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

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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.

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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).

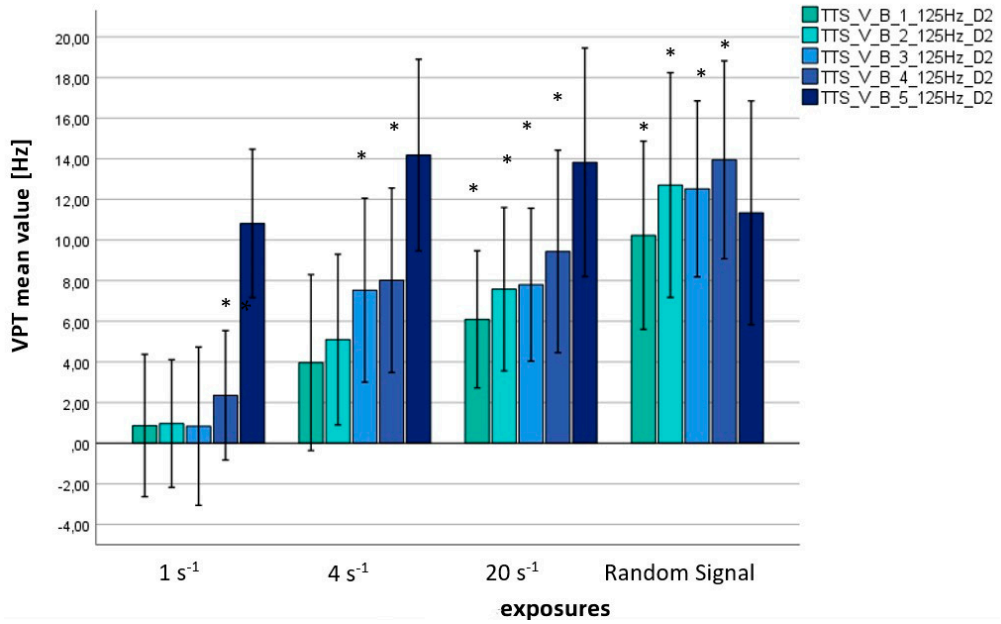

Figure 1. VPT (baseline exposures 1–5) at finger D2 of the exposed right hand (Hz: test frequency 125 Hz, bars: mean values, whiskers: 95% CI; N total = 52); *: $p < 0.05$.

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).

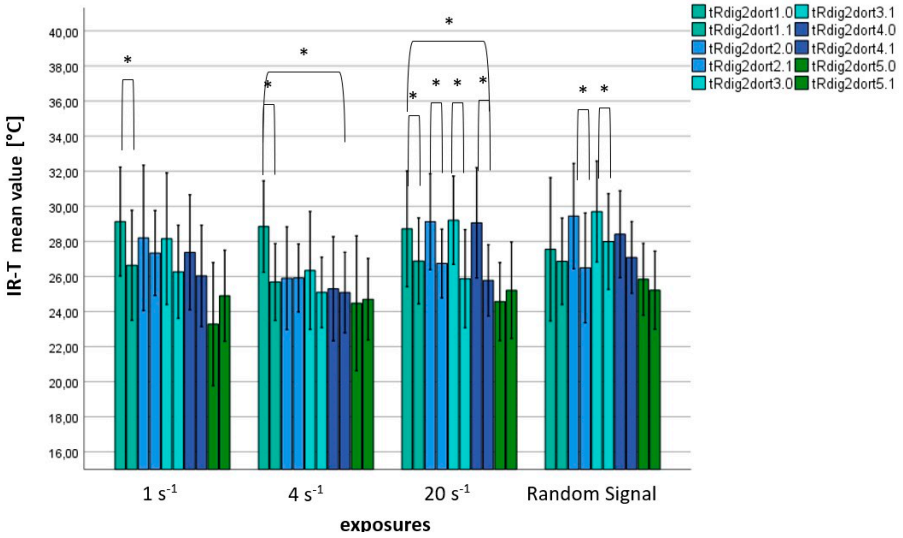

Figure 2. IR temperature measurements (pre and post exposure) at dorsal finger D2 of the exposed right hand (°C, bars: mean values, whiskers: 95% CI; N total = 52); exposure 1—exposure 5; *: $p < 0.05$.

3.3. Correlations between Exposure Parameters and VPT and IR-T

We could not identify repeating correlation patterns between exposure parameters at different frequencies and the examined physiological outcomes.

4. Discussion and Conclusions

Physiological effects after single shock exposure comprise temporary threshold shifts of vibration perception and skin temperature, similar to the expected responses caused by the hand-arm vibration in general. We found evidence that the (vascular and neurological) effects of single shock exposures might occur frequency- and dose-dependent, but also noticed that both endpoints do not follow the same patterns. We propose that this finding could be related to different causal pathways of the respective vascular and neurological endpoints. Different pathological mechanisms, to some extent, could also explain the lack of repeating patterns with regard to correlation between exposure and outcome parameters. 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.

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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.

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

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