Physiological Effects of Single Shocks on the Hand-Arm System—A Randomized Experiment †

Elke Ochsmann 1,*, Alexandra Corominas 1, Uwe Kaulbars 2, Hans Lindell 3 and Benjamin Ernst 2

1 Department of Medicine, Institute of Occupational Medicine, University of Lübeck, 23562 Lübeck, Germany
2 Department Ergonomics, Section Vibration, Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA), 53757 St. Augustin, Germany
3 Division Materials and Production, Research Institute Sweden (RISE), 43144 Mölndal, Sweden
* Correspondence: elke.ochsmann@uksh.de
† Presented at the 15th International Conference on Hand-Arm Vibration, Nancy, France, 6–9 June 2023.

Abstract: Physiological health effects (vibration perception thresholds and infrared skin temperature) of single-impact exposures and vibration exposures have been evaluated. In this experiment, a total of 52 healthy male participants were randomly exposed to single shocks of different frequencies (1 s\(^{-1}\), 4 s\(^{-1}\), and 20 s\(^{-1}\)) and to random signal vibration exposures (4 × 5 min exposure duration). We observed frequency-dependent and eventually dose-dependent physiological effects. No exposure parameter systematically correlated to any of the examined physiological outcomes. This could hint at different pathways for physiological effects.

Keywords: single shock; randomization; physiological effect

1. Introduction

It is still unclear whether the same physiological or health effects can be expected for low frequency single-impact and vibration exposures [1–4]. This study investigated whether a change in the vibration perception threshold (VPT) and the surface skin temperature (T) can be detected after several single shock exposures of different frequencies (1 s\(^{-1}\), 4 s\(^{-1}\), 20 s\(^{-1}\)) to the hand-arm system (4 × 5 min exposure duration). Furthermore, it was investigated whether the effects of single shock exposures can be compared with those of spectrum frequency exposures (random signal) of the same duration (and dose).

2. Materials and Methods

A total of 52 healthy male participants were randomly assigned to four experimental groups (n = 13 per group). Depending on the group, participants were exposed to either a 4 × 5 min single shock exposure of different frequencies (1 s\(^{-1}\), 4 s\(^{-1}\), and 20 s\(^{-1}\)), followed by a random signal exposure, or a 4 × 5 min (+5 min) random signal exposure at the shaker. The participants stood upright during exposure and had their right hand positioned at the aluminum shaker handle with an angle of approx. 100° in the elbow joint. All other external test conditions (room temperature and humidity) were controlled and kept as constant as possible. Vibration perception thresholds (Vibrosense Meter II, VibroSense Dynamics, Malmö, Sweden) and infrared thermography (FLIR One Pro (FLIR Systems, Wilsonville, OR, USA) together with an iPhone 6 (Apple, Cupertino, CA, USA)) were used to detect early physiological effects. SPSS Version 28 (IBM, Armonk, NY, USA) was used for statistical analysis (descriptive analysis, Spearman correlation, and non-parametric tests). p < 0.05 was regarded as statistically significant.
3. Results  
3.1. Vibration Perception Threshold (VPT)  

In all frequency groups (1 s\(^{-1}\); 4 s\(^{-1}\), 20 s\(^{-1}\)), there was a significant change in the VPT between baseline and post-exposure (1–5) measurement. However, the occurrence of the significant change is frequency- and dose-dependent. At a VPT test frequency of 125 Hz, (which seems to be more specific than higher test frequencies) a significant VPT increase occurs only after the 4th exposure sequence for 1 s\(^{-1}\) shocks, after the 3rd exposure sequence for 4 s\(^{-1}\) shocks, and after the 1st sequence for 20 s\(^{-1}\) shocks. The results of the random signal exposure are similar to that of the 20 s\(^{-1}\) exposure (Figure 1).

![VPT graph](image-url)  

**Figure 1.** VPT (baseline exposures 1–5) at finger D2 of the exposed right hand (Hz: test frequency 125 Hz, bars: mean values, whiskers: 95% CI; N total = 52); *: \(p < 0.05\).

3.2. Infrared Thermography (IR-T)  

An overall decrease in the IR temperature of dorsal fingers of the exposed hand could be observed after four single shock exposures of the respective frequencies (exposures 1.0–4.1). In most fingers, this decrease was statistically significant. After four random signal exposures, no statistically significant differences in the IR dorsal finger temperature was observed. The development of the overall negative temperature gradient was based on several episodes of temperature loss during exposure and re-warming between exposures (see Figure 2).
All in all, our results suggest that early onset of physiological effects due to single shock exposures already occur below the existing exposure thresholds. While the prognostic value of these early physiological effects for the development and therefore prevention of the hand-arm vibration syndrome remain as yet unclear, further research is warranted to improve our understanding of underlying mechanisms responsible for single shock related health effects.

Author Contributions: Conceptualization, E.O., H.L. and U.K.; investigation, A.C. and B.E.; analysis, E.O. and B.E.; writing—original draft preparation, E.O.; writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by DGUV Forschungsförderung, FP-415 (www.dguv.de, accessed on 12 April 2023).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Luebeck University (protocol code 20-099, April 2020).

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

Data Availability Statement: Not available.

Acknowledgments: We would like to thank all participants, and all technical staff for supporting this study.

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


Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.