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Using an Impact Wrench in Different Postures—An Analysis of Awkward Hand–Arm Posture and Vibration †

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Abstract: Overhead work and awkward hand–arm posture can impact muscle load. Additional workloads such as hand–arm vibration exposure while carrying or holding a power tool can contribute to adverse health effects. This study investigated the posture and muscle activity of 11 subjects while using an impact wrench in three working directions: upwards, forwards, and downwards. Although the vibration exposure did not show notable differences in the magnitude (4.6 ± 0.2 m/s^2), postural behaviour and muscle activity showed higher workloads for working upwards and downwards compared to forwards. The results of muscle activity, and the self-reported exposure level, highlight the necessity of considering posture while exposed to vibration exposure.

Keywords: awkward posture; hand–arm vibration; electromyography

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1. Introduction

From an ergonomic perspective, overhead work should be avoided. When an awkward body posture is adopted, stress is placed on the musculoskeletal system, which can cause irreversible damage to a person's health. Additional exposure to hand–arm vibrations (HAV) can increase the musculoskeletal system's workload and result in adverse health effects. The extent to which body posture affects the impact of vibrations on the hand–arm system has not yet been studied in detail. However, many recent studies highlight the effect of combined exposures to posture and vibration.

Tayler et al. [1] showed that the measured vibration magnitude on a tool handle neither relates to the perception of the exposure nor to the hand-transmitted vibration in varying postures across the test participants. Additionally, other studies [2,3] have shown that flexion of the elbow and wrist position seem to affect the dissipation of HAV exposure and the power absorption into the hand–arm system.

Furthermore, electromyography (EMG) technique is an additional tool used to investigate the surface electric muscle activity. This allows for a detailed analysis of the combined workloads of awkward posture and vibration on the muscles. Therefore, in this study, three different working directions have been investigated in terms of the hand–arm vibration magnitude, shoulder and hand–arm posture, and the response of the body in the form of electric muscle activity.

2. Materials and Methods

2.1. Subjects and Experimental Procedure

A total of 11 healthy, right-handed volunteers (4 female and 7 male, average ± standard deviation = 36 ± 11 years old; 178 ± 8 cm high and 76 ± 15 kg) participated in this project.

Three directions (downwards, forwards, and upwards) were chosen in order to investigate the influence of the working direction while using an impact wrench (Figure 1). A height-adjustable test setup was designed to enable equal starting conditions for each test person (90-degree forearm angle perpendicular to the 100 mm × 800 mm × 300 mm oak plank). 100-mm-long wood screws were screwed in 12 times for each direction. The power tool was the Bosch Professional GDX 18V-LI impact wrench.

(a) (b) (c) (d) (e)

Figure 1. (**a**–**c**): Test setup for examining the three working directions, indicated by arrows, (**d**): impact wrench with a triaxial accelerometer, (**e**): wireless measurement system for body posture (sensor attachment).

2.2. Hand–Arm Vibration and Subjective Perception of the Exposures

In accordance with ISO 5349-1 and 2, the tool handle vibration was measured for a period of 12 screwdriving operations. Accelerometers were glued on the tool handle in accordance with ISO 28927-5 (Figure 1d). The vibration magnitudes were expressed as root-mean-square acceleration, which was frequency-weighted and band-limited using the W_h filter. The vibration total value a_{hv} of the frequency-weighted acceleration values for the x, y, and z axes are calculated using the following:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \tag{1}$$

To analyse the perceived vibration and posture exposure for the individual test sections, the Borg CR10 scale was used: 0 for absolutely nothing to 10 for extremely strong.

2.3. Posture

To measure body posture data, the Xsens Awinda wireless measurement system (18 inertial measurement units) with 60 Hz measurement frequency was used (Figure 1e). After the recording of the body posture (MVN 2022.0 Analyse), the data was imported into WIDAAN, an analysing software developed by The Institute for Occupational Safety and Health of the German Social Accident Insurance [4]. In WIDAAN, the angle of the body is analysed in accordance with DIN EN 1005-4. The amount of time a body angle is within a range of motion is specified as a percentage of the total measurement. The following angles (Table 1) will be presented in this paper, along with the associated categories for neutral, moderate, and awkward movement ranges:

Table 1. Investigated body angles with associated categories for movement ranges.

Category	Shoulder Flexion	Upper-Arm Inclination	Wrist Flexion	Wrist Radialduktion
neutral	0–20°	0–20°	−25–20°	−10–10°
moderate	20–60°	20–60°	−25–−50° or 20–45°	−10–−25° or 10°–15°
awkward	<0° or >60°	<0° or >60°	<−50° or >45°	<−25° or >15°

2.4. Electromyography

A wireless surface electromyography measuring system, Cometa Wave Plus (sampling rate 2000 Hz) has been used to analyse the electrical muscle activity. Four transducers were placed on the right-hand side of the hand–arm system. Following Hansson et al.1997 [5], a bandpass filtering of 30–400 Hz and a RMS calculation was carried out with a rectangular window (0.125 s). A percentage value is calculated based on the maximum voluntary contraction (MVCP values) of the individual muscles. The electrodes were positioned at the following muscles: musculus trapezius descendens, musculus biceps brachii, musculus flexor capri ulnaris, and musculus extensor digitorum.

2.5. Data Analysis and Statistics

For the evaluations, only the screwing-in processes were included with no pauses. The EMG and HAV measurement data were imported to the body posture analysis software "WIDAAN", followed by synchronisation with body angles and video data.

3. Results

3.1. Experimental Procedure

On average, 6.3 s were required for the forwards direction, while the upwards and downwards directions required 6.0 and 5.8 s, respectively.

3.2. Hand–Arm Vibration and Subjective Perception of the Exposures

The vibration total values for the upwards (4.8 m/s^2) and downwards (4.7 m/s^2) directions are comparable. For the forwards working direction, a total vibration value of 4.4 m/s^2 was recorded (Figure 2a).

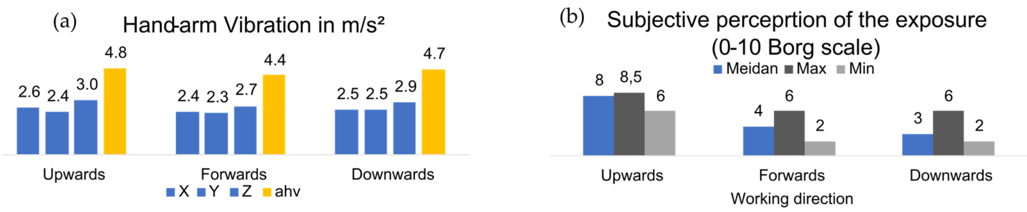

Figure 2. (**a**) Vibration exposure for x, y, and z axis and the vibration total value; (**b**) subjective perception for the exposure of vibration and posture in three working directions.

Figure 2b shows the test subjects' perceived rating of the vibration and posture exposure, using the Borg scale. While the test subjects rated the combined exposures as "very strong", when working in the upwards direction (median 8), the combined exposures in the forwards (median 4) and downwards direction (median 3) were rated as medium.

3.3. Posture

Figure 3a–d shows the recorded body angles while using the impact wrench as box plots (5th to 95th percentile). Concerning shoulder flexion, upper arm inclination, and wrist flexion, working in the upwards direction shows more percentages in the awkward and moderate range of movements than the other directions. For wrist radialduction (Figure 3d), the data suggest a neutral-to-moderate range when working in the upwards and forwards working directions. However, when working in the downwards direction, the data for radialduction was very different to the other working directions. In this direction, radialduction was entirely in the moderate risk category, whereas the direction of radialduction changed completely to ulnarduction (outwards, negative values).

3.4. Electromyography

In Figure 3e–h, the EMG data are grouped according to muscles and working directions. The highest MVCP values were observed by working upwards. However, for the extensor digitorum (Figure 3h), the highest level of muscle activity was in the downwards working direction (median 74%).

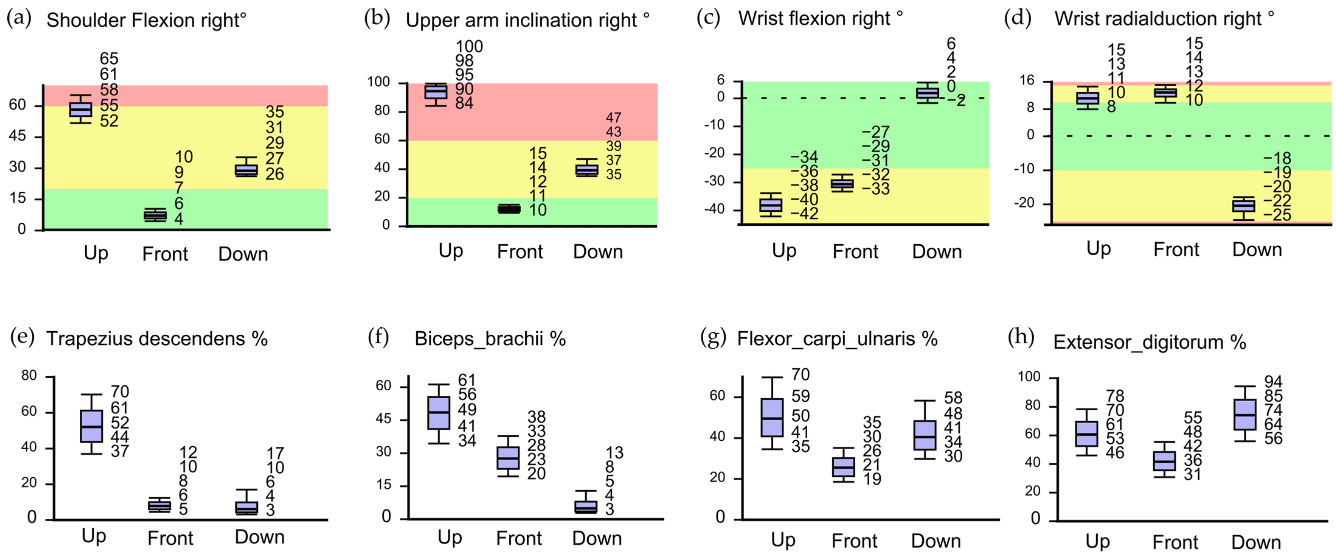

Figure 3. (**a**–**d**): Posture analysis for three working directions while using an impact wrench for different angles, colour coding represents: green for neutral posture, yellow for moderate posture and red for awkward posture, (**e**–**h**): electro muscle activity in three working directions for different muscles.

4. Discussion

The overall vibration values from the power tool are just under the limit of 5 m/s^2 [EU-Directive 2002/44/EC 2002] and did not show a noticeable difference in magnitude in the three different directions. When looking at the risk categories, it is evident that the test subjects frequently adopted an awkward posture when working in the upwards direction. When working in the downwards direction, the level of wrist flexion is improved, while a high level of ulnarduction is seen since the wrist needs to be in a highly angled position for the downwards screwdriving motion. These findings line up with those of the studies carried out by Besa et al. [3] in that they also highlight the impact of hand–arm posture on the transmission of energy to the hand–arm system. In relation to the MVCP values, for the trapezius descendens, biceps brachii, and extensor digitorum, the upwards working direction showed the highest level of muscle activation. With the flexor carpi ulnaris, the highest level of muscle activation was seen in the downwards working direction. This could be caused by a high level of radialduction. Due to the lack of grip force measurements, it is not possible to interpret the forces in relation to the EMG data and wrist postures. However, the levels of perceived exposures were also rated as very strong while working in upwards direction. Considering the effects of the combined exposures of hand–arm vibration and awkward posture in terms of muscle load and self-reported perceived exposures, the standard analysis of hand–arm vibration as a magnitude of the acceleration is insufficient. Therefore, combined exposures require further investigation to understand the influence of hand–arm posture and also to provide preventive actions.

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References

1. Taylor, M.; Maeda, S.; Miyashita, K. An Investigation of the Effects of Drill Operator Posture on Vibration Exposure and Temporary Threshold Shift of Vibrotactile Perception Threshold. *Vibration* **2021**, *4*, 25. [CrossRef]
2. Aldien., Y.; Marcotte., P.; Rakheja., S.; Boileau., P.-E. Influence of hand-arm posture on biodynamic response of the human hand-arm exposed to zh-axis vibration. *Int. J. Ind. Ergon.* **2006**, *36*, 45–59. [CrossRef]
3. Besa, A.J.; Valero, F.J.; Suner, J.L.; Carballeria, J. Characterisation of the mechanical impedance of the human hand-arm system: The influence of vibration direction, hand-arm posture and muscle tension. *Ind. Ergon.* **2007**, *37*, 225–231. [CrossRef]
4. 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]
5. 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.