«Comparison between the biomechanical responses of the hand and foot when exposed to vertical vibration»

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BACKGROUND

Occupational exposure to Foot-Transmitted Vibration (FTV)

Workers on means of transport, in manufacturing industries and in mines

- Musculoskeletal disorders
- Motion sickness
- Neurological diseases
- Vascular diseases

Prolonged standing on a vibrating floor

The occurrence of the occupational diseases related to Whole-Body Vibration (WBV) exposure is mitigate by ISO 2631-1

- The same standard for standing, seating and recumbent posture
- Effects of vibration on health → Musculoskeletal disorders
BACKGROUND

Case reports have documented that HTV can cause Vibration-Induced White-Foot (VIWF)

Neurological and vascular disease:

Raynoud’s syndrome
decreased blood flow, blanching, and numbness in the toes

Hand–Transmitted Vibration (HTV) exposure regulates by ISO 5349

Hand–Arm Vibration Syndrome (HAVS)
OBJECTIVE

Considering epidemiological data, the ISO 2631 is not appropriate to regulate the feet vascular risks exposure. Are ISO 5349 and its weighting curve more appropriate to evaluate feet risks at high frequencies?

Hand VS Foot

Similarity of:
- Occupational vascular diseases
- Anatomy and biomechanics

Are ISO 5349 and its weighting curve more appropriate to evaluate feet risks at high frequencies?

Comparison of Frequency Response Functions (FRFs) measured on the hand and on the foot.
METHODOLOGY

Hand


- 14 participants
- Random vertical vibration with an RMS of 17 m/s² in a frequency range between 5 and 500 Hz
- The transmissibility functions between acceleration at the driving point (flat plate) and the acceleration measured by a laser Doppler vibrometer at 41 anatomical locations of the hand–arm system in 7 different contact conditions

Foot

Goggins, K.A. et al., «Biomechanical Response of the Human Foot When Standing in a Natural Position While Exposed to Vertical Vibration from 10–200 Hz», 2019

Goggins, K.A. et al., «Standing Centre of Pressure Alters the Vibration Transmissibility Response of the Foot», 2019

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METHODOLOGY

**Hand**


- 21 participants
- A sine sweep of 10 to 200 Hz with a constant peak velocity of 30 mm/s
- The transmissibility functions between acceleration at the driving point (vertically vibrating platform) and the acceleration measured by a laser Doppler vibrometer at 24 anatomical locations of the foot in 3 different standing Center Of Pressure (COP) conditions

**Foot**

Goggins, K.A. et al., «Biomechanical Response of the Human Foot When Standing in a Natural Position While Exposed to Vertical Vibration from 10–200 Hz», 2019

Goggins, K.A. et al., «Standing Centre of Pressure Alters the Vibration Transmissibility Response of the Foot», 2019
METHODOLOGY

Similar **conditions** and anatomical locations between hand and foot have been compared.

**Condition 1**
Whole hand on the plate compared to the **natural standing COP** position.

**Condition 2**
Only the fingers entirely on the plate compared to the **forward COP** position (body weight shifted towards the toes).

**Condition 3**
Only the palm on the plate compared to the **backward COP** position (body weight shifted towards the heel).
METHODOLOGY

Similar conditions and **anatomical locations** between hand and foot have been compared.

Transmissibility of **12 paired anatomical points** from 10 to 150 Hz

- Tips of the fingers - the tips of the toes (1-T1P1, 3-T2P1, 6-T3P1, 9-T4P1, and 12-T5P1)
- Knuckles - metatarsal heads (2-T1P3, 5-T2P3, 8-T3P3, 11-T4P3, and 14-T5P3)
- Wrist - ankle (25-M4 and 34-L4)
RESULTS

Anatomical locations:

Conditions:
1)  
2)  
3)  

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REsults

- **Wrist - ankle**
  Similar FRFs in all three conditions, with a peak below 50 Hz and a decreasing magnitude up to 150 Hz.

- **Fingers - toes and knuckles - metatarsal heads**
  - In Condition 1 and 2 the transmissibility response is similar until ~75 Hz.
  - Above 75 Hz transmissibility of the foot increases, while the hand transmissibility decreases.
  - Toes’ resonance frequency (above ~80 Hz) is larger than the fingers’ resonance frequency (10-60 Hz).
CONCLUSION

The comparison between the biomechanical responses of the hand (Concettoni, E. et al., 2009) and the foot (Goggins, K.A. et al., 2019) when exposed to vertical vibration showed similar FRFs.

The similarity between the vibration transmissibility of HTV and FTV suggests the need for new approaches for FTV evaluation as an alternative to ISO 2631, based on the HAV standards as reference.

A specific standard is needed to assess FTV exposure and reduce the occurrence of neurovascular disease.
References