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Using an Impact Wrench in Different Working Directions—An Analysis of the Individual Forces †

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† Presented at the 15th International Conference on Hand-Arm Vibration, Nancy, France, 6–9 June 2023.

Abstract: When working in different directions, factors such as awkward postures can lead to different physical stresses, which can have an influence on the effects of hand–arm vibrations. In this regard, the individual forces can have an influence on the hand–arm-vibration (HAV). In this context, a force plate can be used to determine the feed force. In the case of different working directions, the measured values determined in this way can lead to misinterpretations if the force direction is not considered correctly. Within the scope of the study, screwdriving activities were carried out using an impact wrench in different working directions by 5 test subjects. In addition to the HAV, the feed force, body posture and muscle activity were recorded and evaluated. The results showed that there was a significantly different load for similar HAV.

Keywords: awkward posture; hand–arm vibration; force measuring plate; feed force; EMG

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Citation: Wilzopolski, T.; Raffler, N.; Freitag, C. Using an Impact Wrench in Different Working Directions—An Analysis of the Individual Forces. *Proceedings* **2023**, *86*, 39. https://doi.org/10.3390/proceedings2023086039

Academic Editors: Christophe Noël and Jacques Chatillon

Published: 25 April 2023

1. Introduction

In order to address the occupational disease caused by HAV, vibration exposure can be measured using the acceleration values. According to DIN 45679, the coupling forces must be considered as a correction factor. However, the data of these factors are constant and do not consider the different working directions required by different postures. Therefore, the focus of this project was to investigate the influence of the working direction on the individual workload.

2. Materials and Methods

The studies were performed with 5 healthy, voluntary, right-handed male subjects (average ± standard deviation = 31 ± 4 years old; 185 ± 4 cm high and 85 ± 11 kg). The working directions, upwards (Figure 1a) and downwards (Figure 1b), were applied in a randomized order.

A height-adjustable experimental setup was used to set a basic position for the subjects, on which 12 screwdriving operations, driving 100 mm long wood screws into an oak panel, were performed with an electrical impact screwdriver in each working direction.

2.1. Force Measuring Plate and Forces

During the tests, the test subjects were supposed to stand on a force measuring plate (FMP—Figure 1d) which recorded the forces in the *X*- and *Z*-axis (F_X, F_Z).

To determine the total force (F_f) from the forces of the individual measuring axes, a vector was calculated using Formula (1).

$$F_f = \sqrt{F_X^2 + F_Z^2} \tag{1}$$

(**a**) (**b**) (**c**) (**d**)

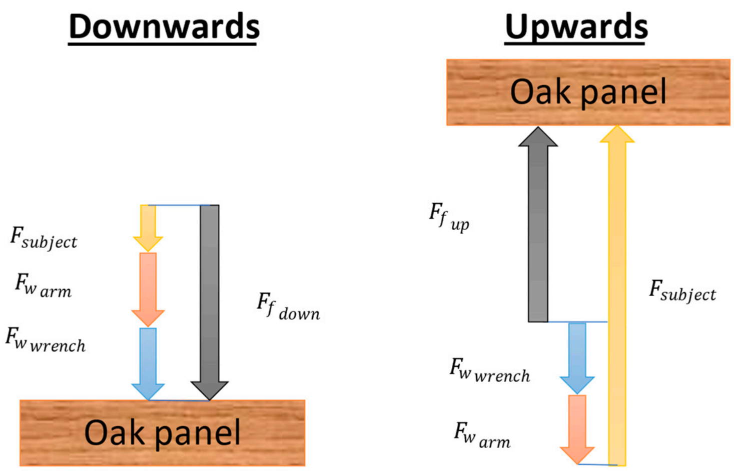
Figure 1. (**a**,**b**) Test setup for examining the two working directions, (**c**) impact wrench with accelerometer, (**d**) force measurement platform.

According to ISO 15230, the feed force (F_f) is the external force acting on the machine. In addition, the weight force of the device and the arm are defined as $F_{w\ wrench}$ and $F_{w\ arm}$. The weight force of the arm was determined using the Dortmunder model [1] as a dependence of the total weight of the individual test subjects.

Figure 2 shows the interaction of the forces for the two working directions. The total force of the subject ($F_{subject}$) is calculated for each direction following Equations (2) and (3).

$$F_{subject\ up} = F_{f\ up} + F_{w\ wrench} + F_{w\ arm} \quad (2)$$

$$F_{subject\ down} = F_{f\ down} - F_{w\ wrench} - F_{w\ arm} \quad (3)$$



(**a**) (**b**)

Figure 2. Interaction of forces in the working directions (**a**) upwards (**b**) downwards.

2.2. Hand–Arm Vibration

In accordance with ISO 5349 1 and 2, the HAV was recorded on the handle of the machine during the tests. For this purpose, the accelerometer was attached to the handle of the tool using cyanoacrylate, in accordance with ISO 28927 5. For the evaluation of the measurement results, the total vibration value (a_{hv}) as the sum of the frequency-weighted acceleration in three measurement axes is calculated using Equation (4).

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad (4)$$

2.3. Electromyography

To record muscle activity, surface electromyography (EMG) was performed using the Cometa Wave Plus measurement system. Sensors were placed on the skin of the subjects, over the biceps brachii and trapezius descendens, using surface electrodes. The measured values were processed according to the recommendations of Hansson et al. [2], and a relative percentage value, related to maximum voluntary contraction (MVCP), was calculated for each muscle.

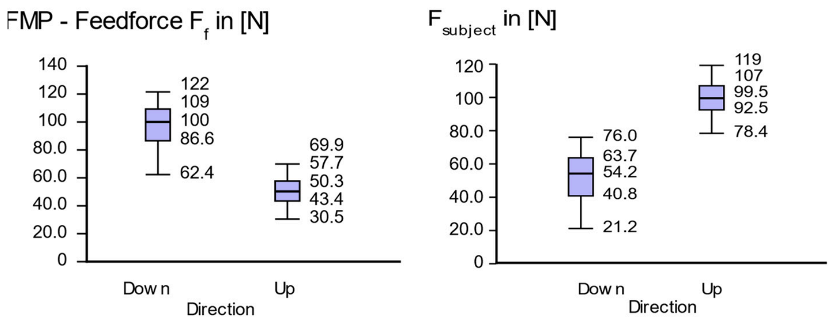
2.4. Data Analysis and Statistics

The evaluation of the data was carried out in the software WIDAAN, an analysing software from the Institute for Occupational Safety and Health of the German Social Accident Insurance [3]. For this purpose, the individual screwing operations of the subjects were considered, and the individual measurement systems were synchronized with the help of video data.

3. Results & Discussion

Working downwards an a_{hv} of 5.0 ± 0.5 ms^{-2}, and working upwards a value 4.8 ± 0.6 ms^{-2}, was measured. This shows a similar workload in the different working directions.

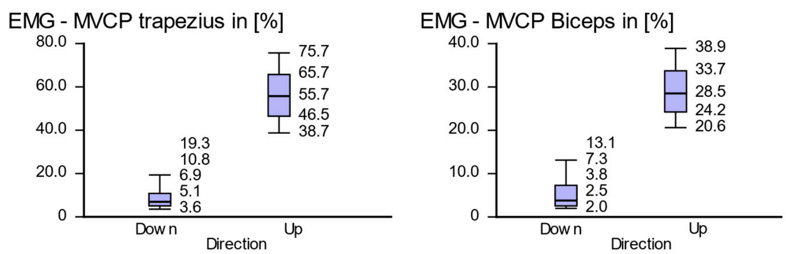
Figure 3a shows the forces resulted from the FMP. It was shown that a significantly greater feed force was applied when working downwards compared to working upwards. However, considering the forces of the subject derived from Equations (2) and (3), the pattern of the forces is completely different.



(**a**) (**b**)

Figure 3. Measurement results of the force measuring plate (FMP) for the working directions (**a**) feed force measured with the FMP, (**b**) Fsubject considering the weight of the arm and the device.

Figure 4 shows the muscle activity values for the trapezius descendens and the biceps brachii. It indicates that there was significantly greater muscle activity when working upwards than working downwards. This also lines up very well with the calculated force $F_{subject}$ from Figure 3b.



(**a**) (**b**)

Figure 4. Results of muscle activity measurements as the percentage of the maximum voluntary contraction (MVCP) (**a**) trapezius descendens, (**b**) biceps brachii.

Although the measurement of the vibration in different working directions did not show any differences, the assessment of the forces and muscle activity indicated very different workloads for the subjects.

Summarizing these results, they highlights the fact that analysing the vibrational workload only by means of acceleration measurements overlooks many other impacting factors. Thus, an unfair and insufficient assessment of the actual workload is the consequence.

Therefore, in order to achieve a fair assessment, in addition to the correction factors for the gripping and contact forces according to DIN 45679, further factors such as the working direction must be taken into account.

Author Contributions: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision, project administration: T.W., N.R. and C.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author, T.W., upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jäger, M. The Dortmunder—Biomechanical model for quantification and assessment of the load on the lumbar spine. *J. Passeng. Car Mech. Syst. J.* **2001**, *110*, 2163–2171.
2. Hansson, G.Å.; Asterland, P.; Skerfving, S. Acquisition and analysis of whole-day electromyographic field recordings. In Proceedings of the Second General SENIAM (Surface EMG for Non Invasive Assessment of Muscles) Workshop, Stockholm, Sweden, 13–14 June 1997.
3. Hermanns, I.; Raffler, N.; Rolf, E.; Siegfried, F.; Benno, G. Simultaneous field measuring method of vibration and body posture for assessment of seated occupational driving tasks. *Int. J. Ind. Ergon.* **2008**, *38*, 255–263. [CrossRef]