Lower Back Disorders Among Forklift Operators: An Emerging Occupational Health Problem?

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Background *Most studies focusing 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 musculoskeletal disorders (MSDs). We review and critically appraise the epidemiological studies conducted on forklift operators in relation to MSDs, such as lower back pain and neck problems.*

Methods *A comprehensive search of databases resulted in the identification of seven epidemiological studies that addressed MSDs. A critical appraisal of these studies was conducted using epidemiological principles and a meta-analysis approach that involved the use of the confidence limit method to determine an overall "meta-odds ratio."*

Results *The methodological quality of these studies ranged from "marginal" to "average" with the exception of one study, which was considered "good." The meta-odds ratio for lower back pain among forklift operators was 2.13 (95% CI: 1.57, 2.87).*

Conclusions *Our results suggest that forklift operators are at increased risk of lower back pain. Additional high quality epidemiological studies are needed in the US, however, to determine the magnitude of risk for MSDs. In this regard, studies should address not only lower back pain among forklifts operators, but also neck pain. A full exposure assessment of physical and non-physical factors in these studies is needed.* Am. J. Ind. Med. 47:333–340, 2005. *Published 2005 Wiley-Liss, Inc.*†

KEY WORDS: forklift; musculoskeletal disorders; risk factors; meta-analysis

INTRODUCTION

Forklifts are widely used in manufacturing, service, and warehousing enterprises, with an estimated 1.2 million workers operating as many as 800,000 forklifts in the US alone [Swartz, 1998]. A number of occupational hazards associated with operation of forklifts have been identified. Fatalities and traumatic injuries associated with forklift operations are well documented [Stout-Wiegand, 1987; Miller, 1988; Swartz, 1998; Collins et al., 1999a,b,c; NIOSH, 2001]. It is estimated that, each year in the US, nearly 100 workers are killed and another 20,000 are seriously injured in forklift-related incidents, involving crashes and overturns, with overturns being the leading cause of forklift fatalities and representing 25% of all forklift-related deaths [NIOSH, 2001]. In a case-control study by Collins et al. [1999a], the possible risk factors associated with collision injuries include internal environment characteristics (obstruction, volume of pedestrian traffic, presence of stop signs, and aisle widths) as well as vehicle

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characteristics (vehicle loaded). In another study by Collins et al. [1999b], the five most frequent characteristics of fatal forklift incidents include pedestrian struck by, overturns, crushed by forklift, worker fell from forklift, and forklift fell on worker.

In addition to the increased risk of fatalities and traumatic injuries, however, forklift operators may also be at a significantly increased risk of musculoskeletal disorders (MSDs) [e.g., Bovenzi et al., 2002]. The potential risk factors that may lead to MSDs among forklift operators, include: static sedentary position while driving (hands and feet held steady on handles and pedals); repeated exposure to short and long-term awkward trunk postures (trunk twisting and bending), especially during reverse operation; repeated exposure to short and long-term awkward neck postures during reverse operation; and, exposure to whole-body vibration while driving [National Safety Council, 1982; Brendstrup and Biering-Sorensen, 1987]. Currently, US statistics on the prevalence of MSDs among forklift operators are not readily available.

The current study explores the existing epidemiological evidence linking forklift operation and risk of MSDs, such as lower back and neck disorders. The primary objectives of this study were to conduct a systematic review and a critical appraisal of the epidemiological studies relating exposure to forklift operation to MSDs. The systematic review of these studies consisted of: (1) describing the evidence in terms of exposure, outcome, study design, study population, and main results; and (2) deriving a meta-risk estimate from the reviewed studies. The critical appraisal of these studies dealt with a critical evaluation of evidence reporting, potential bias due to subject selection/observation/confounders and covariates, positive features of causation, and external validity. In this regard, we have used a modified epidemiological appraisal checklist from the published literature to perform this evaluation [Crombie, 1996; Elwood, 2000].

METHODS

Search Strategy and Inclusion Criteria

The target population of this review is forklift operators and the outcome of interest is musculoskeletal outcomes. Any type of observational studies were considered in this review. There was no restriction on the exposure variable collected from the target population. At minimum, the subjects should have been in service as forklift operators for at least 1 year.

A comprehensive search of several databases (MEDLINE, Ergonomics Abstracts, BIOSIS, Health and Science Abstracts, NIOSHTIC, PsycINFO) was conducted with forklift, back/neck/musculoskeletal pain or disorder as key words.

Data Extraction

From all the included studies, we documented the following items: exposure, outcome, study design, study population, and main results. 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

We critically appraised the reviewed epidemiological studies based on epidemiological principles reported in the published literature. This was accomplished using the ‘‘Epidemiological Appraisal Instrument’’ developed by Genaidy [2004].

Table I includes the elements of critical appraisal and items used in evaluating each element. Each item was evaluated as follows: yes (2 points), partial (1 point), no or unable to determine (0 point). The final score for each element was taken as the average of the values recorded for each item.

TABLE I. Elements of Critical Appraisal of Studies of Forklift Operators

Element	Items
Generalization	Application of study results to eligible population, application of study results to other relevant groups
Positive features of causation	Adequacy of follow-up time, dose-response relationship, examination of relationships in different subgroups
Covariates/confounders	Accountability for covariates and confounders
Observation bias	
Observation period	Comparability of observation period among different groups, account for different lengths of follow-up time
Outcome	Reliability and validity
Blind measurement	Observers, subjects
Exposure	Validity and reliability, appropriateness to the hypothesis, comparability of assessment methods among groups
Subject selection	Group comparability, participation rate, time period, dropouts
Evidence reporting	Hypothesis, exposure, outcome, study design, study population, covariates/confounders, statistical tests and analysis strategies, main results

Two members of our research team (AG and HB) conducted the critical appraisal independently. They were blinded to the studies' author information. The results of the evaluations were compared, and areas of disagreement were discussed and resolved in a follow-up session.

Statistical Methods

A meta-analysis of the reviewed studies was conducted to derive an overall estimate for the odds ratio of lower back pain among forklift operators (meta-odds ratio). In order to calculate the odds ratio and confidence limits for each study, we have extracted the total number of subjects participating in the exposure and control groups, as well as the prevalence rates. The ''LOGISTIC'' procedure of the Statistical Analysis Software was used to calculate the odds ratio and 95% confidence limits for each study. The confidence limit method was used to calculate the meta-odds ratio and 95% confidence limits [Elwood, 2000].

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

RESULTS

Identification of Studies

On the basis of the search, we identified eight epidemiological studies linking forklift operation with MSDs [Brendstrup and Biering-Sorensen, 1987; Boshuizen et al., 1992; Miyashita et al., 1992; Franzini and Benedyk, 1996; Poppel et al., 1998; Schwarze et al., 1998; Shinozaki et al., 2001; Bovenzi et al., 2002]. One cohort study was excluded because it was not originally designed for forklift operators [Poppel et al., 1998]. The remaining seven studies dealt with: whole-body vibration as the primary exposure in two cross-sectional and one prospective cohort studies [Boshuizen et al., 1992; Schwarze et al., 1998; Bovenzi et al., 2002]; cold as the primary exposure in one cross-sectional study [Franzini and Benedyk, 1996]; forklift occupation as the primary exposure parameter in two cross-sectional studies [Brendstrup and Biering-Sorensen, 1987; Miyashita et al., 1992]; and, one intervention study including personal (i.e., lumbar support, arctic jacket, and physical exercise) and engineering controls (i.e., improvement of forklift seats and tires) [Shinozaki et al., 2001].

Description of Evidence

Evidence for the seven epidemiological studies linking forklift exposure to MSDs is summarized in Table II. In general, these observational studies reported significant associations between forklift operation as an occupation and MSDs. All studies, except one, are cross-sectional investigations. The study by Schwarze et al. [1998] included cross-sectional and cohort prospective examinations. The main outcome was lower back pain. The primary exposure variable was whole-body vibration in two studies, whole-body vibration and postural loading in one study, cold temperature in one study, and forklift as an occupational exposure in three studies.

Most studies showed significant association between exposure to forklift operation and lower back pain. No study examined the impact of forklift operation on neck pain, upper extremity MSDs, or other musculoskeletal outcomes.

Critical Epidemiological Appraisal

Findings from the critical appraisal summarized are below and in Figure 1.

Evidence reporting

Most studies (5) did not clearly describe the various aspects of the investigation (i.e., a study is given a partial score). The only exceptions are the studies by Bovenzi et al. [2002] and Schwarze et al. [1998].

Subject selection

All studies lacked details about subject selection. The scores ranged from ''marginal'' (0.5) to ''average'' (1.0).

Observation bias

The critical appraisal reveals that there is ''some'' potential for bias in most studies (6). At best, these studies scored ''marginal'' adequacy for addressing observation bias.

Confounders/covariates

Four studies accounted partially for some covariates, such as age. Two investigations did not account for covariates and one study covered all principal covariates.

Positive features of causation

Two studies examined dose-response relationships [Schwarze et al., 1998; Bovenzi et al., 2002]. Furthermore, one of the studies [Bovenzi et al., 2002] investigated the consistency of the relationship between exposure and outcome for different age groups.

External validity

Generalization of the results, from the study participants to the eligible and other relevant groups, can be extended to

TABLE II. Description of Evidence for Lower Back Disorder Studies Among Forklift Operators

Source	Description
Shinozaki et al. [2001]	
Exposure	Occupation as exposure variable (forklift operators)
Outcome	Lower back pain
Study design	Cross-sectional and intervention
Study population	27 forklift workers
	233 blue-collar workers (control group)
	Employed at copper-smelter plant in Northeast Japan
Main results	Forklift operators had significantly higher lower back pain than control at baseline
	Lower back pain among forklift operators was not significantly different from that of controls after 2 years intervention
	Overall 12-month prevalence for exposure group = 0.63
	Overall 12-month prevalence for control group = 0.32
Franzini and Benedyk [1996]	
Exposure	Cold temperature among forklift operators
Outcome	Musculoskeletal symptoms across several body regions
Study design	Cross-sectional
Study population	12 forklift operators in permanent cold store
	9 forklift operators in part-time cold store
	7 forklift operators in non-cold store (control group)
Main results	The cumulative musculoskeletal symptoms were higher for forklift operators in cold stores
	12-month prevalence ratio = 2.94 for permanent cold store and 2.15 for part-time cold store
Bovenzi et al. [2002]	
Exposure	Whole-body vibration and postural load among forklift and crane operators, straddle carrier operators in a transportation company
Outcome	Lower back pain
Study design	Cross-sectional
Study population	88 forklift drivers
	85 straddle carrier operators
	46 crane operators
	85 maintenance workers (control group)
	Transportation company in Northern Italy
Main results	Whole-body vibration and postural loading were significantly associated with lower back pain
	Overall 12-month prevalence ratio for forklift operators: 1.42 (95% CI 1.13–1.78) (adjusted for covariates)
Schwarze et al. [1998]	
Exposure	Whole-body vibration among forklift, truck and earth moving machinery operators from more than 30 companies
Outcome	Physicians diagnosed "lumbar syndrome"
Study design	Cross-sectional and prospective cohort
Study population	159 forklift operators
	64 truck drivers
	165 operators of heavy machinery
	65 controls (workers in the same companies who are not exposed to whole body vibration)
	Workers from more than 30 companies in Germany
Main results	The prevalence and incidence of lumbar syndrome was higher in the exposed group
	12-month prevalence for forklift group = 0.65
	12-month prevalence for control group = 0.59

TABLE II. (*Continued*)

Source	Description
Boshuizen et al. [1992]	
Exposure	Whole body vibration among forklift and freight container operators from six companies
Outcome	Lower back pain
Study design	Cross-sectional
Study population	242 drivers
	210 referent workers (control group—workers from the same companies who are not exposed to whole-body vibration)
	Subjects drawn from six ship companies in the Rotterdam harbor (Netherlands)
Main results	Lower back pain significantly higher among the exposure group
	Overall 12-month odds ratio: 2.2 (90% CI 1.03–4.7) (adjusted for multiple cofounders)
Miyashita et al. [1992]	
Exposure	Occupation as exposure variable (power shovel operators, bulldozer operators, forklift operators)
Outcome	Lower back pain
Study design	Cross-sectional
Study population	144 power shovel operators
	127 bulldozer operators
	44 forklift operators
	44 office workers (control group)
	Construction workers from different companies in Japan
Main result	Lower back pain was significantly higher among forklift operators
	12-month prevalence for forklift and control groups = 0.50 and 0.27, respectively
Brendstrup and Biering-Sorensen [1987]	
Exposure	Occupation as exposure variable (forklift operators)
Outcome	Lower back pain
Study design	Cross-sectional
Study population	240 male forklift operators from 13 companies in Copenhagen
	Control group from Copenhagen County (399 working men)
Main results	Forklift operators had significantly higher lower back pain than controls
	12-month prevalence for exposure and control groups = 0.65 and 0.47, respectively

only three studies [Boshuizen et al., 1992; Schwarze et al., 1998; Bovenzi et al., 2002].

The results of detailed critical appraisal of potential observation bias are presented in Figure 2.

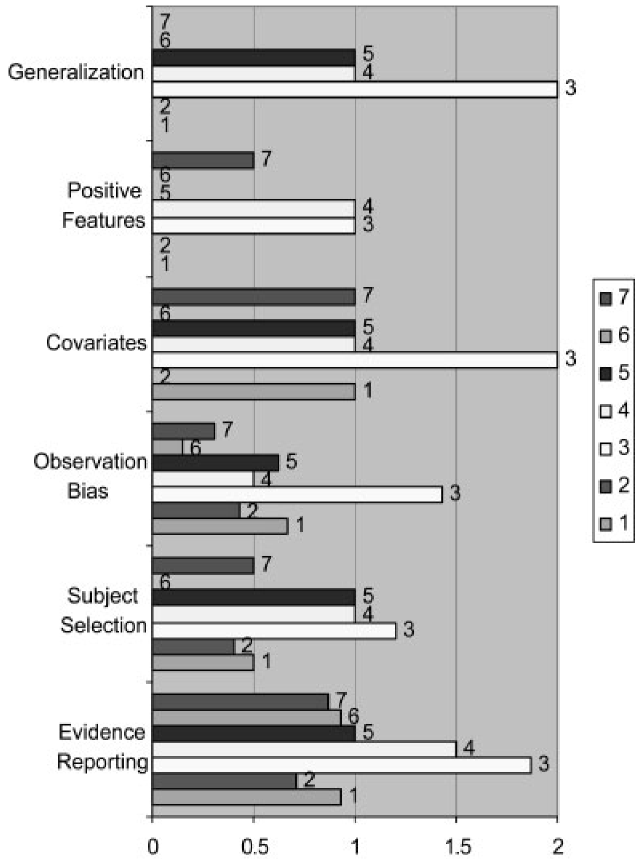
Exposure

The adequacy of exposure assessment ranged from ‘‘marginal’’ (0.5) to ‘‘moderate’’ (1.0). In most studies, the reliability and validity of exposure assessment was not adequately performed. Exposure and control methods were not comparable. For example, the longitudinal study by Schwarze et al. [1998] failed in assessing the exposure of the control group with respect to postural and manual material handling activities. As a result, the original control group was dropped from the follow-up study because the investigators could not explain the high prevalence of lower back pain among the controls in comparison to the exposed group.

Blind measurement/outcome/observation period

All studies except that by Bovenzi et al. [2002] either did not address the details of these items or were not taken into account. These findings may create some doubts about the internal and external validity of these studies.

To help determine the relative quality of the studies, we calculated an overall quality index for each epidemiological study, where the overall quality index is the average value for all items in the critical appraisal (i.e., including Figs. 1 and 2).



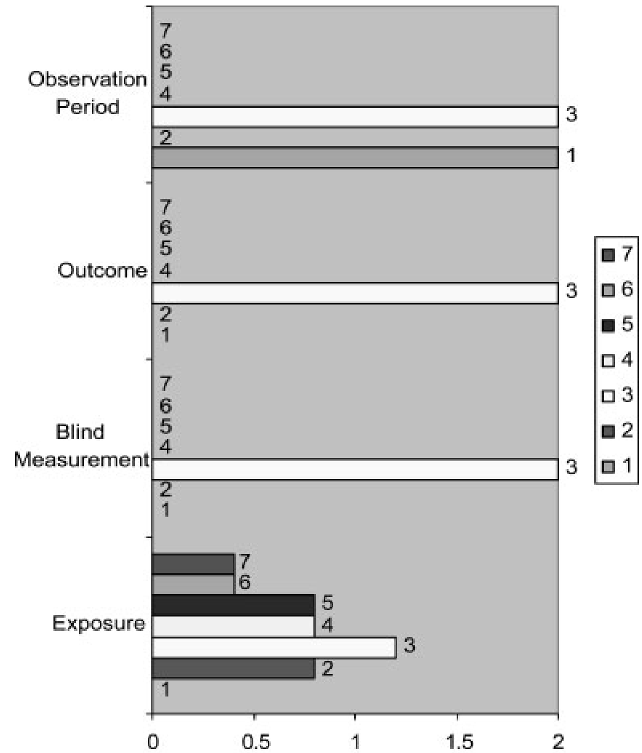
Note:

1 Shinozaki et al. (2001)
2 Franzini and Benedyk (1996)
3 Bovenzi et al. (2002)
4 Schwarze et al. (1998)
5 Boshuizen et al. (1992)
6 Miyashita et al. (1992)
7 Brendstrup and Biering-Sorensen (1987)

Scale interpretation:

"Yes" – 2 pts
"Partial" – 1 pt
"No" – 0 pt
"Unable to determine" – 0 pt

FIGURE 1. Critical appraisal of epidemiological studies on lower back disorders among forklift operators.



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1 Shinozaki et al. (2001)
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4 Schwarze et al. (1998)
5 Boshuizen et al. (1992)
6 Miyashita et al. (1992)
7 Brendstrup and Biering-Sorensen (1987)

Scale interpretation:

"Yes" – 2 pts
"Partial" – 1 pt
"No" – 0 pt
"Unable to determine" – 0 pt

FIGURE 2. Critical appraisal of epidemiological studies on lower back disorders among forklift operators—observation bias.

The results are listed in Table III. With an overall quality index of 1.5, the Bovenzi et al. [2002] study demonstrated the ''best'' methodological quality and, with an overall quality index of 0.22, the Miyashita et al. [1992] study had the lowest quality index value and was rated as the ''least'' adequate in terms of methodological quality.

Meta-Relative Risk

Table III summarizes the details of deriving the meta-odds ratio. The study by Franzini and Benedyk [1996] was excluded because the prevalence rates were not reported for the exposure and control groups, respectively.

Overall, the heterogeneity across the six studies was not significant at the 5% level (overall heterogeneity statistics = 6.226, with six degrees of freedom) [for details of heterogeneity test, see Elwood, 2000]. The meta-odds ratio was

TABLE III. Meta-Analysis for Lower Back Pain Among Forklift Operators (Using Confidence Limits Method)

Study no. (i)	Sample size for forklift group (prevalence)	Sample size for control group (prevalence)	Odds ratio (OR)	95% CL lower	95% CL upper	Variance	Weight (w1)	w1 ln OR	Heterogeneity	Overall quality index (w2)	Weight (w)	w ln OR
1	27 (0.63)	233 (0.32)	3.581	1.565	8.197	0.179	5.602	7.146	1.524	0.620	3.473	4.430
3	88 (0.78)	85 (0.52)	3.384	1.745	6.563	0.114	8.756	10.674	1.894	1.500	13.133	16.010
4	159 (0.65)	65 (0.54)	1.577	0.877	2.833	0.089	11.194	5.099	0.997	1.000	11.194	5.099
5	196 (0.41)	107 (0.31)	1.546	0.938	2.548	0.065	15.389	6.704	1.559	0.720	11.080	4.827
6	44 (0.50)	54 (0.27)	2.667	1.097	6.484	0.205	4.868	4.775	0.251	0.220	1.071	1.050
7	169 (0.65)	399 (0.47)	2.135	1.471	3.098	0.036	27.717	21.023	0.001	0.430	11.918	9.040
Total	683	943					73.525	55.420	6.226		51.870	40.457
		Overall OR w/o quality index weighting						Overall OR with quality index weighting				
		Summary ln OR $= \sum(w_i \times \ln OR_i)/\sum(w_i) =$		0.754				Summary ln OR $= \sum(w_i \times \ln OR_i)/\sum(w_i) =$			0.780	
		Summary OR = exp(ln OR) =		2.125				Summary OR = exp(ln OR) =			2.181	
		95% CI for summary OR $= \exp(\ln OR_i \pm 2.571 \times ((1/\sum w_i)\,\hat{}\,0.5))) =$				1.574	2.868	95% CI for summary OR=			1.527	3.117

1 Shinozaki et al. [2001]; data extracted from Table I; 3, Bovenzi et al. [2002]; prevalence extracted from Figure 1; 4, Schwarze et al. [1998]; prevalence extracted from Figure 1; 5, Boshuizen et al. [1992]; prevalence extracted from Table III; 6, Miyashita et al. [1992]; prevalence extracted from Table III and Figure 1; 7, Brendstrup and Biering-Sorensen [1987]; prevalence data extracted from text in page 448.

2.13 and was significant at the 5% level. In light of this, it is likely that forklift operators are at increased risk of having lower back pain compared to workers who do not operate forklifts.

By taking the overall quality index into account, the meta-odds ratio changed slightly from 2.13 to 2.18. The confidence limits were slightly wider (1.53, 3.12) than without accounting for the study methodological quality (1.57, 2.87).

DISCUSSION

To date, most occupational health and safety studies on forklift operation in the US have focused on the risk factors and conditions leading to fatalities and traumatic injuries [Collins et al., 1999a, 1999b, 1999c]. We were unable to locate any US studies that examined the relative risk of MSDs to which forklift operators may be exposed.

Overall, the methodological quality of the reviewed studies ranged from ''marginal'' to average (with the exception of one ''good'' quality study). In particular, the critical appraisal revealed the following: evidence reporting and accounting for confounders/covariates were ''somewhat adequate'' to ''adequate''; subject selection ranged from ''marginal'' to ''average''; the potential for observation bias was ''above average''; and, the external validity was ''average'' to ''strong'' in only three studies. With the exception of Schwarze et al. [1998], all of the studies were cross-sectional.

The meta-odds ratio of lower back pain among forklift operators was 2.13 and significant at the 5% level. We believe that the meta-odds ratio would be higher if the methodological quality of the studies was improved, as evidenced from the results of Bovenzi et al. [2002].

On the basis of this epidemiological appraisal, the study by Bovenzi et al. [2002] emerged as the ''best'' methodological quality investigation from among those reviewed in this paper. The researchers examined the impact of both postural loading and whole-body vibration among forklift operators, while accounting for potential confounders (age, body mass index, mental stress on current job, and back trauma).

The adjusted prevalence ratios for severe awkward postures and whole-body vibration in the Bovenzi study were significant at the 5% level: (1) bending forward ''very often''—4.00 (1.36, 11.60); (2) twisting ''very often''—2.15 (1.02, 6.21); (3) combined postural load ''very hard''—1.98 (1.38, 2.85); and (4) whole-body vibration—1.42 (1.13, 1.78). In light of these results, it appears that whole-body vibration and awkward postures are significant risk factors for forklift operators.

It should be noted, however, that the type of exposure assessment methods in the Bovenzi study was not the same for whole-body vibration and postural loading. While the assessment of whole-body vibration was based on only objective methods, the evaluation of postural loading was based on self-reports and observational techniques. Thus, there is a potential for observation bias. Additional biases may also be introduced due to self-reporting of both the outcome and postural loading by study participants. The aforementioned discussion suggests that future investigations should carefully evaluate exposure assessments and outcomes.

CONCLUSIONS

Seven epidemiological studies examined lower back disorders among forklift operators. In light of the systematic review conducted in this study, there is a critical need for epidemiological studies among US forklift operators. In this regard, the methodological quality of such studies should adhere to sound epidemiological principles. A comprehensive exposure assessment should be conducted in terms of the work-related factors ‘‘acting upon’’ and ‘‘experienced by’’ the forklift operators. In particular, attention should be paid to awkward postures, whole-body vibration, and their synergistic effects. Furthermore, the health effects with respect to neck pain should be investigated because information on this subject is currently not available.

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