ORIGINAL ARTICLE

Evaluation of an occupational health intervention programme on whole-body vibration in forklift truck drivers: a controlled trial

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Objectives: To evaluate process and outcome of a multifaceted occupational health intervention programme on whole-body vibration (WBV) in forklift truck drivers.
Methods: An experimental pretest/post-test control group study design. The authors trained occupational health services (OHS) in the experimental group in the use of the programme. OHS in the control group were asked to deliver care as usual. In total, 15 OHS, 32 OHS professionals, 26 companies, and 260 forklift drivers were involved. Post-test measurements were carried out one year after the start of the programme.
Results: Baseline data before the start of the programme showed no difference between experimental and control group. Results of the outcome evaluation indicate a slight, although not statistically significant, reduction of WBV exposure in the experimental group ($p = 0.06$). Process evaluation revealed a positive influence on company policy toward WBV, attitude and intended behaviour of forklift drivers, and a trend towards an increase in knowledge of OHS professionals and company managers. The number of observed control measures with a major impact (levelling of surface and reduction of speed) was rather low. In those cases where control measures had been taken, there was a significant reduction in WBV exposure. This limited effect of the programme might be caused by the short period of follow up and the dropout of participants. The feasibility and the usefulness of the programme within the OHS setting were rated good by the participants.
Conclusions: This programme to decrease WBV exposure was partially effective. Significant effects on intermediate objectives were observed. More research on the effectiveness of intervention in the field of WBV is needed.

Low back pain (LBP) is among the most common and costly health problems.[1 2] Occupational, non-occupational, and individual risk factors play a role in the development, the duration, and the recurrence of LBP. Several critical reviews have discussed the evidence on occupational risk factors for back disorders.[3–7] All these reviews conclude that there is strong epidemiological evidence for a relation between occupational exposure to whole-body vibration (WBV) and LBP. Whether this exposure is only a "modest"[7] or a substantial risk factor for the onset and recurrence of LBP is still a matter of debate. In five European countries (Belgium, Germany, Netherlands, France, Denmark), LBP and spinal disorders due to WBV are currently recognised as an occupational disease.[8] However, high exposures and adverse effects still occur as WBV is a common occupational risk factor for LBP, affecting 4% to 8% of the workforce in industrialised countries.[9] Important high risk groups are drivers of off-road vehicles (for example, earth moving, forestry, and agricultural machines), drivers of forklift trucks, lorries, or buses, crane operators, and helicopter pilots.

Knowledge about this occupational risk factor for LBP does not automatically lead to knowledge about the most effective strategy to cope with it. Earlier, Wegman expressed his concern with the danger of the academic discipline of epidemiology becoming divorced from applications to prevention in the workplace, thus increasing the distance between the development of and the practical application of new knowledge in the field of occupational health.[10] In this practical application of knowledge, Occupational Health Services (OHS) are urged to play a prominent role. Unfortunately, relatively little is known about the quality and effects of the care provided by OHS. This domain of health services research is largely underdeveloped in the field of occupational health.[11] In line with these findings, it is not surprising that literature on the effects of occupational health interventions with respect to WBV is lacking. Most of the research on vibration has concentrated on the "aetiological pathway" between external exposure, internal load of the human body (physiological and biomechanical effects), and adverse health effects.

We conducted a research project on development and evaluation of a prevention programme on WBV carried out by OHS. The objective of the study presented in this paper is to evaluate process and outcome of the programme developed for the occupational group of forklift drivers.

The following study objectives were formulated:

- Does training and instruction of OHS staff lead to an increase of knowledge and attitude on WBV related issues of the OHS professionals?
- What is the feasibility and usefulness of the programme within OHS, as judged by OHS professionals?
- What is the effect of the programme on knowledge, attitude, and behaviour among company management and forklift drivers?

Abbreviations: INRS, Institute National de Recherche de Sécurité; LBP, low back pain; OH, occupational hygienist; OHS, occupational health services; OP, occupational physicist; WBV, whole-body vibration

- Is there a reduction of WBV exposure magnitude in work situations where the programme has been carried out in comparison to work situations without the programme?

METHODS

The intervention: a multifaceted OHS programme on WBV

A comprehensive survey in Dutch OHS revealed a low involvement in vibration problems, a lack of skills by professionals, and a demand for practice guidelines.[12] We selected the occupational group of forklift truck drivers because of their high exposure to WBV, its significance in industry, and a high prevalence of LBP.[13] The major determining factors of the vibration exposure in this group are rather well known.[13–15] A specific OHS programme on WBV was designed for drivers of forklift trucks consisting of measurement and evaluation of WBV, report and advice to the management, and a health education programme for the drivers. The development of this programme is described elsewhere.[16] The intervention model, presented in figure 1, summarises the intended intermediate objectives and ultimate goal.

We adapted a measurement protocol according to van der Weiden *et al* and in accordance with ISO 2631-1.[17 18] The protocol included guidelines for the determination of the minimum number of work situations to be measured in order to obtain a representative survey of driver's *tasks* (for example, loading/unloading of a lorry). In a task, different *situations* can be distinguished when it is performed in different circumstances (for example, driving on different surfaces) or by different workers. Acceleration magnitude of WBV was measured according to the requirements proposed by the Council of the European Union in the Directive for physical agents.[19]

A standardised format of a report for managers provided information on legislation on WBV, measurement results, and advice on strategies to reduce exposure. Additional material contained information on ''vibration and shock in forklift trucks'' based on the ''rule of seven''—seven basic measures to decrease exposure to WBV in forklift drivers, adapted from the Institute National de Recherche de Sécurité (INRS) in France.[20] These measures comprise: levelling of the ground surface, adaptation of the driving speed, suitable tyres, choice of a truck adapted to the task, optimal suspension of the seat, adjustment and maintenance of the seat.

The educational programme for forklift drivers provided information on the major causes of high exposure to WBV in forklifts and offered guidance for safe behaviour. The leaflet *Back complaints on the fork-lift truck: they are preventable* urges drivers to reduce speed and adopt a calm driving style. It also presents guidelines on seat adjustment. Parts of this leaflet were also, with permission, adapted from an INRS example.

During two halfday plenary sessions and one halfday in-company instruction, we trained occupational physicians (OPs) and occupational hygienists (OHs) from the experimental group. Information aids were distributed. Instruction in vibration measurement was carried out in one of the selected plants separately for each OHS.

Study sample

Occupational health services in the Netherlands were informed about the project and asked to participate. We used the following as inclusion criteria for OHS participation:

- able to select two different companies or plant departments, each with a minimum of 10 forklift drivers, to carry out the intervention programme
- participation of two OHS professionals (OP and OH or occupational health nurse)
- readiness of these professionals to attend an information and instruction course.

As a result, 23 OHS were interested. Six services were not able to obtain collaboration of the selected companies. Initially, 17 OHS agreed to participate. Sample size requirements were determined by the major question in this study: the effect of the programme on WBV exposure levels of work situations in the selected companies. According to a power calculation (power of 0.90 with one-sided $\alpha = 0.05$), with the requirement to detect a 15% reduction for the intervention group, based on previous data of vibration measurement accuracy,[14 17] at least 18 observations of work situations should be included in both the experimental and control group. For this purpose, the number of participants was considered sufficient.

Because of possible selective assignment, four OHS with (self-reported) available expertise on WBV were equally distributed over the experimental ($n = 9$) and the control group ($n = 8$) while the other OHS were randomly assigned. Just before the start of the study, two OHS in the control group withdrew for reasons not related to this study. Ultimately, 15 OHS participated in the study—nine in the experimental group and six in the control group. Two of the participating OHS in each group could select only one company or department for the study. The total number of plants or plant departments included in the study is 26 of which 16 were in the experimental group (180 drivers) and 10 the control group (80 drivers) (table 1).

Study design

Pretest questionnaire measurements in the experimental group were conducted before the start of the training. Post-test measurements were conducted one year after the start of the programme. OHS professionals in the control group did not receive training and were asked to deliver care ''as usual'' in the chosen plants. Pre- and post-test measurements in the control group were conducted in the same time period as in the experimental group. After the post-test measurements, the programme was also offered to the control group (''waiting list or delayed programme design'').

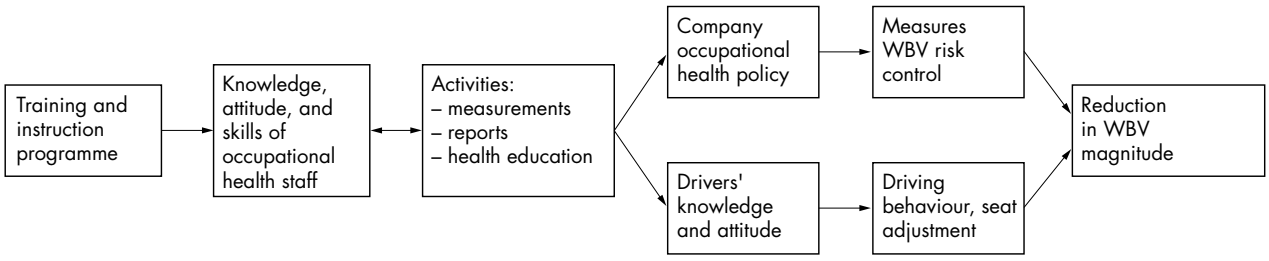

Figure 1 Model of intervention programme to decrease exposure to whole-body vibration (WBV).

Table 1 Number of participants involved in various parts of the study, number of dropouts, non-responders, and final numbers included in the analyses (both pre- and post-test)

	Experimental group (n)				Control group (n)			
Participants	At start	Dropout	No response	Both pre- and post-test	At start	Dropout	No response	Both pre- and post-test
Occupational Health Services	9	1		8	6	2 pre		6
OHS professionals	18	5		13	11	1 pre, 2 post		8
Departments	16	4		12	10	1 post		9
Managers	12	7		5	10	1		9
Drivers	158	62	31	65	76	15	27	34
Worksites	141	61		80	62	16		46

Process evaluation monitors how the outcome of a programme was achieved and it may sometimes be even more informative than outcome evaluation.[21] We therefore studied the degree of compliance with programme components and evaluated whether the programme affected intermediate objectives such as knowledge of management and changes made at the workplace.

Measures

Occupational health service professionals' knowledge of and attitude towards WBV was assessed with a self-administered questionnaire. For knowledge, a sum score was made of 22 questions on WBV related issues—for example, effects, measurement, legislation, standards, control measures (range 0 to 22). In 18 questions on attitude, we asked the professionals' opinions about prevention of WBV effects, influence of the OHS itself, the role of company management and forklift drivers, and expectancy with regard to the programme. Answers on a five-point Likert scale were rated by assigning a value from −2 to +2, where a positive score was related to a positive attitude and expectancy towards the preventive possibilities of the programme and a negative score to a negative attitude and a pessimistic expectancy.[22] A sum score was calculated of all attitude questions (range −36 to +36).

We measured compliance with the programme with a questionnaire completed by the OPs and OHs. For each plant, a compliance score (range 0–3) was given, one point for each of the three major activities performed by the OHS: evaluation of exposure, a written report to management, and a health education programme for the forklift drivers.

We evaluated managers' knowledge on WBV issues with a 12 item list (sum score range 0–12) and company policy toward WBV with 18 items. Questions asked for floor maintenance, purchase and maintenance of trucks, seats and tyres, instruction of drivers. For both general policy (range 0–4) and specific WBV policy (range 0–11), sum scores were calculated.

Implementation of measures on WBV that could be related to OHS advice were evaluated by observation during post-test vibration measurements. Changes due to OHS advice—for example, other truck, other seat, track improvement—were recorded in the measurement report. A ''risk control score'', ranging from 0 (no changes) to 1 (minor change, one of the parameters) or 2 (major change of surface and speed) was used. For both experimental and control work situations, these risk control scores were assigned independently by two of the authors (CH, IB). The few discrepancies with respect to the score were resolved by consensus.

Whole-body vibration related knowledge, attitude, and actual health and safety behaviour of the forklift drivers was tested with a self-administered questionnaire. We assessed behaviour in relation to driving style, speed, and seat adjustment, track conditions, working schedules, and fitness. An adapted version of the IE-18 locus of control questionnaire was used to investigate how drivers in general perceive their influence on events in their environment.[23] The forklift driver questionnaire was tested on comprehensibility in a group of drivers from a plant not participating in the study.

With all pretest questionnaires, we constructed scales which were tested for internal consistency by Crohnbach's alpha. The reliability was considered acceptable for knowledge ($\alpha = 0.81$), behaviour ($\alpha = 0.56$), and locus of control ($\alpha = 0.67$). Scale scores for knowledge ranged from 0 to 22, for attitude from −42 to +42, for behaviour from −33 to +33, and for locus of control from −50 to +50. Again, a positive score is related to a positive attitude or behaviour toward control of WBV. For the post-test, we added 10 questions on *intention to change behaviour* on WBV and asked whether barriers for such change existed.

Personal experiences with the feasibility and usefulness of the programme within the daily OHS practice setting were evaluated with a process evaluation questionnaire completed by the OHS professionals.

In the experimental group, the results of the vibration measurements were used by the OHS as input for the programme and by the researchers as a pretest evaluation. In the control group plants, measurements were performed and used by the researchers exclusively; neither OHS professionals of the control group nor company management were informed about the results. Work situations that, in agreement with the measurement protocol, constituted a representative survey of driver's tasks were selected and documented. Vibration levels were measured at the seat of the forklift trucks by means of a tri-axial accelerometer (Brüel and Kjær 4322, Naerum, Denmark). In accordance with ISO 2631-1, frequency weighted root mean square (rms) acceleration signals in vertical (z) and horizontal (x and y) directions were recorded using a Brüel and Kjær 2522 human vibration unit. Time weighted averages of the vibration magnitude of at least five minutes per situation were determined using the vector sum of the overall frequency weighted acceleration in the x, y, and z directions in ms^{-2} rms. During the post-test measurements, acceleration magnitudes of vibration for the same work conditions as documented during pretest measurements were determined.

Statistical analysis

All data analyses were performed with SPSS for Windows, version 10.0. The distribution of variables (all continuous or interval variables) at baseline showed no significant deviance from normality. Pretest differences between experimental and control group were investigated by Student *t* tests and by analysis of variance (ANOVA). For this we used a two-tailed

Table 2 Baseline measurements of whole-body vibration (WBV) questionnaires, mean (SD), differences non-significant if not stated otherwise

	Experimental group	Control group	95% CI for difference
OHS professionals	(n = 18)	(n = 11)	
OHS size: serving <20 000 employees	15%	17%	
Knowledge on WBV (0 to 22)	12.5 (3.0)	13.7 (2.9)	(−1.2 to 3.5)
Attitude (−36 to +36)	12.1 (6.1)	8.2 (8.2)	(−10.2 to 2.5)
OHS can play important role in prevention of effects of WBV (agree)	44%	45%	
Plant managers	(n = 12)	(n = 10)	
Knowledge on WBV (0 to 12)	9.8 (1.3)	10.8 (0.8)	(0.1 to 1.9)*
General company policy on health and safety (0 to 4)	2.3 (1.0)	2.1 (1.0)	(−1.0 to 0.7)
Written annual health and safety plan available? (yes)	75%	90%	
Company policy on WBV (0 to 11)	4.9 (2.2)	5.2 (1.6)	(−1.4 to 1.9)
Attention for WBV is included in the annual health and safety plan (yes)	17%	30%	
Forklift drivers	(n = 158)	(n = 76)	
Mean age (years)	36.9 (10.1)	36.7 (9.0)	(−2.8 to 2.4)
Lower vocational education (%)	68%	72%	
Experience on the truck (years)	8.1 (7.7)	10.1 (7.6)	(−0.1 to 4.1)
Knowledge on WBV (0 to 22)	15.7 (3.0)	15.8 (2.6)	(−0.7 to 0.8)
Driving fast leads to higher vibration level (yes)	92%	88%	
Attitude on WBV (−42 to +42)	13.1 (10.0)	14.9 (10.0)	(−1.0 to 4.7)
Driving fast is inevitable (agree)	50%	47%	
Actual behaviour on WBV (−33 to +33)	2.8 (9.1)	1.2 (9.3)	(−4.4 to 1.1)
I adjust my seat (often or always)	77%	72%	
My driving speed is fast (idem)	68%	72%	
I pay attention to surface conditions	49%	50%	
Locus of control (−50 to +50)	31.6 (5.9)	32.2 (7.5)	(−1.4 to 2.6)

*Two-tailed *t* test, p = 0.04.

test and 95% confidence intervals. For the evaluation of the effect on the major outcome and process variables, gain scores (post-test minus pretest results) were calculated. Two-sample *t* tests or Mann-Whitney U tests were used to test differences between the gain scores in the experimental and the control group. For testing the differences between post-test and pretest, we have used one-tailed tests because of our hypothesis and a priori expectancy that the direction of the changes in the intervention group was only in one side. In order to decrease the probability of a type II error (given the small sample size) and also to detect a possible trend in the results, we chose to use 90% confidence intervals. A significance level of $p<0.05$ was used. A p value between 0.05 and 0.10 was considered a trend. The relation between process variables and outcome was studied by analysis of variance. To evaluate the effects of the programme, only the results of paired observations—that is, WBV exposure levels of work situations or completed questionnaires from which both pretest and post-test measurements were available, are included in the analysis. We analysed the relation between process variables and outcome with one-way analysis of variance. For that purpose, we calculated tertiles from the intermediary process variables that subsequently were used in the analysis of variance. Within the intermediate objectives, mean scores of tertiles showed relevant differences. The F values and p values from the one degree of freedom test of the orthogonal polynomials are reported as a measure of trend over the tertiles.

RESULTS

Post-test data could be obtained from 12 companies covered by eight OHS in the experimental group, and nine companies of the six OHS in the control group. One OHS with two companies and one company from another OHS in the experimental group withdrew after the pretest because of severe financial problems. Lack of time of the participating OP was the cause of the fourth dropout. One company in the control group was lost to follow up because approval for the post-test could not be obtained (table 1).

Table 3 Pre- and post-test means and gain scores of the whole-body vibration (WBV) exposure levels of work situations for whom pre- and post-test data were available

	Experimental group (n = 73)	Control group (n = 39)	
	Mean a_{sit} (m/s^2) (SD)	Mean a_{sit} (m/s^2) (SD)	90% CI for difference
Pretest mean M1	0.92 (0.33)	0.86 (0.25)	(−0.05 to 0.17)
Post-test mean M2	0.84 (0.29)	0.89 (0.49)	(−0.21 to 0.11)
Gain score M2- M1	−0.08 (0.35)	0.03 (0.33)	(−0.22 to 0.00)*

*Difference in gain score: p = 0.06, *t* test, one tailed.
(a_{sit}, vectorsum of the frequency weighted accelerations; M1, measurement at pretest; M2, measurement at post-test).

From 203 work situations, data were collected during the pretest measurements; 141 situations in the experimental group plants and 62 in the control group. The frequency weighted rms acceleration magnitude of vibration averaged 0.81 m/s^2 (SD 0.34) in the experimental group and 0.80 m/s^2 (SD 0.28) in the control group. In the majority (86%) of the operating conditions, exposure to WBV was in excess of 0.50 m/s^2 rms (the EU action value at the time of the study).[19] In 56% of the conditions, the acceleration magnitude of vibration exceeded 0.70 m/s^2 rms (the maximum limit value at the time of the study). Table 2 summarises the results of the pretest questionnaires. This is considered as enough potential for changes in the desired direction.

Effects on WBV exposure levels

Because OHS professionals generally limited their advice to reduce the WBV exposure to situations above the action value

Table 4 Pre- and post-test means and gain of sum scores on knowledge and attitude on whole-body vibration (WBV) issues among OHS professionals for whom pre- and post-test data were available

	Experimental group (n = 13)	Control group (n = 8)
	Mean sum score (SD)	Mean sum score (SD)
Knowledge		
Pretest mean M1	12.3 (3.2)	12.5 (2.1)
Post-test mean M2	15.3 (2.2)	13.3 (2.5)
Gain score M2-M1	3.0 (2.9)	0.8 (3.0)*
Attitude		
Pretest mean M1	13.5 (5.7)	6.4 (8.9)
Post-test mean M2	13.0 (8.5)	8.5 (7.7)
Gain score M2-M1	−0.7† (7.6)	2.7† (7.3)

†Due to missing values, a gain score from one case could not be calculated.
*Difference in gain score: Mann Whitney U test, p = 0.08, one-tailed.

of 0.50 m/s^2, only work situations with a vibration magnitude above 0.50 m/s^2 during the pretest measurements were included in the analysis (table 3). This excludes 11% of the available paired observations. The results in table 3 show a reduction of about 10% of the mean value of rms acceleration magnitude in the experimental group, which is lacking in the control group ($p = 0.06$).

Effects on knowledge and attitude of OHS professionals

The knowledge score of the professionals in the experimental group showed a trend towards improvement which did not show for attitude (table 4). In the control group, an increase towards a positive attitude on an active OHS and company approach was found. The pretest score in the experimental group was already at a higher (more positive) level. Neither of the differences is statistically significant.

Compliance

The degree of compliance with the programme shows some variation between the participants. Our information material was not always used; some OHS in the intervention group developed their own information aids. Also health education activities towards the forklift drivers have been conducted in different ways. However, the main three programme components were carried out in most companies by the OHS in the experimental group. The compliance score, assessed by two of the authors (CH, IB) independently from the answers of the process evaluation questionnaire completed by the OHS professionals and from the available documents (for example, measurement reports), ranged from 2 (in two companies) to 3 (in 10 companies).

Effects on managers

Of the 11 post-test questionnaires in the experimental group, only five were completed. There was a trend towards improvement for knowledge and a significant improvement in company policy in the experimental group (table 5).

Effects on forklift truck drivers

The scores for attitude and intention to change behaviour improved significantly more in the experimental group in comparison with the control group. Improvements in knowledge and actual behaviour were not different (table 6).

Effects on changes at the workplace

In the experimental group, changes due to OHS advice occurred in 51% of the work situations, in 37% leading to a risk control score of 1 (minor change) and in 14% to a score of 2 (major change). In the control group, no changes due to OHS advice were observed.

Table 5 Pre- and post-test means and gain of sum scores on knowledge of plant managers on whole-body vibration (WBV) and company policy on WBV control

	Experimental group (n = 5)	Control group (n = 9)
	Mean sum (SD)	Mean sum (SD)
Knowledge		
Pretest mean M1	10.0 (0.7)	10.9 (0.8)
Post-test mean M2	10.4 (1.5)	9.9 (1.5)
Gain score M2-M1	0.4 (1.3)	−1.0 (1.7)*
Company policy on WBV		
Pretest mean M1	4.4 (1.5)	5.0 (1.6)
Post-test mean M2	8.6 (1.9)	6.8 (2.6)
Gain score M2-M1	4.2 (2.3)	1.8 (1.7)**

*p for difference in gain score = 0.08, Mann-Whitney U test, one-tailed
**p = 0.02, Mann-Whitney U test, one-tailed.

Feasibility and usefulness of the programme within OHS

Fourteen OPs and OHs completed the process evaluation questionnaire (response 78%). Feasibility and usefulness of the programme was rated positive: 92% judged the measurement protocol, 64% the standardised report, and 93% the information material (transparencies, document, leaflet) as useful in the OHS practice. Fifty seven per cent reported to have actually used the offered standardised report, 93% the information document and the leaflet, and 71% the transparencies. Some OPs and OHs indicated to have spent more time on the programme than was estimated before the start. The mean time used for participation in the project and execution of the programme was 42 hours (ranging from 14 to 80). This was rated ''too much'' by 36% and ''acceptable'' by 57%.

Relation between process variables and outcome

ANOVAs revealed a statistically significant relationship between ''risk control score'' and change in WBV exposure (table 7). A clear difference exists between the work situations without observed control measures and those with the highest risk control score which indicates a major change after the pretest. Additional analyses showed that, for this last category, a significant and meaningful reduction in the mean value of acceleration magnitude was observed during operating conditions (0.26 m/s^2 rms, $p = 0.02$). However, with the exception of knowledge of OH for the other intermediate objectives, no clear and significant relation could be observed.

DISCUSSION

We found a marginally significantly higher reduction of vibration exposure in the experimental group in accordance with better results for OH professionals' and managers' knowledge, company policy, and workers' attitudes. The more changed at the workplace the better the reduction of WBV exposure.

As far as we know, we are the first to report on a controlled trial with pre- and post-test measurements on the reduction of WBV. The strength of our study is that we were able to measure the WBV exposure in both experimental and control group before and after the intervention. The intervention was a complex one, educating occupational health professionals, management, and workers at the same time. This is in line with what is advocated for complex behavioural interventions to change, for example, medical practice—that it is best to intervene at multiple points.[24] Still, the programme's feasibility to be carried out in real practice was good. The

Table 6 Pre- and post-test means and gain of sumscores on knowledge, attitude, actual behaviour, and intended behaviour of forklift drivers

	Experimental group (n = 65)	Control group (n = 34)	90% CI for difference
	Mean sum (SD)	Mean sum (SD)	
Knowledge			
Pretest mean M1	15.9 (2.8)	16.2 (2.4)	(−1.5 to 0.7)
Post-test mean M2	16.5 (2.3)	16.3 (3.0)	(−1.0 to 1.3)
Gain score M2-M1	0.6 (2.2)	0.1 (3.1)	(−0.5 to 1.6)
Attitude			
Pretest mean M1	13.5 (10.2)	16.1 (9.5)	(−6.8 to 1.7)
Post-test mean M2	18.1 (10.7)	16.5 (9.4)	(−2.7 to 6.0)
Gain score M2-M1	4.7 (8.8)	0.6 (9.7)	(0.6 to 7.3)*
Actual behaviour			
Pretest mean M1	2.9 (9.7)	0.7 (10.3)	(−2.2 to 6.8)
Post-test mean M2	4.0 (9.7)	3.4 (8.1)	(−3.2 to 4.3)
Gain score M2-M1	1.3 (7.7)	3.2 (6.9)	(−4.6 to 0.8)
Intended behaviour			
Mean sum score	8.3 (1.7)	6.8 (1.7)	(0.8 to 2.1)**

*p for difference = 0.03, *t* test, one-tailed; **p<0.001, *t* test, one-tailed.

circumstances were almost similar to ordinary occupational health practice.

In addition, we were able to measure many different aspects of the chain of events between the education of occupational health professionals and the final outcome of reduction of WBV. In all links we found at least one positive outcome.

We used both objective and subjective measurement instruments to measure the outcome and process variables. Measurements of the vibration levels with adequate and calibrated measuring equipment were conducted according to the guidelines of the international standard ISO 2631-1. In this study, we did not perform duplo measurements. From previous studies, using the same equipment and following the same guidelines, it is known that measuring inaccuracy was around 5%, which was regarded acceptable.[25] Regarding the evaluation of the changes after the intervention, the evaluators were not blinded for the group assignment. This could have biased the results. However, we feel that there was little room for a subjective influence because the risk control score had clear criteria.

As we were unable to find previously used and validated questionnaires for our study, we have designed different questionnaires directed to the target groups. We derived different scales for evaluating the effects on the intermediate objectives. All Crohnbach's alpha values of the used scales were above 0.50, which, for this purpose, generally is considered acceptable. An insufficient ''discriminating power'' of some of these scales may have contributed to limitations in effects—for example, for knowledge, plant managers' and drivers' score at pretest were already at a relatively high level suggesting that questions may have been too easy.

We feel that we were well able to control contamination or spill over of programme effects to the control group. We withheld information on the results of the pretest measurements to the OHS of the control group during the follow up period. During the study period, we received one request from a plant manager belonging to the control group for advice and information material. This was refused and he was referred to his own OHS.

However, a weakness of our study is that we were not able to convincingly show that the programme led to a greater reduction in WBV exposure than in the control group. It is possible that the design of our programme was based on too optimistic expectations of the impact of the OHS activities in the companies and perhaps should have been more rigorous. A drawback of such an approach would be the limited feasibility in an OHS daily practice setting. In a review on intervention research in occupational health and safety, Goldenhar and Schulte concluded that many of the studies reviewed suffered from too short duration of intervention exposure and/or too short period of follow up.[26] In our study, post-test measurements were conducted one year after the start of the programme. This relatively short follow up could have resulted in the limited effect. However, after the post-test measurements, the programme was also offered to the OHS of the control group. All participating OHS in the control group accepted this offer. Therefore, investigation of a sustained effect by comparing experimental and control group over a longer period was not possible. Although the follow up may have been short with respect to expected outcome, comparability of work situations between pretest and post-test was already problematic. During the post-test measurements, we were confronted with a considerable turnover of forklift drivers and a change in work tasks of

Table 7 Results of analyses of variance of the relation between gain scores of intermediate objectives and change in whole-body vibration (WBV) exposure level; mean levels and standard deviations of WBV change (post–pre) per tertile of the intermediary objective

	n	First tertile	Second tertile	Third tertile	F value	p Value
Knowledge of OH	16	0.10±0.26	−0.01±0.09	−0.17±0.11	4.81	0.047
Knowledge of OP	10	0.11±0.24	−0.17±0.11	−0.03±0.08	1.02	0.344
Company policy on WBV	13	0.06±0.22	−0.03±0.23	0.09±0.22	0.04	0.853
Attitude of drivers	69	−0.02±0.19	0.00±0.26	−0.04±0.29	0.06	0.803
Actual behaviour of drivers	74	−0.05±0.28	−0.01±0.25	0.01±0.22	0.84	0.364
Intended behaviour	70	0.04±0.19	−0.02±0.16	−0.03±0.28	1.1	0.290
Risk control score*	110	0.01±0.32	−0.09±0.27	−0.26±0.62	5.4	0.022

*For this variable we did not use tertiles but the actual score (respectively 0, 1, 2).

some of the companies. This may hamper similarly designed studies with a longer follow up.

The self-report of actual driver behaviour did not change. Fifty one per cent of the drivers in the experimental group and 47% in the control group saw barriers for reduction of the driving speed, and 43% (35%) reported barriers for paying attention to the surface. In both cases, the tight working schedule was mentioned as the cause. Another possible explanation for the lack of change is that we did not put enough effort in the health education component of the programme. The OPs of the experimental group were not always present at the health education meetings in their companies.

Our study suffered from dropout of study participants. In the majority of the cases, this resulted from reasons clearly not related to this study—for example, severe financial problems, closing of a factory, changing priority in an OHS, and departure of OP, plant manager, or drivers. To determine if the OHS, plants, and forklift drivers remaining in the study were different from the dropouts, a non-response analysis was conducted. We compared the available pretest data between these groups and found no statistically significant differences on questionnaire results or mean vibration levels. Although the exclusion of participants probably did not result in selective dropout, it possibly had impact on the sample size and consequently on statistical power.

There are, as far as we know, no similar studies on WBV available for comparison. In a short report, Ballé and Köhne described a decrease in disability of earth moving equipment operators in a large mining company over the period 1981–87 due to several preventive measures on WBV, but relevant data are lacking.[27] In a Dutch paper, positive effects on target behaviour of forklift drivers were noticed by an OHS but results were only tentative.[28] Johanning *et al* conducted an intervention study in mass transit operators in Munich, but the impact of improving the work environment could not be assessed.[29] Harvey Cohen and Jensen found that a training programme of forklift drivers improved on the job behaviour, but they did not measure WBV.[30] Shinozaki *et al* studied two different approaches for the prevention of LBP in forklift workers but did not evaluate the effects of these approaches on the WBV magnitude.[31]

The results of our study can be generalised to other OHS because there was a wide variety of OHSs with respect to size, type of organisation, and experience with WBV. In addition, the acceleration magnitude of WBV is consistent with measurement data reported in the literature.[9 13]

In conclusion, the effectiveness of an OHS programme on WBV in forklift drivers is only partially demonstrated. Beneficial effects on company policy, attitude, and intention to change behaviour of drivers were observed. Feasibility and usefulness of the programme within the OHS setting was rated good by the OHS professionals. The insufficient intensity of the programme, the short period of follow up, and the limited power due to dropout of participants may have limited a more positive effect. The findings are encouraging but more prevention effectiveness research in the field of WBV is needed to draw more definite conclusions.

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Main messages

- Measures to reduce exposure to whole-body vibration (WBV) in companies can be aimed at improvement of workplace, working equipment, and driver behaviour.
- Occupational health services can be trained in the reduction of WBV exposure.
- If preventive measures are taken, WBV magnitude can decrease.
- Advice to companies has a positive impact on knowledge of managers and company's preventive policy.
- It is unclear if forklift truck driver behaviour can be changed with health education.
- The evidence of the overall effectiveness of a prevention programme for WBV is inconclusive.

Policy implications

- Occupational health services should be trained in evaluation and reduction of WBV exposure.
- Measures such as workplace improvement and changing forklift truck drivers' behaviour should be better promoted.
- Companies are entitled to adequate advice about the reduction of WBV.
- Until better evidence is available, a broad range of preventive measures for WBV should be implemented at the same time.

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