Assessment of vibration and other physical work demands at the work site: A longitudinal study

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Abstract

In the light of the new European directive to protect workers against harmful whole body vibration (WBV) during working activities, new preventive measures are needed. Therefore insight in the physical work demands for workers who are exposed to WBV is necessary. In this study the physical work demands are assessed (5 in total) by using the PalmTrac system during a normal working day. To explore the validity of this assessment in combination with a WBV measurement, drivers (n=10) are measured at two different time points, at baseline (T0) and after a follow-up period of 11 months (T1). Analysis revealed a significant difference in total time (in min) spend for each individual driver on the physical work demand sitting twisted / leaning back; (95 % CI [1.8 21.6], p= 0.03). An obvious trend (lower WBV values for T1 compared to T0) but no significant differences are found between To and T1 for WBV levels in the three directions. It is concluded that intra individual assessment over time of physical working demands show considerable variations in total time. Therefore in formulating preventive measures to reduce exposure for drivers, one should account for individual differences over time.

2.2. Keywords: Methodological, physical work demands, whole body vibration, longitudinal

1. Introduction

Workers exposed to whole body vibration (WBV) are at high risk of developing low back pain. A new European directive on Physical agents (July 2002) is developed and introduced in the national legislation. This Directive establishes minimum requirements for the protection of workers from risks to their health and safety that arise or are likely to arise from exposure to mechanical vibration. In the light of this newly introduced Directive a multi-centre project on the risks of Occupational Vibration Injuries (VIBRISKS) was started with a grant from the European Commission (www.humanvibration.com). This paper presents a study that forms a part of Work Package 5 of this project.

Exposure to WBV is often related to other physical work demands as sitting in a constrained posture or lifting heavy loads. An advantage of measuring different physical work demands simultaneously with measurement of the vibration exposure is that it yields information about the physical work demands during the measurement period. Apart form epidemiological purposes, this information might be helpful for formulating preventive measures.

Physical work demands in general can be assessed by using (self administered) questionnaires and by using more objective measures. One of these more objective methods is the PalmTrac (Task Recording and Analysis on Computer) system [3]. Previous studies [1, 4] show that subjective assessments of physical work demands are not very reliable. It is known that using PalmTrac gives reliable results as the inter-observer reliability in terms of percentage agreement of different observations varied between 85% and 95% (dependent of body region) [8] although very dynamic work reduces the validity of the system [2, 6].Most of this studies used, however, cross sectional data. Observation of a specific group of drivers more than once to assess possible differences in total time spend on physical work demands in relation to exposure to WBV within comparable working environments is to our knowledge, not yet done.

Therefore the aim of this article is to explore longitudinally a group of drivers for variance in total time spend on physical work demands in combination with the exposure to WBV in working situations.

2. Methods

2.1. Population

A group of drivers (N=10) of wheeled loaders and other earth moving equipment vehicles were randomly selected and included from a larger population. This larger study population was selected for the previous mentioned VIBRISKS study and consists of drivers exposed to WBV during their normal work activities. The included drivers were working in 7 different companies.

2.2. Longitudinal study

In this study WBV is measured according to ISO 2631-1 together with the simultaneously measurement of 5 different physical work demands:(1) Walking + Standing, (2) Bending over (straight or twisted), (3) Sitting, (4) Sitting- twisted / lean back and (5) Lifting. In a pilot study these five physical work demands appear to comprise the demands during a normal working day of the drivers chosen in this study. The WBV and the physical work demands, with the use of the PalmTrac system, are assessed at two different time points for the same group of drivers and during their normal working duties. At baseline (T0) and after a follow up period of 11 months (T1) for the same group of drivers and during their normal working duties.

2.3. *Physical work demands*

The physical work demands were assessed by the use of the PalmTrac system: an inexpensive, easy to learn and quick to use (direct) observation method. Trac is an observation method which was originally developed at the Robens Institute (University of Surrey, UK) and further adapted by the Study Centre on Work and Health/ERGOcare (Academic Medical Centre, Universiteit van Amsterdam & Vrije Universiteit, Amsterdam the Netherlands) [3]. Figure 1 shows the different features of the system. Step 1 is the observation at the workplace by video camera of the population of interest. During this observation the timing and elements of the most important and representative certain work cycles are assessed together with their repetitions. Step 2: based on analyzing the video, tasks as well as the activities, postures and extra information should be ordered in a tree-diagram (the library). In the creation of this library an important activity is the accurate definition of the tasks, the activities, the postures and the extra information. This is to ensure high intra- and inter observer reliability. PalmTrac enables the observer to choose and define the variables and the categories within variables to be recorded at the workplace. Step 3 is the transfer of the library to the Personal Digital Assistant (PDA). Step 4 is performing the actual observation at the worksite followed by step 5 the transfer of the observed data to the computer. Step 6 is the last step to edit, process, link and calculate the duration, the frequency and the intensity of the physical demands of the assessed observation during the normal work day. A full description of the Trac system is published earlier [3].

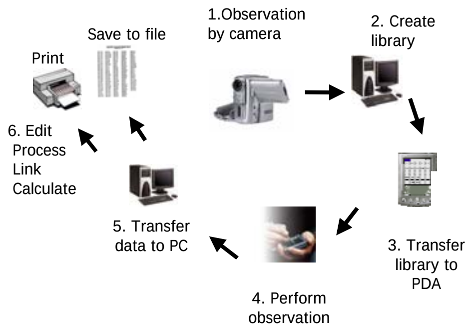

Figure 1: Different steps involved in the use of the PalmTrac system

2.4. WBV measurement

WBV was measured under actual working conditions according to the requirements of the international ISO standard 2631-1. WBV was measured at the drivers/ seat interface by using a tri axial seat accelerometer (type 4322 Brűel & Kjaer, including DIN-microdot Cable WL 0547). The 3-axis recorded signals were amplified, converted to voltage and filtered with type 1700 (Brűel & Kjaer) 3-channel Human vibration front end, one channeled connected to a 2260-I observer modular precision sound analyzer (Brűel & Kjaer). From one third octave band frequency spectra (1-80 Hz) of the signal recorded in the back-to-chest direction (x-axis), right-to-left direction (y-axis) and vertical direction (z-axis), frequency weighted root mean square (r.m.s.) accelerations ($a_{x,}$ a_y and a_z) were obtained by using the weighting factors of ISO 2631-1.

2.5. *PalmTrac data*

The results of the included 10 drivers were used for the comparison in total duration spent at the 5 defined physical work demands for each individual between T0 and T1. PalmTrac data was being recorded for about 4 hrs [5](due to practical matters, the exact time of the PalmTrac observations varied as the drivers were randomly measured during the working day). To correct for this, the proportion of 4 hrs (= 240 minutes) / the exact recording time (in minutes) by PalmTrac, was calculated. This proportion was multiplied with the total recorded time of the 5 physical work demands based on the actual PalmTrac measurement. With this calculation (extrapolation) the total time of the 5 different physical work demands or recorded activities over four hours was assessed.

2.6. Simultaneous measurement

To ensure that the PalmTrac system and the WBV measurement would work simultaneously, the start of the measurement was synchronized. The measurement of the WBV level during representative work cycle of interest lasted in general between 15 and 25 minutes, and the observation period by PalmTrac lasted approximately four hours.

2.7. Data analysis and statistics

The WBV measurement data were exported and stored in an Excel spreadsheet, using the Noise Explorer type 7815 version 4.7 software. For further analysis, the first two minutes of the total recorded time were deleted, as it was necessary to install both the equipment and the driver properly. In addition, zero values in the actual measurement were deleted and extrapolated, using the average of the values one second before and one second after the zero value, as the WBV signal was logged every second.

For the purpose of this pilot study analyzing the data in SPSS (version 11.5 for windows) was limited to a comparisons between T0 and T1 with a paired sample t-test and a significant level of $p < 0.05$ for variance between each individual subject with a 95% confidence interval (CI).

3. Results

The population (N=10) consisted of all male drivers with an average (± SD) age of 44 ±10.6 yrs, weight of 90.7 ± 9.9 kg and height of 180.1 ± 9.1cm. They all drove different kind of vehicles like: mobile cranes (2), wheeled loaders (4), bulldozers (1), excavators (2) or a lorry (1).

3.1. Physical work demands assessment

Values are standardized for a total duration of a half four-hours working day. Average time for the 5 physical work demands for all subjects at T0 and T1 is presented in table 1. Sitting is the most prevalent physical work demand on both time points. The other physical demands are less intense and frequent. The table shows that the variance within subjects increases while spending more time to one specific physical work demand. For the whole group of drivers, not much change is found over time in average time spent on the 5 different physical work demands during the half working day (4 hrs).

Table 1
Mean time (± SD) for the 5 different physical work demands at T0 and T1 for 10 drivers measured over 4 hours

Physical Work demand	**T0; Average time (hrs: min: sec) ± SD**	**T1; Average time (hrs: min: sec) ± SD**
(1) Walking + Standing	0:34:20 ± 0:25:05	0:32:29 ± 0:27:50
(2) Bending over (straight or twisted)	0:01:37 ± 0:03:11	0:02:17 ± 0:04:10
(3) Sitting	3:09:54 ± 0:27:18	3:22:22 ± 0:28:26
(4) Sitting-twisted/ lean back	0:13:18 ± 0:16:40	0:01:35 ± 0:03:04
(5) Lifting	0:00:39 ± 0:01:46	0:00:00 ± 0:00:00

Results of the comparison between the physical work demands assessed at T0 and T1 and the total difference in time between T0 and T1 for each individual have been calculated. The sum of these individual differences is determined (see table 2). The differences (Δ(T0-T1)) for each individual over time for all the 5 physical work demands revealed a significant difference (in minutes) for the physical work demand sitting- twisted / lean back (95% IC: [1.8 21.6], p= 0.03); at T1 the drivers appear to be spending less time to this physical work demand compared to at time point T0. No significant changes are found for the individual differences (Δ(T0-T1)) for the other four physical work demands over time (see table 2).

Table 2
The sum of the individual differences (T0-T1) over 10 drivers in total time for the 5 physical work demands, including 95% IC and p- values

Physical work demand	**Δ(T0-T1)** (hrs: min: sec)	**95% CI (minutes)**	**p-value**
(1) Walking + Standing	0:10:51	[-27.8 31.4]	0.89
(2) Bending over (straight or twisted)	-0:06:38	[-4.0 2.7]	0.67
(3) Sitting	-1:19:16	[-44.2 19.2]	0.40
(4) Sitting- twisted/ lean back	1:11:36	[1.8 21.6]	0.03
(5) Lifting	0:06:30	[-0.6 1.9]	0.28

3.2. WBV measurement

Average WBV values (m/s^2) in x- (front-back), y- (left-right) and z-direction (up-down) and the vector sum (Av) for all drivers at T0 and T1 is presented in table 3. The WBV in x- direction at both time points appeared to be the highest magnitude. The vibration values in y- and z- direction are lower. Over time for the whole group of drivers the average WBV magnitude in all directions at T1 during the measurement period appears to be a little lower.

Table 3
Mean WBV (± SD), in x, y and z direction and the vector sum (Av) for the 10 drivers measured over 20 min under working circumstances

WBV (m/s^2) ± SD	**T0**	**T1**
Ax	0.63 ± 0.34	0.48 ± 0.25
Ay	0.55 ± .38	0.41 ± 0.26
Az	0.41 ± 0.20	0.32 ± 0.14
Av	1.16 ± 0.59	0.87 ± 0.43

Results of the comparison between the WBV assessed at T0 and T1 and the total difference in WBV between T0 and T1 for each individual have been calculated. The sum of these individual differences is determined (see table 4). The differences (Δ(T0-T1)) in WBV for each individual over time revealed no significant differences for all three directions nor for the vector sum (see table 4). Although, because of marginally significant p values for x and y direction and the vector sum of WBV, an obvious trend can be seen; WBV values at T1 are lower than the WBV values at T0.

Table 4: The sum of the individual differences (T0-T1) in total time for the 5 physical work demands, including 95% IC and p- values

WBV (m/s^2) ± SD	**Δ(T0-T1)**	**95% CI**	**p-value**
Ax	1.57	[-0.15 0.33]	0.069
Ay	1.40	[-0.31 0.31]	0.097
Az	0.91	[-0.32 0.21]	0.129
Av	2.89	[-0.23 0.60]	0.066

4. Discussion

This study tried to explore the variation in vibration magnitude and five other physical work demands by determining if substantial differences exist in WBV levels and in total time (for a half normal working day) at two different time points for a fixed group of drivers. The main findings in this study are (1) no significant difference over time to lower WBV levels in all three directions, although a trend in which the WBV are smaller for T1 compared to T0 can be seen and (2) a significant difference in total time for the physical work demand sitting twisted / leaning back is found for this fixed group of drivers, where the drivers spend less time in this position at T1 compared to T0. The other 3 physical work demands, walking + standing, bending over and lifting show results which are in agreement over the two time points. This difference might be explained by the fact that because we are measuring during actual working circumstances the drivers actually differ in the time spend on the five physical work demands at T0 compared to T1. With different working duties for the drivers differences in total time for different work demands occur.

This study found evidence for the fact that complaints of drivers from the field should be related to the (intra) individually assessed physical work demands and not to the average assessed physical work demands of a whole group of drivers. As in this study hardly any difference can be seen in the average total time spend on the five most prominent physical work demands, the intra individually differences show variation in these physical work demands especially for the demands sitting and sitting twisted / leaning back.

Due to the purpose of this study no analysis of variance has been done. Although this might be attributable to explain the intra individually differences we only wanted to describe if their was any variation over time within a fixed group of drivers. When formulating preventive measures to reduce exposure for the individual driver this analysis of variance might yield some important information and so should be considered.

The new European directive specifies several obligations for employers and formulated action and exposure limits in this regard. These values, which are based on a regular eight-hour working day, are 0.5 m/s^2 and 1.15m/s^2, respectively, in the dominant axis. Looking at the WBV levels at T0 (Ax, Ay and Av > 0.5m/s^2) and T1 (Av > 0.5m/s^2) both appear to be above the action limit. However the presented WBV levels are over the 20 minutes measurement time period so no hard conclusion can be drawn yet. If these values were over eight hours, the drivers are at risk and the employer is obliged to decrease the exposure to WBV for the driver with taking preventive activities.

PalmTrac has the potential to identify possible confounding factors during a vibration measurement that are attributable to LBP and other musculoskeletal problems. However, apparently when assessing information about working postures and activities over time for the same driver one should be aware of the difference in working duties of this driver as this is of influence on the total duration spend in one specific posture or on one specific activity. This should be taken in account while the utility of the extra information about the total time spend on the physical work demands during vibration measurements given by PalmTrac. Another recent study [7] shows the advantage of combining WBV measurements simultaneously with the observations at the worksite by the possibilities to relate high WBV levels to recorded tasks and activities. The PalmTrac data may give important clues for prevention and intervention activities in practice. With this study it is shown that these prevention and intervention activities should account for individual differences in exposure to physical work demands over time.

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