# Determination of hand-transmitted vibration risk on the human


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## Background

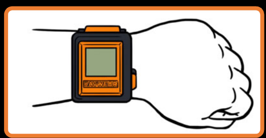
Hand-arm vibration syndrome (HAVS) is a debilitating industrial disease induced by exposure to vibrating machinery. As an irreversible condition, monitoring, controlling and reducing exposure are crucial to minimise the risk of developing the disease. Current standards for assessing risk evaluate vibration on the surface of the tool and thus do not capture the effect of different operator interactions and other variables have on the transmitted vibration energy. Annex D of the current standard (ISO 5349-1) acknowledges the existence of additional factors affecting exposure beyond the tool emitted vibration, such as operator technique, posture and coupling force. This further illustrates the limitations of using a single value for tool emitted vibration when attempting to quantify the risk faced by an individual.

## Objective

Recent Improvements in battery and accelerometer technology have allowed for the development of a wearable device for the purpose of assessing hand transmitted vibration. The nature of a wearable sensor enables it to capture the effects different operator interactions have on transmitted vibration and address some of the limitations listed within Annex D of ISO 5349.

The authors therefore seek to investigate the degree to which vibration exposure captured on the wearable sensor correlates with the human response to vibration as determined through temporary threshold shift (TTS) in vibrotactile perception.

## Methodology



The wearable device mounted on the wrist contains a three-axis accelerometer, capturing a frequency range of 0-650 Hz.

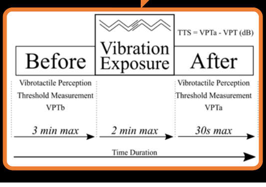
$$[1]\quad a_{rhx}(n) = \sqrt{\sum w_{rhx}(i)^2 \cdot a_{hx}(n,i)^2}$$

$$[2]\quad a_{rhx} = \sqrt{\frac{\sum_n a_{rhx}(n)^2}{n}}$$

$$[3]\quad a_{rhv} = \sqrt{a_{rhx}^2 + a_{rhy}^2 + a_{rhz}^2}$$

For each axis, a transfer function is applied to compensate for the attenuation through the hand arm system[1]. A running average is calculated[2], and the running averages for all axes are combined into an RMS[3].

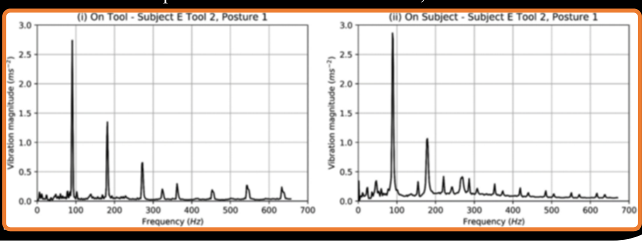

To evaluate correlation with human response a total of 12 subjects with no previous exposure performed a series of 2 minutes tool operations using 3 different power tools in 3 different working postures. Push force was maintained utilizing a force plate at a constant 50N. Concurrent measurements were taken on the wrist and on the tool.




Vibrotactile sensitivity was assessed 3 min prior to the tool activity and within 30s of finishing, obtaining TTS as the difference between both measurements. A test frequency of 125Hz was used and 4h of rest were allowed between multiple tests.

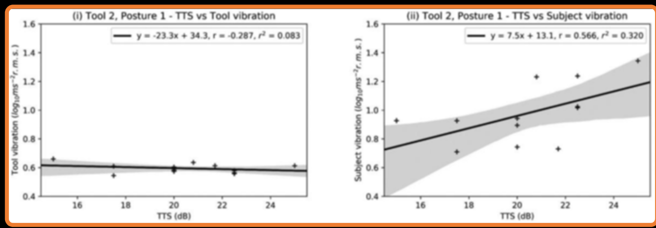
## Results: validation of method

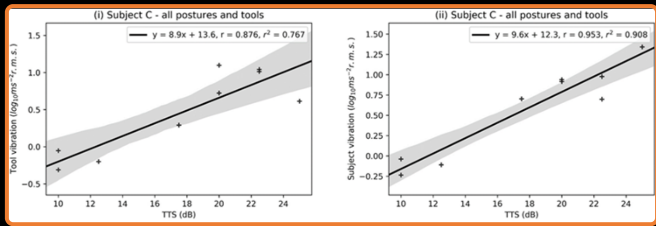
The results obtained by the wearable sensors are compared to concurrent on-tool (ISO-5349 compliant) measurements in order to evaluate the frequency response the proposed method. With the wearable device designed to correlate with conventional techniques under controlled conditions, the similarities are evident.




## Results: TTS determination

A broad range of human responses was present across the group even under the same tool and posture configuration. However this was not always predicted by the on tool measurement as evidenced by the top left figure. Measurements on the wrist, on the other hand, showed a positive correlation between increased vibration exposure and increased human response (top right).




## The need for monitoring

**18.9%** OF INDIVIDUALS EXPERIENCE **80%** OF THE VIBRATION LEVELS AND HAVE THEIR RISK UNDERESTIMATED BY **76%**

| Population groups according to vibration exposure | Number of individuals | % of total population | Mean exposure from static assessment | Mean exposure from continuous monitoring |
|---|---|---|---|---|
| Top 20% | 97 | 0.7% | 142 | 625 |
| 20 – 40 % | 319 | 2.3% | 124 | 210 |
| 40 – 60 % | 694 | 5.0% | 73 | 105 |
| 60 – 80 % | 1506 | 10.9% | 49 | 64 |
| Bottom 20% | 11215 | 81.1% | 34 | 37 |

The table above illustrates the cumulative effect over reliance on assumed on tool vibration data can have on actual risk faced in the work place. A total of 13831 operators were monitored for vibration exposure, both using a wearable device for continuous monitoring and using static assessment.

## Conclusions

The test results demonstrate that the assessment of vibration transmitted to the tool operator using a wearable device of the proposed methodology is positively correlated with the human subjects' response to vibration.

The research further demonstrates that the principle of a wrist worn wearable device as an indicator of HAVS health risk is valid and can address a number of limitations identified with the use of tool emission data.

Utilising data from this technology it is apparent that reliance on conventional methods can significantly underestimate the risk faced by the most exposed individuals.

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