). An angle of 120° caused less height loss than an angle of 110° when exposed to vibration.
7. Twisted postures when vibration is present cause an increase in energy consumption than vibration or posture alone (Magnusson and Pope 1998).

8. Magnusson et al. (1987) found that seated vibration expends 14.3% more energy compared to non-vibration seated position.

Postures

Awkward postures including static sitting, trunk twisting and bending, neck flexion and rotation may cause lower back and neck disorders. Fork-lift operators adopt a variety of postures to help them to overcome the visibility restrictions and their seated posture is determined by the seat design and the task to be performed. The characteristics of the seat like; inclination and height of the seat, the type and/or presence of backrest and armrest; influence the seated posture. The steering wheel, controls and high backrest restrict shoulder rotation, increasing the head rotation in detrimental viewing angles causing discomfort (Eklund et al. 1994). Wikstrom (1993) studied the effects of twisted neck and trunk postures while driving two forklifts and one agricultural tractor. The discomfort appeared to be solely in the neck-shoulder and the lower back and increased with the twist of the sitting posture and the vibration level and the rotation of the neck from 30 to 50 degrees produced substantial effects on both discomfort and EMG-level. Working with the trunk twisted more than 20° (e.g. while driving forklift) requires a high muscle effort from the external oblique muscles, therefore the time exposure and/or repetition of this jobs under this posture makes the subject susceptible to lower back pain (Torén 2001, Bodén and Öberg 1998). Regardless of seat type, the upright posture has been found the most uncomfortable one comparison with the forward and full-back posture (Wilder et al. 1994).

Some of the biological mechanisms between posture and lower back pain are outlined below:

1. Sitting produces the pelvis to rotate and flattening of the lumbar lordosis.
During vibration, this arm moment created by the anterior offset of the ischial tuberosities, may provoke additional rocking motion to the pelvis and amplify the vibration transmitted to the spine (Wilder and Pope 1996).
2. There is a specific link between prolonged sitting and the incidence of disc herniation (Kelsey 1975). More upright sitting postures, and the concomitant psoas and other muscle activation, impose additional compressive loads to the spine. The change of lumbar postures causes a migration of the loads from one tissue to another.
3. When sitting in an unsupported upright posture the disc pressure at the L3 level is 40% more than upright standing (Magnusson and Pope 1998).
4. Lack of motion leads to an accumulation of metabolites, which probably accelerates the degeneration of the disc (Magnusson and Pope 1998).
5. The risk of lower back pain increases after prolonged sitting by the changes in the passive flexion stiffness of the lumbar spine (Tyson et al. 2005).
6. Seated posture increases the lumbar intradiscal pressure producing a tension increasing effect on the disc collagen fibers (Wilder et al. 1996).
7. The posterior and posterolateral collagen fibers of the annulus fibrosus are thinner and fewer in number. These collagen fibers are mechanically

strained when sitting due to increase in posterior disc height (Wilder et al 1996).

8. Adams et al (1996) explain that “High stresses and stress gradients might elicit pain from nociceptive endings in the outer annulus because this region of the disc appears to be sensitive to mechanical stimulation. Alternatively, stress peaks in the disc might elicit pain from adjacent vertebrae by deforming the relatively weak vertebral body endplate. Pain originating from either of these mechanisms would be expected to increase during the course of a day, especially in an individual who had spent a considerable amount of time with his/her lumbar spine flexed, so that disc creep would have been unchecked by the apophysial joints. This could explain why prolonged automobile driving is so closely associated with back pain and disc prolapse.”
9. Twisting reduces the intrinsic strength of the disc annulus by disabling some of its supporting fibers while increasing the stress in the remaining fibers under load. Since there is no muscle designed to produce only axial torque, the collective ability of the muscles to resist axial torque is limited, and they may not be able to protect the spine in certain postures. The additional compressive burden on the spine is substantial for even a low amount of axial torque production (McGill 2002).

IMPLEMENTATION OF USEFUL FINDINGS IN OCCUPATIONAL HEALTH AND SAFETY PRACTICES

Once the evidence was critically appraised, meta-analysis was calculated, strong and consistent association has been found, and biological plausibility has been examined. The evidence obtained throughout the search was used to develop practical health guidelines for the control of lower back pain among forklift operators. These guidelines could be used on selection of effective intervention strategies, equipment design, personnel training, policy and further research study.

The science of ergonomics involves designing the workplace, tools, equipment, and work environment to fit the human operator. The application of ergonomics could meet the following simultaneous goals: 1) decrease injury rates and suffering for the human operator, and 2) increased production and efficiency of the operation. Apart from a radical change in forklift truck design, the driver's working condition could be improved by the following ergonomic recommendations that are summarized in tables 3-5 and 3-6.

Ergonomic recommendations to reduce the impact of whole-body vibration

1. It is important to choose the correct suspension seat according to the dynamic properties of the forklift. Vehicle seats frequently are vibration amplifiers. This takes place when the vibration frequency is less than the cut-off vibration frequency of the seat. Therefore the seat suspension cut-off frequency and travel should be known. So it is recommended to

- replace the seat by suspension seats for vehicles whose dominant motion frequencies are higher than the seat attenuation frequency (Griffin 1990; Troup 1978; Donati 2002; Pope et al. 1998). The effectiveness of the suspension seat depends on the weight adjustment in the seat, so this one is at or close to mid-travel when the operator is seated.
2. The suspension travel must prevent bottoming or topping against end stops (Donati 2002). The length of the seat suspension travel depends of the attenuation frequency, lower attenuation equal longer seat suspension travel (range: 3 cm above 3 Hz - 15 cm at 1.5 Hz).
 3. Electric trucks are preferable to diesel trucks because less vibration is obtained due mainly to the lower speed (Malchaire et al. 1996).
 4. The ground surface needs to be as smooth as possible to reduce vibration levels. The acceleration is about 70% greater on rough surfaces than smooth surfaces (Malchaire et al. 1996).
 5. Pneumatic tires are preferable to cushion. These tires may be more effective at accommodating irregularities in ground surface and may reduce the floor induced vibration of a loaded truck by up to 50% (Donati et al.).
 6. After exposure to whole-body vibration the muscles are fatigued and the discs are compressed consequently the discs are less capable of absorbing and distributing load. Therefore is recommended to avoid heavy lifting immediately after vibration exposure (Pope et al. 1998).

Ergonomic recommendations to reduce the impact of postures

1. Walk for five minutes after receiving whole-body vibration (Wilder et al. 1996) and to avoid the inactivity resulting from the seated postures (Callaghan et al. 1999). Standing appears to be a good rest from sitting, for the passive tissues, given the change in lumbar spine posture and shift in loading of the posture dependent passive tissues. Therefore, standing, used alternatively as a rest from sitting, could form a basis for injury prevention (Callaghan and McGill 2001).
2. There is a specific link between prolonged sitting and the incidence of herniation (Kelsey 1975). More upright sitting postures, and the concomitant psoas and other muscle activation, impose additional compressive loads to the spine. The change of lumbar postures causes a migration of the loads from one tissue to another. Because no ideal sitting posture exists, a variable posture is recommended to minimize the risk of tissue overload.
3. Spinal stress can be minimized by using a back rest of a 110 or 120 degree angle, the seat incline 6 degree upward and additional curved support for the spine with a peak level with the third lumbar vertebra (Troup 1978, Wilder and Pope 1996). For comfort, the height of the back rest should be between 29 to 35 cm from the Seat Index Point (SIP = the intersection on the central vertical plane through the seat centerline of the theoretical pivot axis between a human torso and thighs) and the cushion should be softer than standard seat cushions (Donati and Patel 1999).

When a backrest is used part of the body is transferred to it when a person leans back, reducing the load on the lumbar spine caused by the upper body weight. Therefore an increase in backrest inclination (backward) means an increase in load transfer to the backrest resulting in reduced disc pressure.

4. The cushion width, length, angle and softness are important characteristics for drivers comfort (Donati and Patel 1999). The width of the cushion, at the front side, should be more than 47 cm and the length should be at least 42 cm from the backrest (29 cm from the SIP). The cushion angle is recommended to be between 8 and 13 degrees. And a cushion softness with a depression of more than 2.7 cm by 1.5 cm.
5. Disc pressure can be reduced by the use of an arm rest. The use of an arm rest supports the weight of the arm and at a small extent the upper body, resulting in reduction of disc pressure. With arms bent and elbows on armrests, the seat must be adjustable.
6. The front edge of the seat should be rounded and there should be 30-50 mm of clearance between it and the back of the operator's knees.
7. In terms of the horizontal and vertical head movements, the operator should not turn their head more than 30° to either side, and the head should not be tilted more than 5° up and 25° down for sustained comfort. Occasional head movements within extreme limits of 50° to the side and 40° up and 50° down are acceptable (Barron et al. 2005).

8. A partial seat rotation from 15 to 20 degrees is recommended for multiple observation tasks that are performed in a rearward turned position (Donati 2002).

DISCUSSION

The forklift is a versatile material handling equipment because it can be used in a variety of different tasks. This versatility makes this vehicle the most used in industrial operations. The majority of the forklift operation studies in the US have focused on conditions or situations that result in accidents (including fatalities and other type of injuries) and not on musculoskeletal disorders among drivers. In addition, studies that have examined the relationship between heavy equipment operators and musculoskeletal disorders did not include the ingredients of an evidence-based approach (e.g. critical appraisal, meta-analysis, biological plausibility). This research was conducted to examine the association between lower back pain and forklift operation, and to accomplish this goal an evidence based approach was adopted. The basic steps of evidence based approach adopted in this study were the following: 1) formulation of a clear research question from a worker occupational problem; 2) search the literature for the best evidence with which to answer the question; 3) critically appraise the evidence; and 4) implementation of useful findings in occupational health and safety practices

A search of the literature for studies that relates lower back pain with forklift operation was conducted. A total of six epidemiological studies, all cross-sectional, found in the literature were critically appraised and meta-relative risk

was calculated. The overall quality of the studies ranged from marginal to average. The meta-relative risk obtained from the studies was 2.1 (significant at 5% level). If the overall study quality index was considered the meta-relative risk remained about the same (2.1). The results suggest that forklift drivers are at twice the risk of having lower back pain compared to workers that do not operate forklift equipment.

The main risk factors for forklift operators being susceptible to lower back pain are whole body vibration and postures. Whole body vibration is transmitted to an operator from a vibrating seat. When the frequency emerging from the seat is identical to the frequency of the human spinal system (4.5 – 5.5 Hz), resonance can occur and can lead to large internal stresses and strain. To avoid vibration through the seat a suspension seat with its highest cut-off frequency less than the cab floor vibration dominant frequency is needed. An additional recommendation to reduce the vibration exposure is to use electric trucks or install speed limiting controls; ground surfaces need to be smooth as possible (concrete); and the use of pneumatic tires, if suitable for the load application. Other effects of WBV exposure is that it can produce vascular changes and increase the rate of development of fatigue in the erector spinae muscles and disc compression. As a consequence, discs are less capable of absorbing and distributing load. Therefore it is recommended to avoid heavy lifting and rough terrain that can result in shocks. Further, the energy expended was more in a vibration seated position than not-vibration seated position. Twisted postures

and vibration create a synergistic effect that produces an increase in energy consumption that vibration or postures alone do not.

The posture adopted by the forklift operator is determined by the seat design and the task to be performed. The lack of motion (e.g. prolonged sitting) produces the accumulation of metabolites which most likely accelerate the degeneration of the discs and prolonged sitting has been found related to disc herniation. Additionally, the collagen fibers are mechanically strained when sitting due to increase in posterior disc height. If sitting is in an unsupported upright posture, the disc pressure at the L3 level is 40% more than upright standing. Further, the sitting posture may amplify the vibration transmitted to the spine, as a consequence of an arm moment created by the anterior offset of the ischial tuberosities. To reduce the impact of static postures (sitting) it is recommended to walk for five minutes and use variable postures. An adjustable seat is necessary that can accommodate different operator height and weight, thus providing more comfortable postures to the operator. Plus a backrest of 110 or 120 degrees can be used to minimize the spinal stress due to a load transfer to the backrest. The armrest helps to reduce the disc pressure by supporting the weight of the arm and to a lesser degree the upper body.

In summary, to minimize the risk of lower back pain among forklift operators, apart from a radical change in the traditional forklift truck design, some strategies could be followed. The driver working conditions can be improved by reducing the levels of vibration and by reducing the awkward postures adopted while operating the forklift. Some of the factors that influenced vibration are: seat,

speed, floor surface, and tires. Awkward postures and static postures are affected by: seat, time spend seated, and the task performed. These factors influencing vibration and postures among forklift operators and need to be addressed. Interventions need to be implemented to reduce the risk of lower back pain. A starting point to deal with this problem could be to follow the recommendations suggested in this study.

Table 3-1. Summary of description of evidence for cross-sectional studies involving forklift operators

Type of Equipment	Source	Description
Forklift	Hoy et al. (2005)	Whole-body vibration and postural load among forklift operators
	<i>Exposure</i>	Lower back pain
	<i>Outcome</i>	Cross-sectional
	<i>Study design</i>	23 forklift operators
	<i>Study population</i>	23 workers from other departments who did not drive vehicles at work (control group)
		Paper mill company in the UK
	<i>Main results</i>	Lower back pain in last 12 months was significantly more prevalent among drivers than 12-month prevalence for forklift group (65%)
		12-month prevalence for controls (35%)
		Odds ratio for forklift operators 3.52 (95% CI 1.04-11.83) (not adjusted for confounders)
	Bovenzi et al. (2002)	Whole-body vibration and postural load among forklift, crane, and straddle carrier
	<i>Exposure</i>	Lower back pain
	<i>Outcome</i>	Cross-sectional
	<i>Study design</i>	88 forklift drivers
	<i>Study population</i>	85 straddle carrier operators
		46 crane operators
		85 maintenance workers (control group)
		Transportation company in Northern Italy
	<i>Main results</i>	Whole-body vibration and postural loading were significantly associated with lower back pain
		12-month prevalence ratio for forklift operators: 1.42 (95% CI 1.13-1.78) (adjusted for covariates)
	Schwarze et al. (1998)	Whole-body vibration among forklift, and earth moving machinery operators
	<i>Exposure</i>	Physician diagnosed "lumber syndrome"
	<i>Outcome</i>	Cross-sectional
	<i>Study design</i>	159 forklift operators
	<i>Study population</i>	64 truck drivers
		165 operators of earth moving machinery operators
		65 controls (workers in same companies not exposed to whole body vibration)
		Workers from more than 30 companies in Germany

Type of Equipment	Source	Description
	<i>Main results</i>	Prevalence of lumbar syndrome among forklift operators (0.65), earth moving machinery operators (0.60), and controls (0.58)
	Miyashita et al. (1992)	
	<i>Exposure</i>	Whole body vibration among workers (forklift and earth moving machinery operators)
	<i>Outcome</i>	Low back pain
	<i>Study design</i>	Cross-sectional
	<i>Study population</i>	184 power shovel operators 127 bulldozer operators 44 forklift operators 85 office workers (control group)
	<i>Main results</i>	Construction workers from different companies in Japan Lower back pain was only significantly higher among forklift operators 12-month prevalence for forklift operators (50%), bulldozer operators (36%), and controls (27%)
	Boshuizen et al. (1992)	
	<i>Exposure</i>	Whole body vibration among forklift operators
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross-sectional
	<i>Study population</i>	242 drivers 210 referent workers (workers from the same companies who were not exposed to whole-body vibration)
	<i>Main results</i>	Workers drawn from six ship companies in the Rotterdam harbor (Netherlands) Lower back pain significantly higher among exposure group Overall 12-month odds ratio 2.2 (90% CI 1.03-4.7) (adjusted for confounders)
	Brendstrup and Biering-Sorensen (1987)	
	<i>Exposure</i>	Occupation as exposure (forklift operators)
	<i>Outcome</i>	Lower back pain
	<i>Study design</i>	Cross sectional
	<i>Study population</i>	240 male forklift operators from 13 companies in Copenhagen Control group from Copenhagen County (399 working men)
	<i>Main results</i>	Forklift operators had significantly higher lower back pain than controls 12-month prevalence for exposure and control groups are 0.65 and 0.47, respectively

Table 3-2. Meta analysis for lower back pain among forklift operators

Study # (i)	Sample Size for Exposed Group (Prevalence)	Sample Size for Non- Exposed Group (Prevalence)	Odds Ratio (OR)	Ln (OR)	95% CL Lower	95% CL Upper	Variance	Weight (w 1)	Weight (w 1) ²	w 1 ln OR	Heterogeneity	D
1	23(0.652)	23(0.348)	3.516	1.257	1.045	11.831	0.383	2.610	6.810	3.281	0.723	
2	88(0.78)	85(0.52)	3.384	1.219	1.745	6.563	0.114	8.758	76.700	10.676	2.085	
3	159(0.65)	65(0.54)	1.577	0.456	0.877	2.833	0.090	11.158	124.493	5.083	0.847	
4	44(0.50)	44(0.27)	2.667	0.981	1.097	6.484	0.205	4.868	23.694	4.775	0.304	0.006
5	196(0.41)	107(0.31)	1.546	0.436	0.938	2.548	0.065	15.386	236.739	6.703	1.343	
6	169(0.65)	399(0.47)	2.135	0.758	1.471	3.098	0.036	27.682	766.313	20.996	0.021	
Total	679.00	723.00						70.461	1234.749	51.514	5.323	

Summary Ln OR = $\Sigma(w_i \ln OR_i) / \Sigma(w_i)$			0.731
Summary OR = $\exp(\ln OR)$ =			2.077
95% CI for Summary OR = $\exp(\ln OR \pm 1.96 * ((1/\Sigma w_i)^{0.5}))$ =			1.645 2.624
α level for Homogeneity Test			0.378

Study #

1. Hoy et al. (2005)
2. Bovenzi et al. (2002)
3. Shw arze et al. (1998)
4. Miyashita et al. (1992)
5. Boshuizen et al. (1992)
6. Bendstrup and Biering-Sorensen (1987)

Table 3-3. Meta analysis for lower back pain among forklift operators – with study quality

Study # (i)	Sample Size for Exposed Group (Prevalence)	Sample Size for Non- Exposed Group (Prevalence)	Odds Ratio (OR)	Ln (OR)	95% CL Lower	95% CL Upper	Variance	Weight (w 1)	Study Quality	Weight (w 1a)	Weight (w 1a) ²	w 1a ln OR	Heterogeneity	D	Weight (w 2)
1	23(0.652)	23(0.348)	3.516	1.257	1.045	11.831	0.383	2.610	0.33334	0.870	0.757	1.094	0.225		1.013
2	88(0.78)	85(0.52)	3.384	1.219	1.745	6.563	0.114	8.758	0.47143	4.129	17.046	5.033	0.912		12.532
3	159(0.65)	65(0.54)	1.577	0.456	0.877	2.833	0.090	11.158	0.47059	5.251	27.570	2.392	0.452		35.658
4	44(0.50)	44(0.27)	2.667	0.981	1.097	6.484	0.205	4.868	0.25	1.217	1.481	1.194	0.065	-0.162	1.517
5	196(0.41)	107(0.31)	1.546	0.436	0.938	2.548	0.065	15.386	0.25	3.847	14.796	1.676	0.378		10.250
6	169(0.65)	399(0.47)	2.135	0.758	1.471	3.098	0.036	27.682	0.3125	8.651	74.835	6.561	0.001		-21.363
Total	3151	1728						70.461	2.088	23.963	136.485	17.950	2.033		39.607

Summary Ln OR = $\sum(w_i \ln OR_i) / \sum(w_i)$	0.749
Summary OR = $\exp(\ln OR)$	2.115
95% CI for Summary OR = $\exp(\ln OR \pm 1.96 * ((1/\sum w_i)^{0.5}))$	1.417
α level for Homogeneity Test	1.000

Study #

1. Hoy et al. (2005)
2. Bovenzi et al. (2002)
3. Shw arze et al. (1998)
4. Myashita et al. (1992)
5. Boshuizen et al. (1992)
6. Bendstrup and Biering-Sorensen (1987)

Table 3-4. Summary of main results of studies involving forklift equipment and vibration

Source	Main Results
Jönsson and Johansson (2005)	<ul style="list-style-type: none"> ■ Subjective responses showed that speed and height had significant effects on VSPM*. ■ The frequency that most accurately correlate with vibration discomfort was the 1/3 octave band analysis with frequencies 1.6, 6.3, 10 and above 50 Hz
Jang and Kook (2004)	<ul style="list-style-type: none"> ■ The index equation obtained using regression between the perceptual vibrations (vibration dose value) and the subjective rating scores, in the form of Steven's psychophysical power law were $\psi = 1.912\phi^{0.601}$ (ψ - sensation magnitude of start-motion quality; ϕ - the stimulus magnitude of the vibration dose value)
Wijaya et al. (2003)	<ul style="list-style-type: none"> ■ Sliding seat is better than a fixed seat in attenuating vibrations containing single transient vibration in the horizontal direction ■ The sliding seat was perceived as giving less overall discomfort, less low back discomfort, and less pitch motion
Verschoore et al. (2003)	<ul style="list-style-type: none"> ■ Solid tyres gave better comfort than pneumatic ones because the positive influence of the higher damping was greater than the negative influence of the higher stiffness ■ The seats were found to have the most important influence. With the anti-vibration seat the results were analogous, but the differences decreased
<i>Paddan and Griffin (2002B)</i>	<ul style="list-style-type: none"> ■ The average SEAT value (seat isolation efficiency) for most categories was less than 100% (meaning that the seat provides some attenuation) ■ Calculation suggest that 94% of the vehicles investigated might benefit by using a seat from one of the other vehicles

Table 3-4. Cont'd

Source	Main Results
<i>Paddan and Griffin (2002A)</i>	<ul style="list-style-type: none"> ■ Evaluations of vibration in accord with ISO 2631, using the most severe axis, gave lower values than evaluations in accord with BS 684 ■ ISO 2631 allowas appreciably longer daily exposures to whole-body vibration than BS 684¹
<i>Donati and Patel (1999)</i>	<ul style="list-style-type: none"> ■ The forward-backward and backrest inclination adjustments were assessed at the most important adjustments ■ While the drivers had previous experience in the use of suspension seats, they did not understand the purpose of the weight adjustment
<i>Malchaire et al. (1996)</i>	<ul style="list-style-type: none"> ■ Vibration exposure is influenced by: roughness of the track, speed and the quality of the seat. ■ If an anti-vibration seat with low resonance frequency is used, inflated tires are preferable.
<i>Burdorf and Swuste (1993)</i>	<ul style="list-style-type: none"> ■ In the laboratory 83% (20/24) measurements of vibration transmission through suspended seats resulted in attenuation of the vibration ■ In the field 71% (17/24) the vibration at the seat's surface was attenuated. ■ Laboratory measurements of the dynamic response of the seat suspension did not provide adequate basis for predicting its performance in the field ■ The magnitude and duration of vibration exceeded the 8 hr fatigue-decreased proficiency boundary Of 0.32 ms⁻² in the vertical axis, therefore suspended seats will not protect professional drivers from exposure to whole-body vibration

Table 3-4. Cont'd

Source	Main Results
Kjellberg et al. (1985)	<ul style="list-style-type: none"> ■ Increase in subjective discomfort probably is linear up to at least 1 hour
Joubert	<ul style="list-style-type: none"> ■ Whole-body vibration values exceeded the threshold of vibration level set out in the EU machinery directive of 0.2 ms^{-2} in all 9 forklifts and the majority exceeded the action of 0.5 ms^{-2} by the ISO 2631/1-1997 standard
De Man et al.	<ul style="list-style-type: none"> ■ Substantial improvement of the cabin stability with respect to tilting were obtained when testing on field test including realistic obstacles, turning, braking and slalom, while retaining the filtering properties of the passive suspension

Table 3-5. Ergonomic recommendations to reduce the impact of whole-body vibration in forklifts

Recommendation	Parameter	Objective
Suspension seats		<ul style="list-style-type: none"> ■ Is recommended to replace the seat by suspension seats in vehicles whose dominant frequencies from floor to the seat are higher than the seat attenuation frequency (Griffin 1990; Troup 1978; Donati 2002; Pope et al. 1998).
	<i>Suspension travel</i>	<ul style="list-style-type: none"> ■ The suspension travel must prevent bottoming or topping against end stops (Donati 2002). The length of the seat suspension travel depends of the attenuation frequency, lower attenuation = longer seat suspension travel (range: 3 cm above 3 Hz - 15 cm at 1.5 Hz).
	<i>Weight adjustment</i>	<ul style="list-style-type: none"> ■ The effectiveness of the suspension seat depends on the weight adjustment in the seat, so this one is at or close to mid-travel when the operator is seated.
Pneumatic tyres		<ul style="list-style-type: none"> ■ Pneumatic tyres are preferable to cushion. These tyres may be more effective at accommodating irregularities in ground surface and may reduce the floor induced vibration of a loaded truck by up to 50% (Donati et al.).
Electric trucks		<ul style="list-style-type: none"> ■ Electric trucks are preferable than diesel trucks because less vibration are obtained due mainly to the speed (Malchaire et al. 1996).
Smooth ground surface		<ul style="list-style-type: none"> ■ The ground surface needs to be the smooth (concrete) as possible to reduce the vibration levels. The acceleration is about 70% greater on rough surfaces than smooth surfaces (Malchaire et al. 1996).
Avoid heavy lifting		<ul style="list-style-type: none"> ■ After exposure to whole-body vibration the muscles are fatigued and the discs are compressed consequently the discs are less capable of absorbing and distributing load. Therefore is recommended to avoid heavy lifting immediately after vibration exposure (Pope et al. 1998).

Table 3-6. Ergonomic recommendations to reduce the impact of postures in forklifts operation

Recommendation	Parameter	Objective
Walk for five minutes		<ul style="list-style-type: none"> ■ Magnusson et al. (1987) found that seated vibration expends 14.3% more energy compared to non-vibration seated position. Lack of motion leads to an accumulation of metabolites, which probably accelerates the degeneration of the disks. Standing appears to be a good rest from sitting, for the passive tissues, given the change in lumbar spine posture and shift in loading of the posture dependent passive tissues. Therefore, standing, used alternatively as a rest from sitting, could form a basis for injury prevention (Callaghan and McGill 2001).
Variable posture		<ul style="list-style-type: none"> ■ There is a specific link between prolonged sitting and the incidence of herniation (Kelsey 1975). More upright sitting postures, and the concomitant psoas and other muscle activation, impose additional compressive loads to the spine. The change of lumbar postures causes a migration of the loads from one tissue to another. Because no ideal sitting posture exists, a variable posture is recommended to minimize the risk of tissue overload.
Back rest	<i>Angle and inclination</i>	<ul style="list-style-type: none"> ■ Spinal stress can be minimized by using a back rest of a 110 degree or more, the seat incline 6 degree and additional curved support for the spine with a peak level with the third lumbar vertebra (Troup 1978, Wilder and Pope 1996). When a backrest is used part of the body is transferred to it when a person leans back, reducing the load on the lumbar spine caused by the upper body weight. Therefore an increase in backrest inclination (backward) means an increase in load transfer to the backrest resulting in reduced disc pressure.
	<i>Height</i>	<ul style="list-style-type: none"> ■ The height of the back rest should be between 29 to 35 cm from the Seat Index Point (SIP = the intersection on the central vertical plane through the seat centerline of the theoretical pivot axis between a human torso and thighs) (Donati and Patel 1999).
	<i>Cushion</i>	<ul style="list-style-type: none"> ■ The cushion should be softer than the seat cushions (Donati and Patel 1999).

Table 3-6. Cont'd

Recommendation	Parameter	Objective
Seat cushion		<ul style="list-style-type: none"> ■ The cushion width, length, angle and softness are important characteristics for drivers comfort. The width of the cushion, at the front side, should be more than 47 cm and the length should be at least 42 cm from the backrest (29 cm from the SIP). The cushion angle is recommended to be between 8 and 13 degrees. And a cushion softness with a depression of more than 2.7 cm by 1.5 cm (Donati and Patel 1999).
Arm rest		<ul style="list-style-type: none"> ■ Disc pressure can be reduced by the use of arm rest. The use of arms rest supports the weight of the arms and at a small extent the upper body, resulting in reduction of disc pressure. With arms bent and elbows on armrests, the seat must be adjustable.
Front of the seat rounded		<ul style="list-style-type: none"> ■ The front edge of the seat should be rounded and there should be 30-50 mm of clearance between it and the back of the operator's knees so that do not cause pressure on these ones.
Partial seat rotation		<ul style="list-style-type: none"> ■ A partial seat rotation from 15 to 20 degrees is recommended for multiple observation tasks are performed in a rearward turned position.
Horizontal and vertical head movements		<ul style="list-style-type: none"> ■ In terms of the horizontal and vertical head movements, the operator should not turn their head more than 30° to either side, and the head should not be tilted more than 5° up and 25° down for sustained comfort. Occasional head movements within extreme limits of 50° to the side and 40° up and 50° down are acceptable (Barron et al. 2005).

Figure 3-1: Contributory factors of lower back pain among forklift operators

Figure 3-2. Overall critical appraisal for individual studies (Forklift)

Figure 3-3. Detailed critical appraisal for individual studies (Forklift)

Figure 3-4. Critical appraisal of measurement quality of individual studies (Forklift)

CHAPTER FOUR

CONCLUSION

Causal relationship between exposure and health outcomes is traditionally described linguistically by three levels, (a) more likely than not (i.e., strong evidence), (b) possible (i.e., moderate evidence), and (c) unlikely (i.e., weak evidence to nil). On the basis of the evidence presented and analyzed in this report, it appears that the causal relationship between working as a heavy equipment and forklift operator and lower back pain may be described at a minimum as “possible” and may be upgraded with limited evidence to higher than “possible” but definitely lower than “more likely than not”. The rationale for this conclusion is summarized below.

Initially, a “possible” level is assigned because the bulk of the evidence was based on: (1) cross-sectional studies; (2) consistency among most studies in reporting elevated risk (i.e., > 1); (3) strong association between exposure and lower back pain; (4) confounding being accounted for in many studies; and (5) moderate evidence of dose-response relationship. The final risk may be upgraded to higher than “possible” but less than “more likely than not” because of the limited evidence derived from prospective and retrospective cohort studies.

In light of the findings of this research, it is strongly recommended that prospective cohort studies be conducted to confirm the conclusion derived from this research. In doing so, attention should be paid to the different methodological qualities of the study such as subject selection, measurement quality, confounders, and generalization.

To minimize the risk of lower back pain among forklift operators, apart from a radical change in the traditional forklift truck design, some strategies can be followed. The driver working conditions can be improved by reducing the levels of vibration and by reducing the awkward postures adopted while operating the forklift. Some of the work environment that influences vibration are: seat, speed, floor surface, and tires. Awkward and static postures are affected by: seat, time spend seated, and the task performed. The factors influencing vibration and postures among forklift operators need to be addressed and interventions need to be implemented to reduce the risk of lower back pain. A starting point to deal with this problem could be to follow the controls suggested in this study.

Lessons for occupational safety and health engineering can be learned from evidence-based medicine. Nevertheless, there are important distinctions between evidence-based medicine and the evidence based approach used in occupational safety and health. The quality and volume of the evidence differ. Evidence-based medicine often relies on randomized controlled trials, which are the most scientifically rigorous of epidemiologic studies. On the other hand, occupational safety and health relies more on cross-sectional studies. Also the volume of evidence in evidence-based medicine is usually larger than in occupational safety and health engineering.

While evidence is limited for many occupational safety and health interventions, approaches should be based on the best possible science, be multidisciplinary, and center on sound planning and evaluation methods. A

systematic approach to evidence-based decision making is likely to improve the occupational safety and health programs of many industrial environments.

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APPENDIX

Study by Hoy et al. (2005)

	Study Description	Item	Assessor			
			A	B	C	D
1		Hypothesis	1	1	1	1
2		Exposure	2	2	2	2
3		Outcome	1	2	1	1
4		Study design	2	2	2	2
5		Source of subject population	2	2	2	2
6		Eligibility criteria	2	0	2	2
7		Participation rate / record availability	0	2	0	0
8		Characteristics of participating subjects / available records	1	1	1	1
9		Characteristics of lost subjects / unavailable records	0	2	2	2
10		Adverse effects	4	3	4	4
11		Covariates / confounders (individual variables)	1	1	1	1
12		Covariates / confounders (environment variables)	2	2	1	1
13		Statistical methods	0	1	1	1
14		Main outcomes	1	1	1	1
15		Estimates of random variability	2	1	1	1
16		Estimates of parameter association	1	2	1	1
17		Sample size calculation	0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Hoy et al. (2005)

	Item	Assessor			
		A	B	C	D
18	Group comparability	2	2	2	2
19	Participation rate / record availability	3	2	3	3
20	Time period for recruitment of different groups	3	3	3	3
21	Lost subjects / unavailable records	0	2	2	2
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	2	2	3	3
28	Assessment of exposure prior to onset of outcome	4	4	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	3	3	3
33	Comparability of outcome assessment methods for different groups	1	2	3	3
34	Observation period for different groups	3	3	3	3
35	Prior history of disease / symptoms	0	1	1	1
36	Covariates / confounders (individual variables)	1	1	0	0
37	Covariates / confounders (environment variables)	1	2	0	0
38	Minimum follow-up time	4	4	4	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
40	Data analysis by levels of exposure or outcome	1	0	0	0
41	Data analysis by subgroups of subjects	1	0	0	0
42	Application of results to study population	3	2	3	3
43	Application of results to relevant populations	3	2	3	3
Study's Methodological Description		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine			

Study by Bovenzi et al. (2002)

	Study Description	Item	Assessor			
			A	B	C	D
1		Hypothesis	1	1	1	1
2		Exposure	1	2	2	2
3		Outcome	1	2	1	1
4		Study design	2	2	2	2
5		Source of subject population	2	2	2	2
6		Eligibility criteria	2	2	2	2
7		Participation rate / record availability	1	2	1	1
8		Characteristics of participating subjects / available records	2	2	2	2
9		Characteristics of lost subjects / unavailable records	2	2	2	2
10		Adverse effects	4	4	4	4
11		Covariates / confounders (individual variables)	2	2	1	1
12		Covariates / confounders (environment variables)	1	0	1	1
13		Statistical methods	2	2	1	1
14		Main outcomes	1	1	1	1
15		Estimates of random variability	2	1	1	1
16		Estimates of parameter association	2	1	1	1
17		Sample size calculation	0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Bovenzi et al. (2002)

	Item	Assessor			
		A	B	C	D
Study's Methodological Description	18 Group comparability	2	2	2	2
	19 Participation rate / record availability	2	2	3	3
	20 Time period for recruitment of different groups	3	3	3	3
	21 Lost subjects / unavailable records	2	2	2	2
	22 Type of cases	4	4	4	4
	23 Randomization of study subjects	4	4	4	4
	24 Randomization of study subjects	4	4	4	4
	25 Reliability of exposure variables	3	3	3	3
	26 Validity of exposure variables	3	3	3	3
	27 Comparability of exposure assessment methods for different groups	2	2	2	2
	28 Assessment of exposure prior to onset of outcome	4	4	4	4
	29 Observer blinding	3	3	3	3
	30 Subject blinding	3	3	3	3
	31 Reliability of outcome variables	3	3	3	3
	32 Validity of outcome variables	3	3	3	3
	33 Comparability of outcome assessment methods for different groups	2	2	2	2
	34 Observation period for different groups	3	3	3	3
	35 Prior history of disease / symptoms	2	2	4	4
	36 Covariates / confounders (individual variables)	2	2	1	1
	37 Covariates / confounders (environment variables)	2	0	1	1
	38 Minimum follow-up time	4	4	4	4
	39 Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
	40 Data analysis by levels of exposure or outcome	2	2	1	1
	41 Data analysis by subgroups of subjects	2	2	1	1
	42 Application of results to study population	2	2	3	3
	43 Application of results to relevant populations	2	2	3	3
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Shwarze et al. (1998)

	Study Description	Item	Assessor			
			A	B	C	D
1	Hypothesis		1	1	1	1
2	Exposure		1	2	1	1
3	Outcome		1	2	2	2
4	Study design		2	2	2	2
5	Source of subject population		2	2	2	2
6	Eligibility criteria		2	1	2	2
7	Participation rate / record availability		4	2	4	2
8	Characteristics of participating subjects / available records		1	1	1	1
9	Characteristics of lost subjects / unavailable records		2	2	0	0
10	Adverse effects		4	4	4	4
11	Covariates / confounders (individual variables)		2	2	1	1
12	Covariates / confounders (environment variables)		2	2	0	0
13	Statistical methods		1	2	1	1
14	Main outcomes		1	1	2	2
15	Estimates of random variability		2	1	2	2
16	Estimates of parameter association		2	1	2	2
17	Sample size calculation		0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Shwarze et al. (1998)

	Item	Assessor			
		A	B	C	D
Study's Methodological Description	18 Group comparability	2	2	2	2
	19 Participation rate / record availability	4	2	4	2
	20 Time period for recruitment of different groups	3	3	0	0
	21 Lost subjects / unavailable records	2	2	0	0
	22 Type of cases	4	4	4	4
	23 Randomization of study subjects	4	4	4	4
	24 Randomization of study subjects	4	4	4	4
	25 Reliability of exposure variables	3	3	3	3
	26 Validity of exposure variables	3	3	3	3
	27 Comparability of exposure assessment methods for different groups	2	2	2	2
	28 Assessment of exposure prior to onset of outcome	2	4	4	4
	29 Observer blinding	3	3	3	3
	30 Subject blinding	3	0	3	3
	31 Reliability of outcome variables	3	3	3	3
	32 Validity of outcome variables	3	2	3	3
	33 Comparability of outcome assessment methods for different groups	3	2	2	2
	34 Observation period for different groups	3	3	3	3
	35 Prior history of disease / symptoms	1	2	2	0
	36 Covariates / confounders (individual variables)	1	2	1	1
	37 Covariates / confounders (environment variables)	0	2	1	1
	38 Minimum follow-up time	4	2	4	4
	39 Adjustment for different follow-up times and time periods between exposure & outcome	0	2	4	4
	40 Data analysis by levels of exposure or outcome	1	2	1	1
	41 Data analysis by subgroups of subjects	0	2	0	0
	42 Application of results to study population	3	2	4	4
	43 Application of results to relevant populations	3	2	4	4
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Miyashita et al. (1992)

	Study Description	Item	Assessor			
			A	B	C	D
1	Hypothesis		1	1	1	1
2	Exposure		2	2	1	1
3	Outcome		1	1	1	1
4	Study design		1	1	1	1
5	Source of subject population		2	2	1	1
6	Eligibility criteria		2	2	2	2
7	Participation rate / record availability		4	4	4	4
8	Characteristics of participating subjects / available records		1	2	2	2
9	Characteristics of lost subjects / unavailable records		2	2	0	0
10	Adverse effects		4	4	4	4
11	Covariates / confounders (individual variables)		1	1	1	1
12	Covariates / confounders (environment variables)		0	0	0	0
13	Statistical methods		2	0	1	1
14	Main outcomes		1	1	1	1
15	Estimates of random variability		1	0	0	0
16	Estimates of parameter association		0	0	0	0
17	Sample size calculation		0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Miyashita et al. (1992)

	Item	Assessor			
		A	B	C	D
Study's Methodological Description	18 Group comparability	3	4	0	0
	19 Participation rate / record availability	4	4	4	4
	20 Time period for recruitment of different groups	3	3	3	3
	21 Lost subjects / unavailable records	2	2	0	0
	22 Type of cases	4	4	4	4
	23 Randomization of study subjects	4	4	4	4
	24 Randomization of study subjects	4	4	4	4
	25 Reliability of exposure variables	3	3	3	3
	26 Validity of exposure variables	3	3	3	3
	27 Comparability of exposure assessment methods for different groups	2	2	2	2
	28 Assessment of exposure prior to onset of outcome	4	4	4	4
	29 Observer blinding	3	3	3	3
	30 Subject blinding	3	3	3	3
	31 Reliability of outcome variables	3	3	3	3
	32 Validity of outcome variables	3	3	3	3
	33 Comparability of outcome assessment methods for different groups	2	2	2	2
	34 Observation period for different groups	3	3	3	3
	35 Prior history of disease / symptoms	0	0	0	0
	36 Covariates / confounders (individual variables)	1	1	0	0
	37 Covariates / confounders (environment variables)	0	0	0	0
	38 Minimum follow-up time	4	4	4	4
	39 Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
	40 Data analysis by levels of exposure or outcome	0	0	0	0
	41 Data analysis by subgroups of subjects	0	2	0	0
	42 Application of results to study population	3	2	4	4
	43 Application of results to relevant populations	3	2	4	4
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Boshuizen et al. (1992)

	Study Description	Item	Assessor			
			A	B	C	D
1		Hypothesis	1	1	1	1
2		Exposure	1	2	1	1
3		Outcome	1	1	1	1
4		Study design	2	2	1	1
5		Source of subject population	2	2	1	1
6		Eligibility criteria	1	2	2	2
7		Participation rate / record availability	0	2	4	4
8		Characteristics of participating subjects / available records	1	1	2	2
9		Characteristics of lost subjects / unavailable records	1	0	1	0
10		Adverse effects	4	4	4	4
11		Covariates / confounders (individual variables)	1	2	1	1
12		Covariates / confounders (environment variables)	1	2	1	0
13		Statistical methods	0	2	1	1
14		Main outcomes	1	1	1	1
15		Estimates of random variability	1	1	1	0
16		Estimates of parameter association	2	1	2	0
17		Sample size calculation	0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Boshuizen et al. (1992)

	Item	Assessor			
		A	B	C	D
18	Group comparability	2	2	3	3
19	Participation rate / record availability	3	2	4	4
20	Time period for recruitment of different groups	3	3	3	3
21	Lost subjects / unavailable records	1	2	0	0
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	2	2	2	2
28	Assessment of exposure prior to onset of outcome	4	4	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	3	3	3
33	Comparability of outcome assessment methods for different groups	3	2	2	2
34	Observation period for different groups	3	3	3	3
35	Prior history of disease / symptoms	1	0	1	0
36	Covariates / confounders (individual variables)	1	1	1	0
37	Covariates / confounders (environment variables)	1	2	0	0
38	Minimum follow-up time	4	4	4	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
40	Data analysis by levels of exposure or outcome	1	2	1	0
41	Data analysis by subgroups of subjects	1	2	1	0
42	Application of results to study population	3	2	3	4
43	Application of results to relevant populations	3	2	3	4
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Bendstrup and Sorensen (1987)

	Study Description	Item	Assessor			
			A	B	C	D
1		Hypothesis	1	1	1	1
2		Exposure	2	2	2	1
3		Outcome	1	2	1	1
4		Study design	1	1	1	1
5		Source of subject population	2	2	2	2
6		Eligibility criteria	1	2	1	1
7		Participation rate / record availability	1	1	1	4
8		Characteristics of participating subjects / available records	1	1	2	2
9		Characteristics of lost subjects / unavailable records	2	2	0	0
10		Adverse effects	4	4	4	4
11		Covariates / confounders (individual variables)	1	1	1	1
12		Covariates / confounders (environment variables)	0	0	0	0
13		Statistical methods	1	2	2	2
14		Main outcomes	1	1	1	1
15		Estimates of random variability	1	0	1	1
16		Estimates of parameter association	1	0	1	0
17		Sample size calculation	0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Bendstrup and Sorensen (1987)

	Item	Assessor			
		A	B	C	D
18	Group comparability	0	1	1	1
19	Participation rate / record availability	2	2	4	4
20	Time period for recruitment of different groups	4	4	3	3
21	Lost subjects / unavailable records	2	2	0	0
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	2	2	0	0
28	Assessment of exposure prior to onset of outcome	4	4	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	3	3	3
33	Comparability of outcome assessment methods for different groups	2	2	2	2
34	Observation period for different groups	3	0	3	3
35	Prior history of disease / symptoms	1	0	1	1
36	Covariates / confounders (individual variables)	1	1	1	1
37	Covariates / confounders (environment variables)	0	0	0	0
38	Minimum follow-up time	4	4	4	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
40	Data analysis by levels of exposure or outcome	1	0	0	0
41	Data analysis by subgroups of subjects	1	2	1	1
42	Application of results to study population	3	2	3	4
43	Application of results to relevant populations	3	2	3	4
Study's Methodological Description		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine			

Study by Burdorf et al. (1993)

	Study Description	Item	Assessor			
			A	B	C	D
1		Hypothesis	1	1	1	1
2		Exposure	2	2	2	2
3		Outcome	1	2	1	1
4		Study design	2	2	2	2
5		Source of subject population	2	2	1	1
6		Eligibility criteria	2	2	2	2
7		Participation rate / record availability	0	2	0	0
8		Characteristics of participating subjects / available records	2	1	2	2
9		Characteristics of lost subjects / unavailable records	2	2	0	0
10		Adverse effects	4	4	4	4
11		Covariates / confounders (individual variables)	1	1	1	1
12		Covariates / confounders (environment variables)	1	2	1	1
13		Statistical methods	1	2	1	1
14		Main outcomes	1	1	1	1
15		Estimates of random variability	1	1	1	1
16		Estimates of parameter association	1	1	1	1
17		Sample size calculation	0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Burdorf et al. (1993)

	Item	Assessor			
		A	B	C	D
18	Group comparability	2	2	2	2
19	Participation rate / record availability	3	2	3	3
20	Time period for recruitment of different groups	3	3	3	3
21	Lost subjects / unavailable records	2	2	0	0
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	2	2	2	2
28	Assessment of exposure prior to onset of outcome	4	4	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	3	3	3
33	Comparability of outcome assessment methods for different groups	2	2	2	2
34	Observation period for different groups	3	3	3	3
35	Prior history of disease / symptoms	1	0	1	4
36	Covariates / confounders (individual variables)	1	1	1	2
37	Covariates / confounders (environment variables)	1	2	1	1
38	Minimum follow-up time	4	4	4	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
40	Data analysis by levels of exposure or outcome	1	0	1	0
41	Data analysis by subgroups of subjects	1	2	1	0
42	Application of results to study population	3	2	3	3
43	Application of results to relevant populations	3	2	3	3
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Burdorf and Zondervan (1990)

	Item	Assessor			
		A	B	C	D
Study Description	1 Hypothesis	1	1	1	1
	2 Exposure	2	2	0	0
	3 Outcome	1	2	1	1
	4 Study design	2	2	1	1
	5 Source of subject population	2	2	1	1
	6 Eligibility criteria	1	2	1	2
	7 Participation rate / record availability	2	2	0	0
	8 Characteristics of participating subjects / available records	2	2	2	2
	9 Characteristics of lost subjects / unavailable records	2	2	0	0
	10 Adverse effects	4	4	4	4
	11 Covariates / confounders (individual variables)	2	1	1	1
	12 Covariates / confounders (environment variables)	1	2	1	0
	13 Statistical methods	1	2	1	1
	14 Main outcomes	1	1	1	1
	15 Estimates of random variability	1	1	1	1
	16 Estimates of parameter association	2	1	1	1
	17 Sample size calculation	0	0	0	0
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Burdorf and Zondervan (1990)

	Item	Assessor			
		A	B	C	D
18	Group comparability	2	2	2	2
19	Participation rate / record availability	1	1	3	3
20	Time period for recruitment of different groups	3	3	3	3
21	Lost subjects / unavailable records	2	2	0	0
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	3	2	3	3
28	Assessment of exposure prior to onset of outcome	4	4	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	3	3	3
33	Comparability of outcome assessment methods for different groups	2	2	2	2
34	Observation period for different groups	3	3	3	3
35	Prior history of disease / symptoms	1	1	1	0
36	Covariates / confounders (individual variables)	1	1	1	1
37	Covariates / confounders (environment variables)	1	2	1	0
38	Minimum follow-up time	4	4	4	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
40	Data analysis by levels of exposure or outcome	0	0	0	0
41	Data analysis by subgroups of subjects	1	0	0	0
42	Application of results to study population	1	1	3	3
43	Application of results to relevant populations	1	1	3	3
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Kumar et al. (1999)

	Study Description	Item	Assessor			
			A	B	C	D
1	Hypothesis		1	1	1	1
2	Exposure		1	2	1	1
3	Outcome		1	2	1	1
4	Study design		2	2	1	1
5	Source of subject population		2	2	2	2
6	Eligibility criteria		2	2	2	2
7	Participation rate / record availability		0	1	0	0
8	Characteristics of participating subjects / available records		2	1	1	1
9	Characteristics of lost subjects / unavailable records		2	2	2	2
10	Adverse effects		4	4	4	4
11	Covariates / confounders (individual variables)		2	2	1	1
12	Covariates / confounders (environment variables)		1	2	1	0
13	Statistical methods		0	0	0	0
14	Main outcomes		1	1	1	1
15	Estimates of random variability		1	0	1	0
16	Estimates of parameter association		0	0	0	0
17	Sample size calculation		0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Kumar et al. (1999)

	Item	Assessor			
		A	B	C	D
18	Group comparability	2	2	1	1
19	Participation rate / record availability	3	2	3	3
20	Time period for recruitment of different groups	3	3	3	3
21	Lost subjects / unavailable records	2	2	2	2
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	2	2	3	3
28	Assessment of exposure prior to onset of outcome	2	2	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	2	3	3
33	Comparability of outcome assessment methods for different groups	1	2	1	2
34	Observation period for different groups	3	3	3	3
35	Prior history of disease / symptoms	1	2	1	1
36	Covariates / confounders (individual variables)	1	2	1	1
37	Covariates / confounders (environment variables)	1	2	1	0
38	Minimum follow-up time	3	2	3	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	3	3	3	4
40	Data analysis by levels of exposure or outcome	1	0	1	0
41	Data analysis by subgroups of subjects	0	1	1	1
42	Application of results to study population	3	2	3	3
43	Application of results to relevant populations	3	2	3	3
Study's Methodological Description		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine			

Study by Bovenzi and Betta (1994)

	Study Description	Item	Assessor			
			A	B	C	D
1	Hypothesis		1	1	1	2
2	Exposure		2	2	2	2
3	Outcome		1	2	1	1
4	Study design		1	1	1	1
5	Source of subject population		2	2	2	2
6	Eligibility criteria		1	2	2	2
7	Participation rate / record availability		1	2	1	1
8	Characteristics of participating subjects / available records		2	2	2	1
9	Characteristics of lost subjects / unavailable records		2	2	2	0
10	Adverse effects		4	4	4	4
11	Covariates / confounders (individual variables)		1	2	1	1
12	Covariates / confounders (environment variables)		2	2	2	0
13	Statistical methods		2	2	2	1
14	Main outcomes		1	1	1	1
15	Estimates of random variability		2	1	1	1
16	Estimates of parameter association		2	1	1	1
17	Sample size calculation		0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Bovenzi and Betta (1994)

	Item	Assessor			
		A	B	C	D
18	Group comparability	0	2	0	3
19	Participation rate / record availability	3	2	3	3
20	Time period for recruitment of different groups	3	3	3	3
21	Lost subjects / unavailable records	2	2	2	0
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	2	2	2	2
28	Assessment of exposure prior to onset of outcome	4	4	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	3	3	3
33	Comparability of outcome assessment methods for different groups	2	2	2	2
34	Observation period for different groups	3	3	3	3
35	Prior history of disease / symptoms	1	2	1	1
36	Covariates / confounders (individual variables)	1	2	1	1
37	Covariates / confounders (environment variables)	2	2	1	1
38	Minimum follow-up time	4	4	4	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
40	Data analysis by levels of exposure or outcome	1	2	1	1
41	Data analysis by subgroups of subjects	0	2	0	1
42	Application of results to study population	2	2	3	3
43	Application of results to relevant populations	2	2	3	3
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Boshuizen et al. (1990)

	Study Description	Item	Assessor			
			A	B	C	D
1	Hypothesis		1	1	1	1
2	Exposure		1	2	1	1
3	Outcome		1	2	1	1
4	Study design		1	1	1	2
5	Source of subject population		2	2	1	1
6	Eligibility criteria		0	0	1	0
7	Participation rate / record availability		0	2	0	0
8	Characteristics of participating subjects / available records		1	1	1	1
9	Characteristics of lost subjects / unavailable records		0	2	0	1
10	Adverse effects		4	4	4	4
11	Covariates / confounders (individual variables)		1	1	1	0
12	Covariates / confounders (environment variables)		2	2	2	0
13	Statistical methods		1	2	1	1
14	Main outcomes		1	1	1	0
15	Estimates of random variability		2	1	1	1
16	Estimates of parameter association		2	1	1	1
17	Sample size calculation		0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Boshuizen et al. (1990)

	Item	Assessor			
		A	B	C	D
18	Group comparability	1	4	1	1
19	Participation rate / record availability	3	1	3	3
20	Time period for recruitment of different groups	3	4	3	3
21	Lost subjects / unavailable records	0	2	0	0
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	1	4	1	1
28	Assessment of exposure prior to onset of outcome	4	4	4	2
29	Observer blinding	3	4	3	3
30	Subject blinding	3	4	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	3	3	3
33	Comparability of outcome assessment methods for different groups	2	4	1	1
34	Observation period for different groups	3	4	3	3
35	Prior history of disease / symptoms	1	0	1	1
36	Covariates / confounders (individual variables)	2	1	1	1
37	Covariates / confounders (environment variables)	2	1	1	0
38	Minimum follow-up time	4	4	4	2
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	3
40	Data analysis by levels of exposure or outcome	1	2	1	1
41	Data analysis by subgroups of subjects	1	0	1	1
42	Application of results to study population	3	1	3	0
43	Application of results to relevant populations	3	1	3	0
Study's Methodological Description		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine			

Study by Dupuis and Zerlett (1987)

	Study Description	Item	Assessor			
			A	B	C	D
1	Hypothesis		1	1	1	1
2	Exposure		1	2	1	1
3	Outcome		1	2	1	1
4	Study design		2	2	2	2
5	Source of subject population		1	1	1	0
6	Eligibility criteria		2	2	1	0
7	Participation rate / record availability		0	1	0	0
8	Characteristics of participating subjects / available records		1	1	1	0
9	Characteristics of lost subjects / unavailable records		2	2	0	0
10	Adverse effects		4	4	4	4
11	Covariates / confounders (individual variables)		1	1	1	0
12	Covariates / confounders (environment variables)		0	0	0	0
13	Statistical methods		1	0	0	0
14	Main outcomes		1	1	2	2
15	Estimates of random variability		0	0	0	0
16	Estimates of parameter association		0	0	0	0
17	Sample size calculation		0	0	0	0
		0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				

Study by Dupuis and Zerlett (1987)

	Item	Assessor			
		A	B	C	D
18	Group comparability	3	2	3	3
19	Participation rate / record availability	3	2	3	3
20	Time period for recruitment of different groups	3	3	3	3
21	Lost subjects / unavailable records	2	2	0	0
22	Type of cases	4	4	4	4
23	Randomization of study subjects	4	4	4	4
24	Randomization of study subjects	4	4	4	4
25	Reliability of exposure variables	3	3	3	3
26	Validity of exposure variables	3	3	3	3
27	Comparability of exposure assessment methods for different groups	3	3	3	3
28	Assessment of exposure prior to onset of outcome	4	4	4	4
29	Observer blinding	3	3	3	3
30	Subject blinding	3	3	3	3
31	Reliability of outcome variables	3	3	3	3
32	Validity of outcome variables	3	1	3	3
33	Comparability of outcome assessment methods for different groups	1	1	3	3
34	Observation period for different groups	3	3	3	3
35	Prior history of disease / symptoms	0	0	0	0
36	Covariates / confounders (individual variables)	1	1	1	0
37	Covariates / confounders (environment variables)	0	0	0	0
38	Minimum follow-up time	4	4	4	4
39	Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
40	Data analysis by levels of exposure or outcome	0	0	4	4
41	Data analysis by subgroups of subjects	1	1	1	1
42	Application of results to study population	3	2	3	3
43	Application of results to relevant populations	3	2	3	3
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Zimmermann et al. (1997)

	Item	Assessor			
		A	B	C	D
Study Description	1 Hypothesis	1	1	1	1
	2 Exposure	1	1	1	1
	3 Outcome	1	1	1	1
	4 Study design	1	1	1	1
	5 Source of subject population	1	1	1	1
	6 Eligibility criteria	0	0	0	0
	7 Participation rate / record availability	0	0	0	0
	8 Characteristics of participating subjects / available records	2	2	2	2
	9 Characteristics of lost subjects / unavailable records	2	2	2	0
	10 Adverse effects	4	4	4	4
	11 Covariates / confounders (individual variables)	1	1	1	1
	12 Covariates / confounders (environment variables)	1	1	1	1
	13 Statistical methods	0	0	0	0
	14 Main outcomes	1	1	0	0
	15 Estimates of random variability	2	1	2	2
	16 Estimates of parameter association	2	1	2	2
	17 Sample size calculation	0	0	0	0
0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine					

Study by Zimmermann et al. (1997)

	Item	Assessor			
		A	B	C	D
Study's Methodological Description	18 Group comparability	4	4	4	4
	19 Participation rate / record availability	3	0	3	3
	20 Time period for recruitment of different groups	4	3	4	4
	21 Lost subjects / unavailable records	2	2	1	0
	22 Type of cases	4	4	4	4
	23 Randomization of study subjects	4	4	4	4
	24 Randomization of study subjects	4	4	4	4
	25 Reliability of exposure variables	3	3	3	3
	26 Validity of exposure variables	3	3	3	3
	27 Comparability of exposure assessment methods for different groups	4	4	4	4
	28 Assessment of exposure prior to onset of outcome	4	4	4	4
	29 Observer blinding	4	3	4	4
	30 Subject blinding	4	3	3	3
	31 Reliability of outcome variables	3	3	3	3
	32 Validity of outcome variables	3	3	3	3
	33 Comparability of outcome assessment methods for different groups	4	4	4	4
	34 Observation period for different groups	4	4	4	4
	35 Prior history of disease / symptoms	0	1	0	0
	36 Covariates / confounders (individual variables)	1	1	1	0
	37 Covariates / confounders (environment variables)	1	1	1	0
	38 Minimum follow-up time	4	4	4	4
	39 Adjustment for different follow-up times and time periods between exposure & outcome	4	4	4	4
	40 Data analysis by levels of exposure or outcome	0	0	0	0
	41 Data analysis by subgroups of subjects	0	0	0	0
	42 Application of results to study population	3	0	3	3
	43 Application of results to relevant populations	3	0	3	3
	0-No, 1-Partial, 2-Yes, 3-Not Applicable, 4-Unable to Determine				