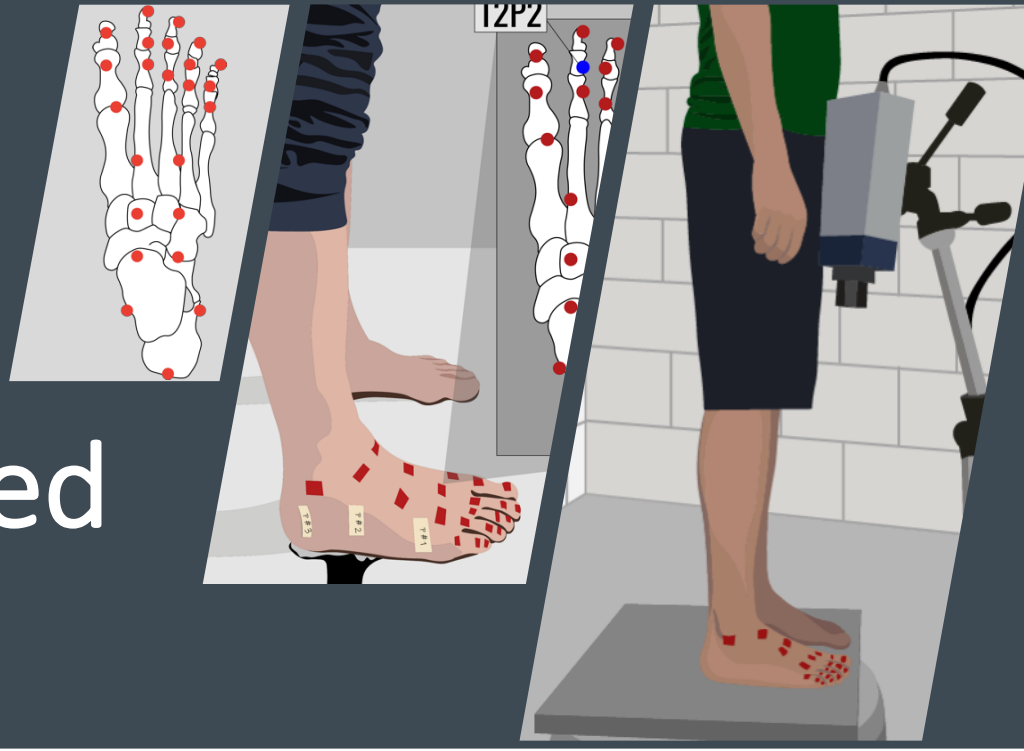
Occupational Health Clinics for Ontario Workers Inc.
Centres de santé des travailleurs (ses) de l'Ontario Inc.

2019 RSI DAY – 20th Anniversary



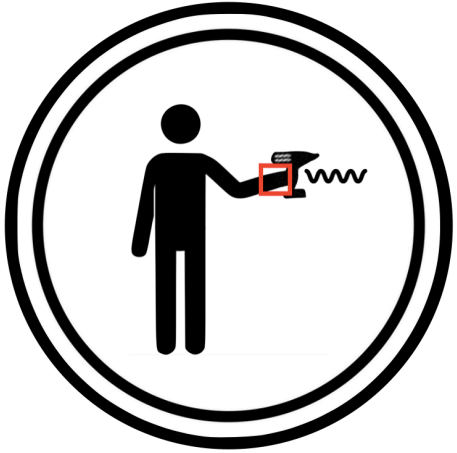
Vibration-Induced White-Foot

Katie Goggins
PhD Candidate
Natural Resources Engineering

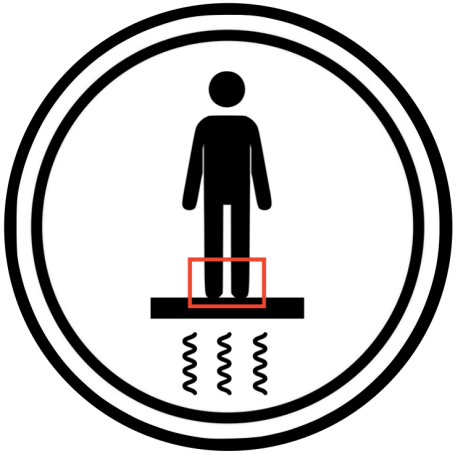
LaurentianUniversity
UniversitéLaurentienne
BHARTI SCHOOL OF ENGINEERING
ÉCOLE DE GÉNIE

Types of Occupational Vibration Exposure

WBV



HTV



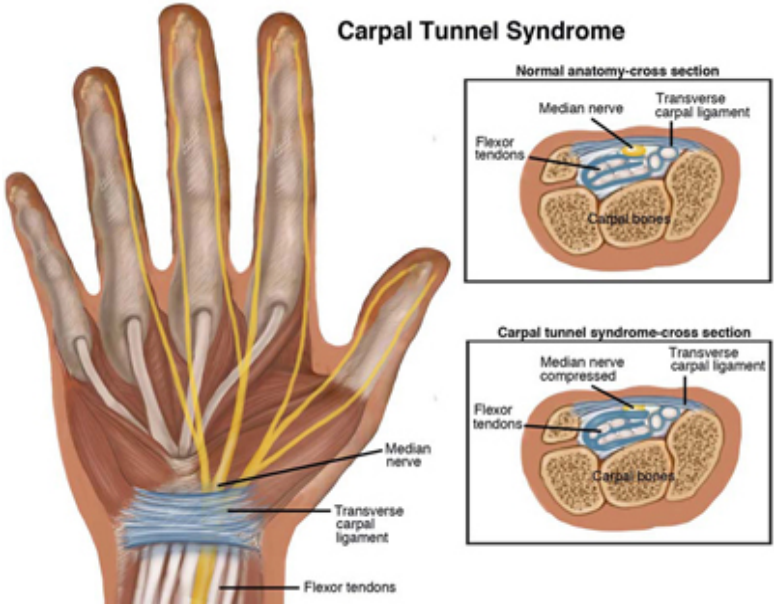
FTV

Epidemiological Evidence of Injury

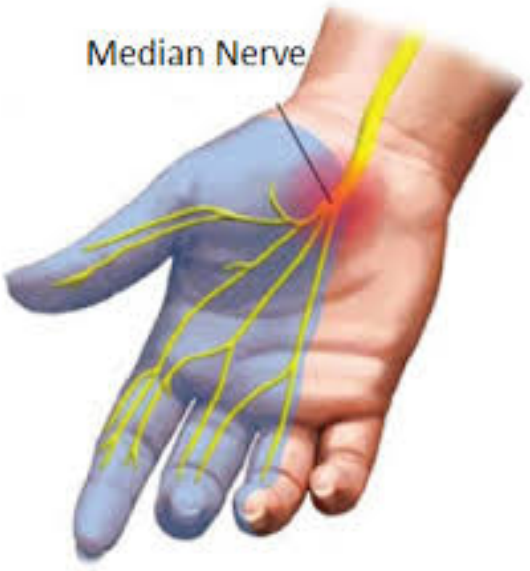
WBV	HTV	FTV
		
• Spine disorders • Neck and shoulder problems • Gastrointestinal disorders • Reproductive effects (Pope et al., 2002; Seidal, 2005; Alem, 2005; Bovenzi et al., 2006)	Osetoarticular, neurological and vascular disorders including vibration-induced white-finger (VIWF) and vibration-induced white-feet (VIWFt) (Bovenzi, 2005; Griffin, 2008; Hagberg et al., 2008; Thomspon et al., 2010)	

HTV – Health Risks

1. Nervous System – Carpal Tunnel Syndrome



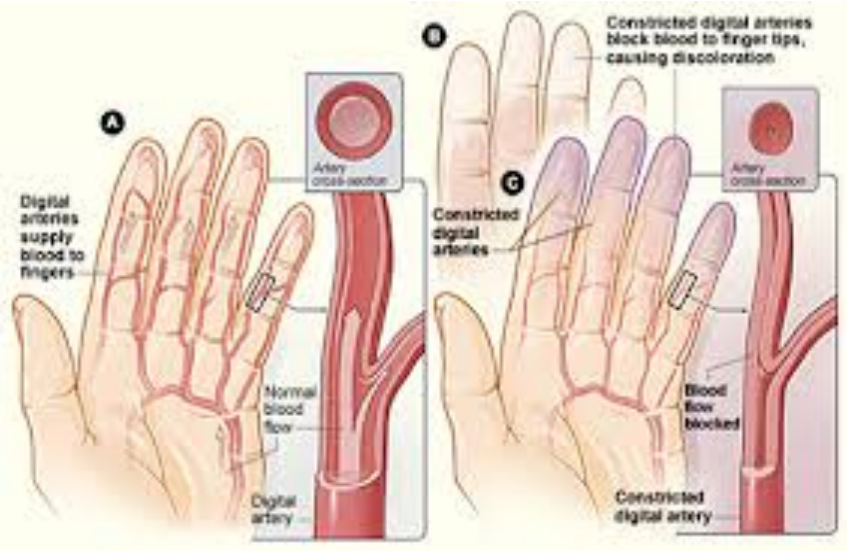
http://www.moveforwardpt.com/symptomsconditionsdetail.aspx?cid=9f3cdf74-3f6f-40ca-b641-d559302a08fc#.VmHIstCpqlI



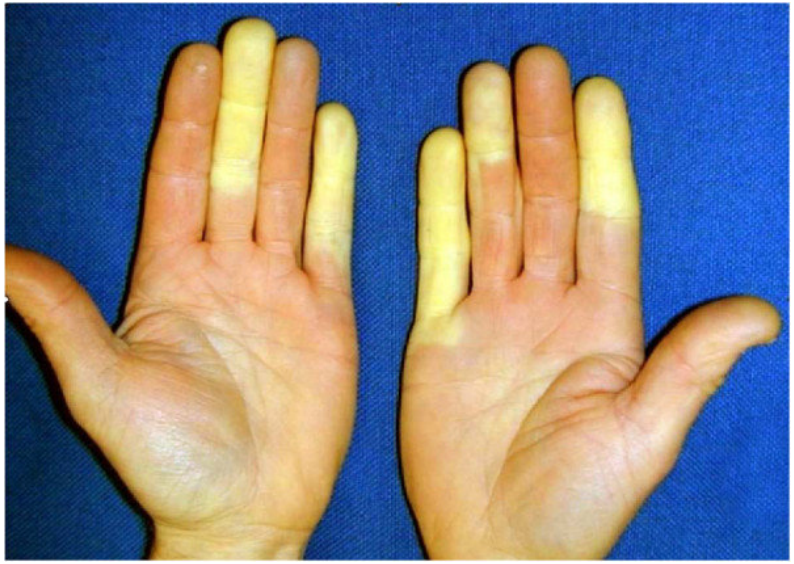
http://www.upngophysiotherapy.com.au/educational-information/carpal-tunnel-syndrome/

HTV – Health Risks

2. Vascular System – Vibration-Induced White Finger (VIWF)



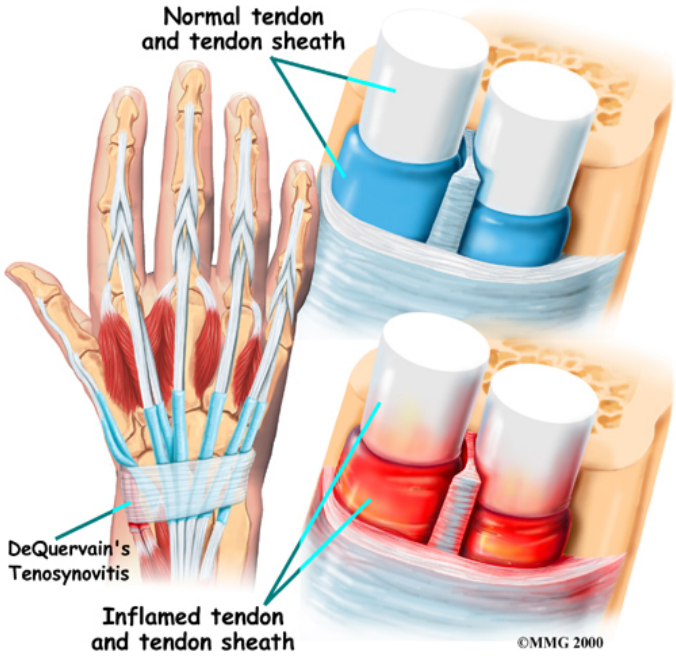
http://divermag.com/raynaud's-symptoms-and-diving/



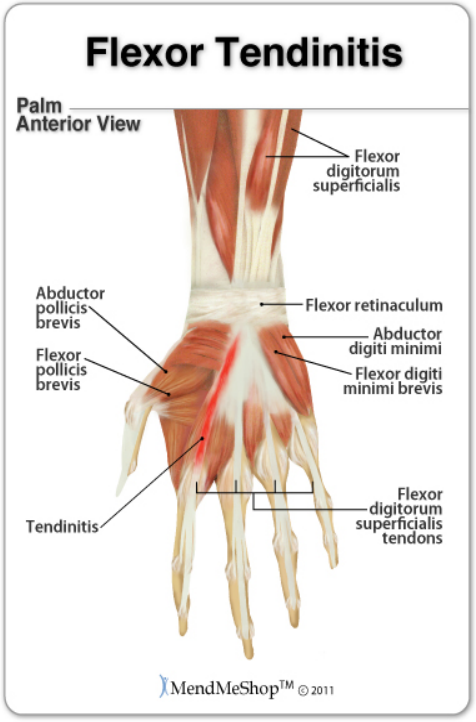
https://www.researchgate.net/figure/Hands-of-a-person-suffering-from-vibration-induced-white-finger-disease_fig1_231740259

HTV – Health Risks

3. Musculoskeletal System – Tendonitis



http://www.eorthopod.com/tendonitis/topic/149



www.mendmeshop.com

FTV – Health Risks

SYMPTOMS

NEUROLOGICAL

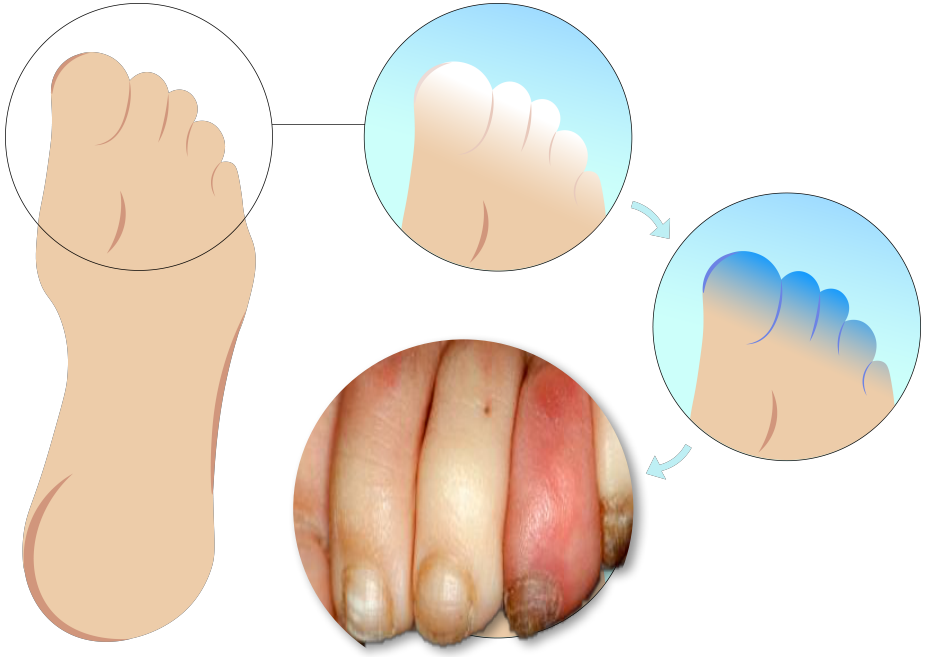
- Numbness and tingling in the toes
- Reduced sense of touch and temperature

VASCULAR (VIWFt)

- Increasing loss of circulation
- Toe blanching

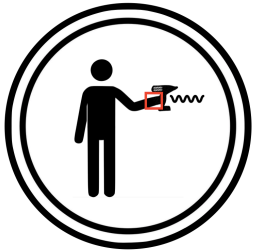
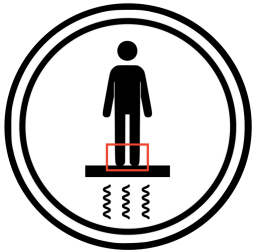
OSTEOARTICULAR

- Bone, joint damage
- Muscular fatigue



(Thompson et al., 2010; Eger et al., 2014)

Measuring Occupational Vibration Exposure

WBV	HTV	FTV
		
ISO 2631-1 (1997) • Uses the most dominant axis (usually z-axis) • 8hr Health Guidance Caution Zone (HGCZ)	**ISO 5349-1(2004)** • Uses a total sum of the axis (Vibration Total Value, a_{hv}) • **a_{hv} greater than 2.0m/s^2** is associated with increased risk for HAVS	Currently NO International Standard

ABOVE	> 0.9 m/s^2
WITHIN	0.45 – 0.9 m/s^2
BELOW	< 0.45 m/s^2

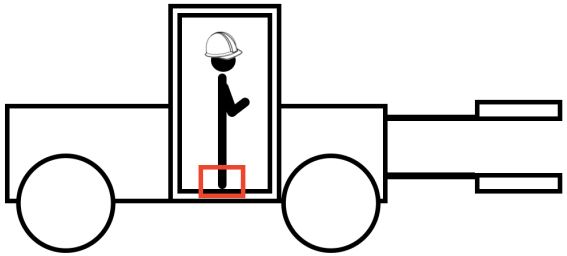
ISO 2631-1 (1997)

Mechanical vibration and shock –
Evaluation of human exposure to whole-body vibration –
Part 1: General Requirements

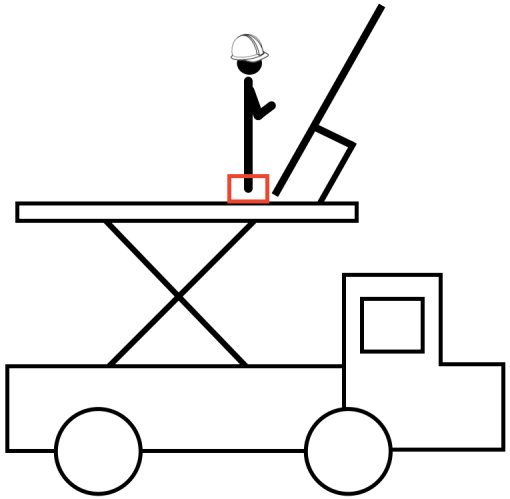
"Is applicable to motions transmitted to the human body as a whole through the supporting surfaces:

- the feet of a standing person,
- the buttocks, back and feet of a seated person,
- or the supporting area of a recumbent person."

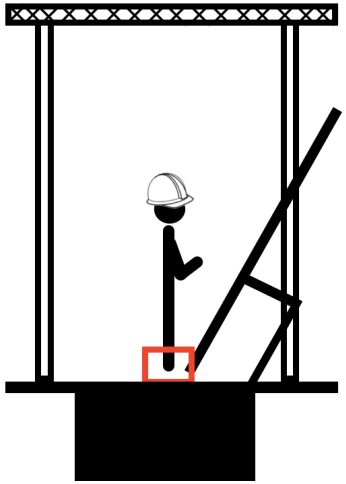
Increase in Foot-Transmitted Vibration



Jumbo Drill



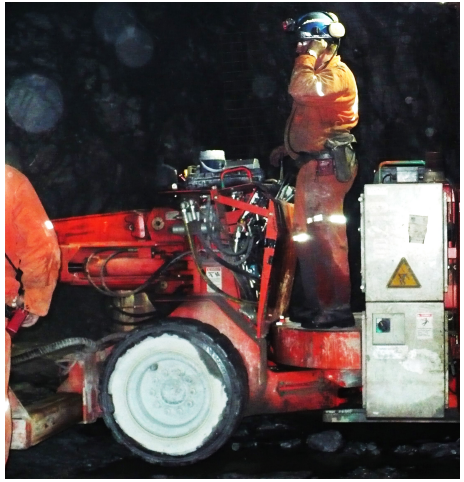
Bolting Platform



Raise Platform

Workers can be exposed to foot-transmitted vibration, **FTV**, when operating mobile equipment or standing on any surface that vibrates.

Summary of Previous Literature on FTV



Jumbo Drill

3/5 miners reported moderate to severe pain/ ache/ discomfort below knees

(Leduc et al., 2011)

Bolter Operator

Case report: 54 year old miner, chief complaint – blanching and pain in toes

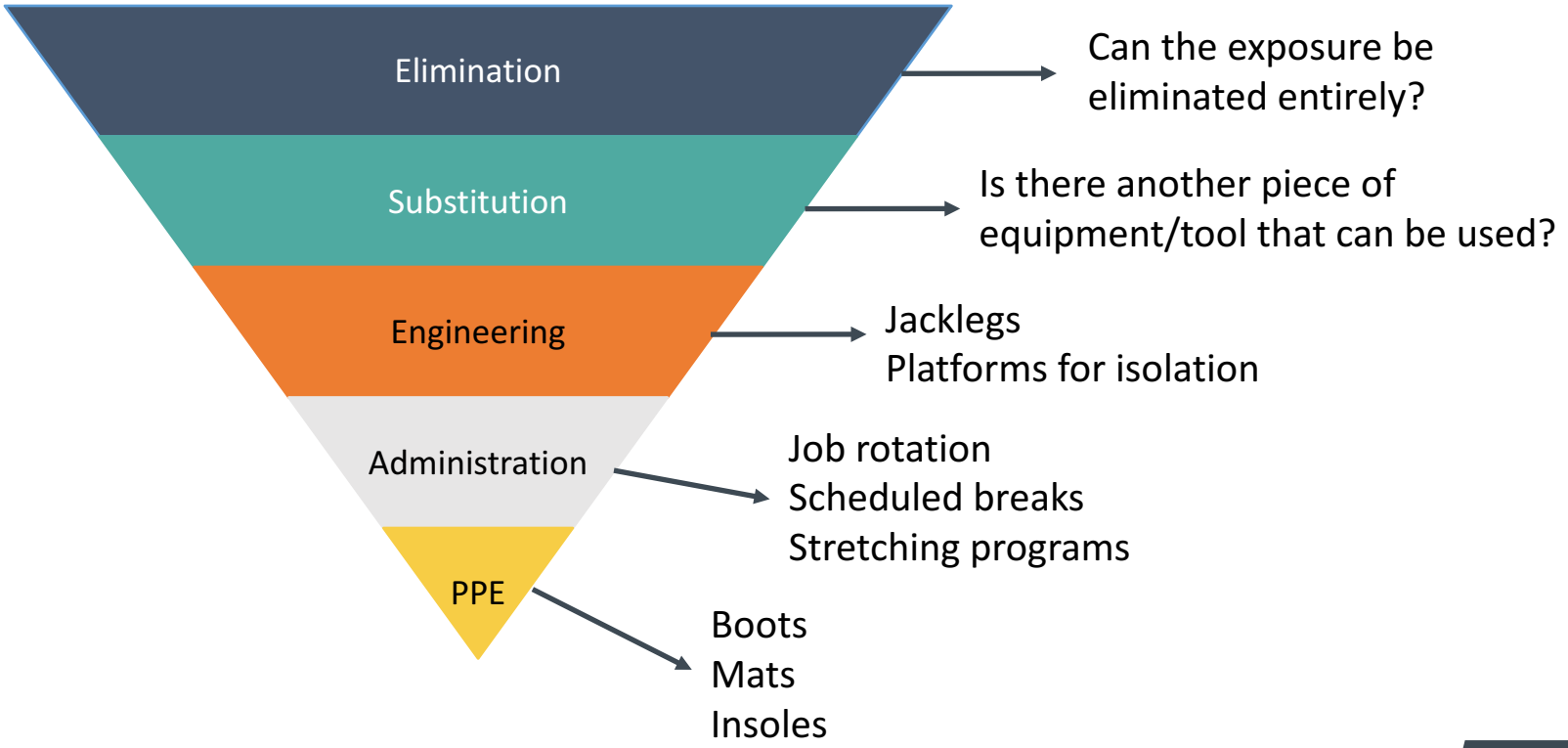
(Thompson et al., 2010)

Drilling Platforms

6/27 miners experienced numbness and blanching in their feet

(Hedlund, 1989)

Designing Possible Prevention Strategies



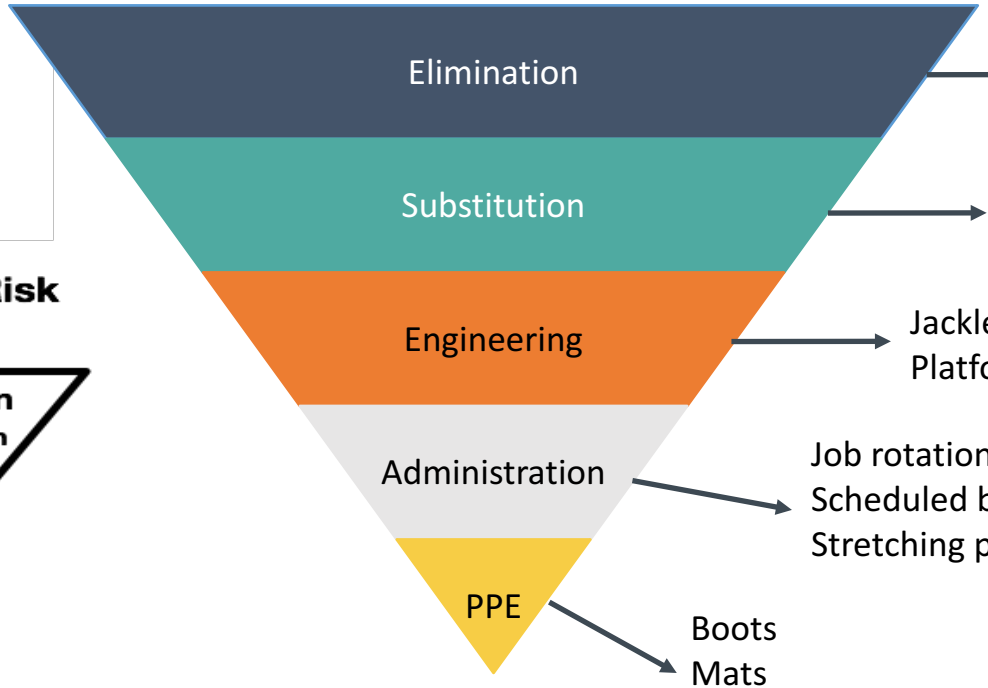
What do we need to know for designing prevention strategies?

- How is vibration transmitted through the foot?
- What frequencies affect the foot the most?
- Do changes in how we apply pressure on the foot affect the transmission of vibration?

What do we need to know for designing prevention strategies?

- How many measurements are required to capture the foot's response to vibration?
- Where should we be taking measurements on the foot?
- What equipment vibrates at the identified higher risk frequencies for the foot?

What do we need to know for designing prevention strategies?



Can the exposure be eliminated entirely?

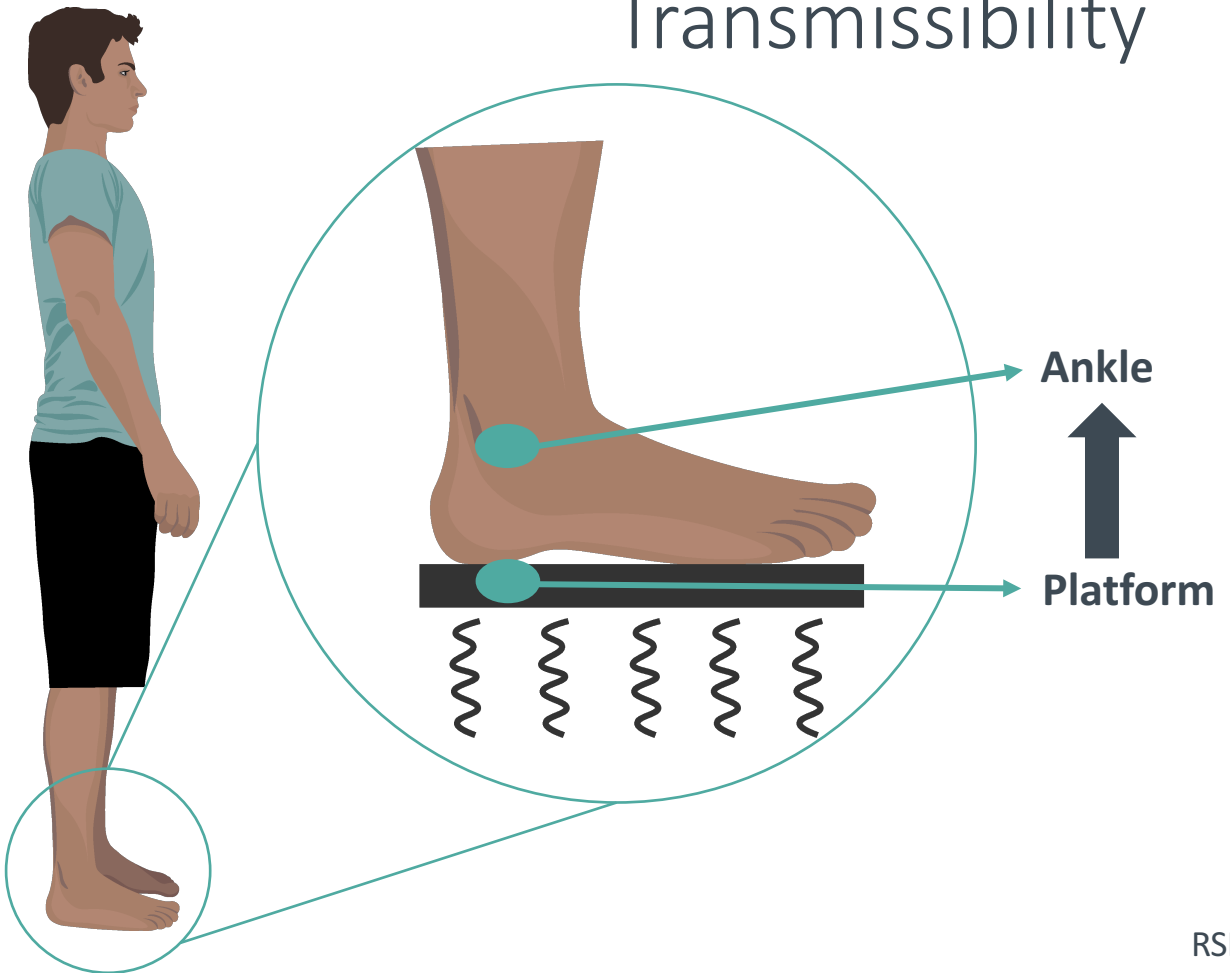
Is there another piece of equipment/tool that can be used?

Jacklegs
Platforms for isolation

Job rotation
Scheduled breaks
Stretching programs

Boots
Mats
Insoles

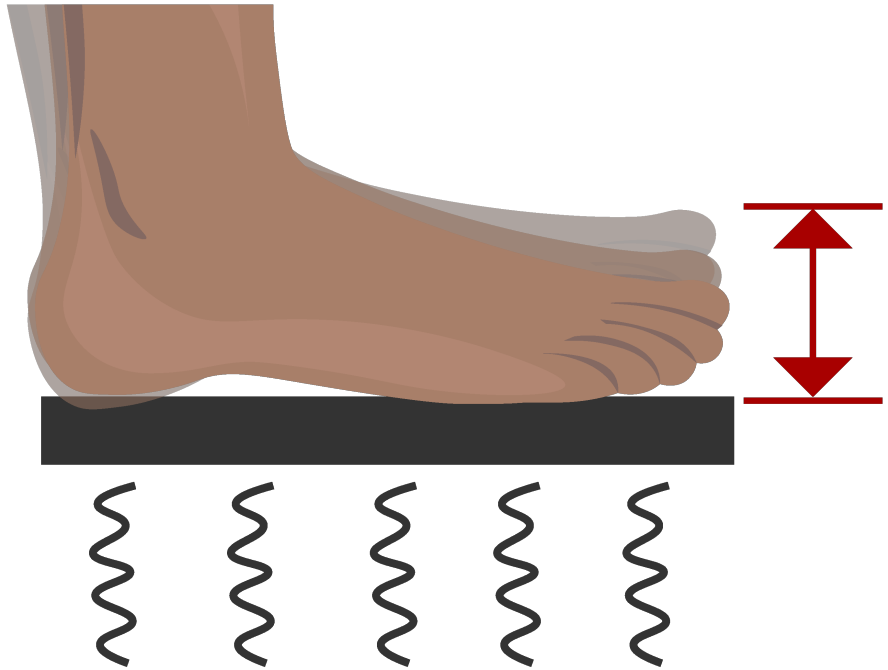
Transmissibility



> 1 = amplification

< 1 = attenuation

Resonant Frequency



Maximum Displacement
= Resonance

Known Resonant Frequencies

Pelvis: 3-5Hz
Lumbar Spine:10-12Hz
(Kitazaki, 1994; Matsumoto & Griffin, 1998; Mansfield & Griffin, 2000)

Hand-Arm: 30-50 Hz
Fingers: 125-300Hz
(Griffin, 1990; Dong et al, 2004)

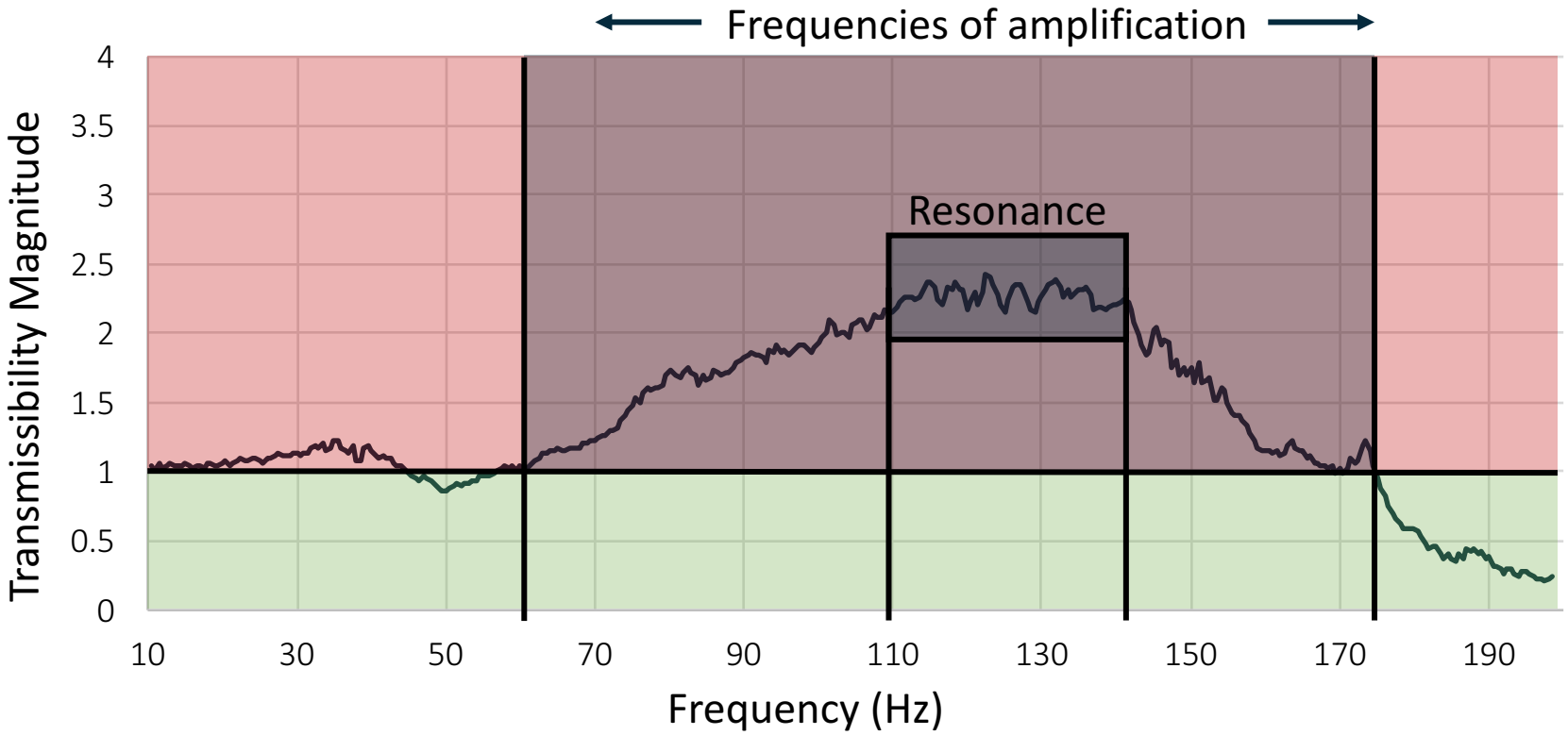
Ankle: ____
Toes: ____

Each region of the body has a **resonant frequency**

Exposure at resonance is linked with an **increased injury risk**

(Boileau et al., 1998; Rao, 2011; Adamo, 2014)

Identifying Resonance from Transmissibility



PhD Research Objectives

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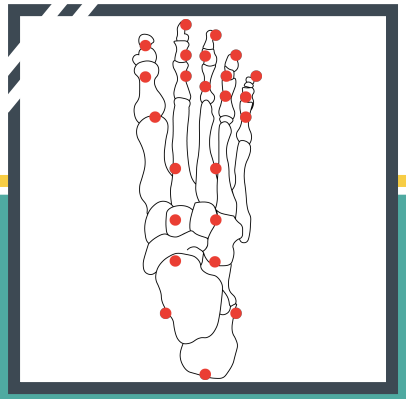

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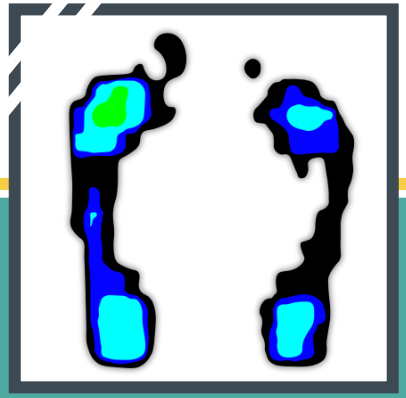

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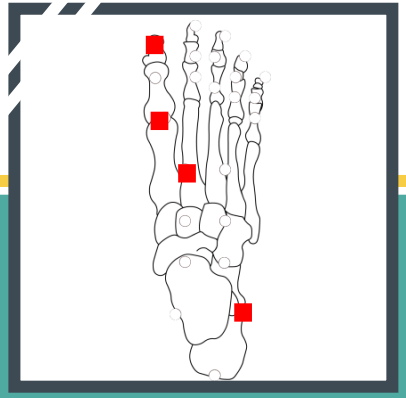
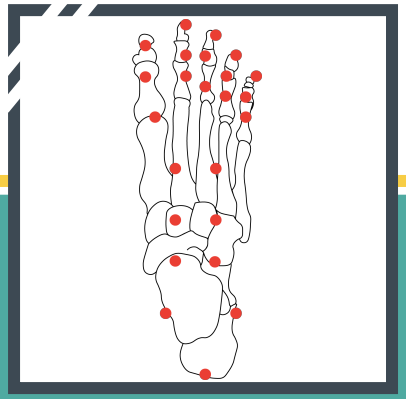


PhD Research Objectives

1



2

3

?

In our natural standing position, how does vibration resonate in different parts of the foot?

Ethics

- Laurentian University Research Ethics Board
- Metro Space Laboratory, Politecnico de Milano (Polimi University), in Lecco Italy

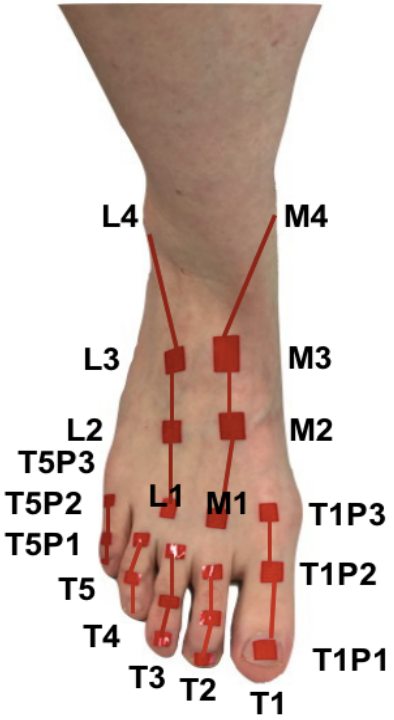
Participants

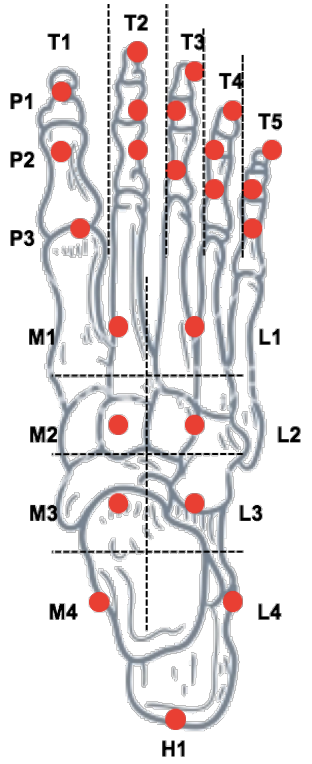
- Number: 21
- Age: 18-65
- Exclusion Criteria: Diabetes, concussion, pregnancy, motion sickness, lower body injury

Anthropometrics

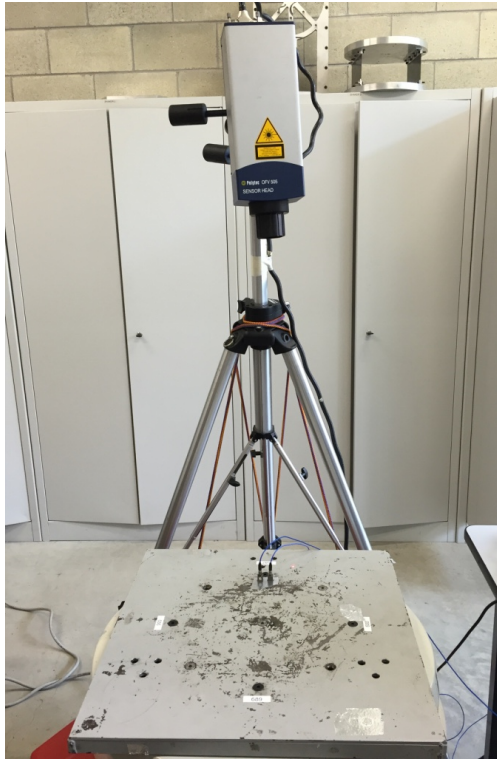
- Height (cm): 175 +/- 9
- Mass (kg): 69 +/- 14
- Foot length (cm): 26 +/- 2

Reflective Marker Set-up





Laser Doppler Vibrometer (LDV)



Polytec LDV

(OFV-505 Sensor Head)

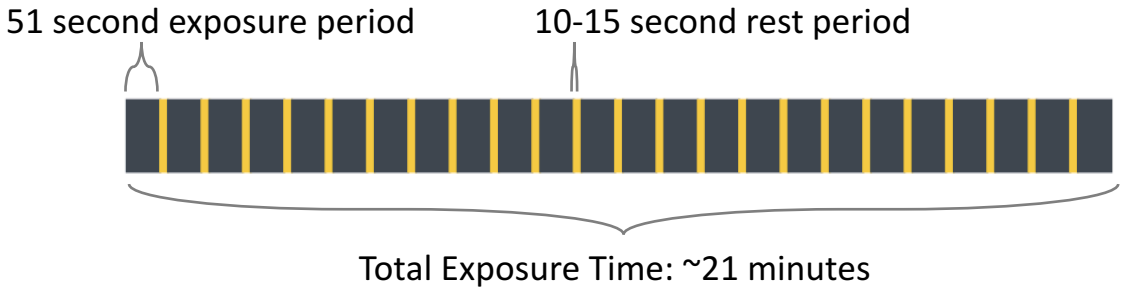
- Pointed at a reflective marker applied to the skin
- Used to record vertical vibration

Vibration Platform and Exposure Profile

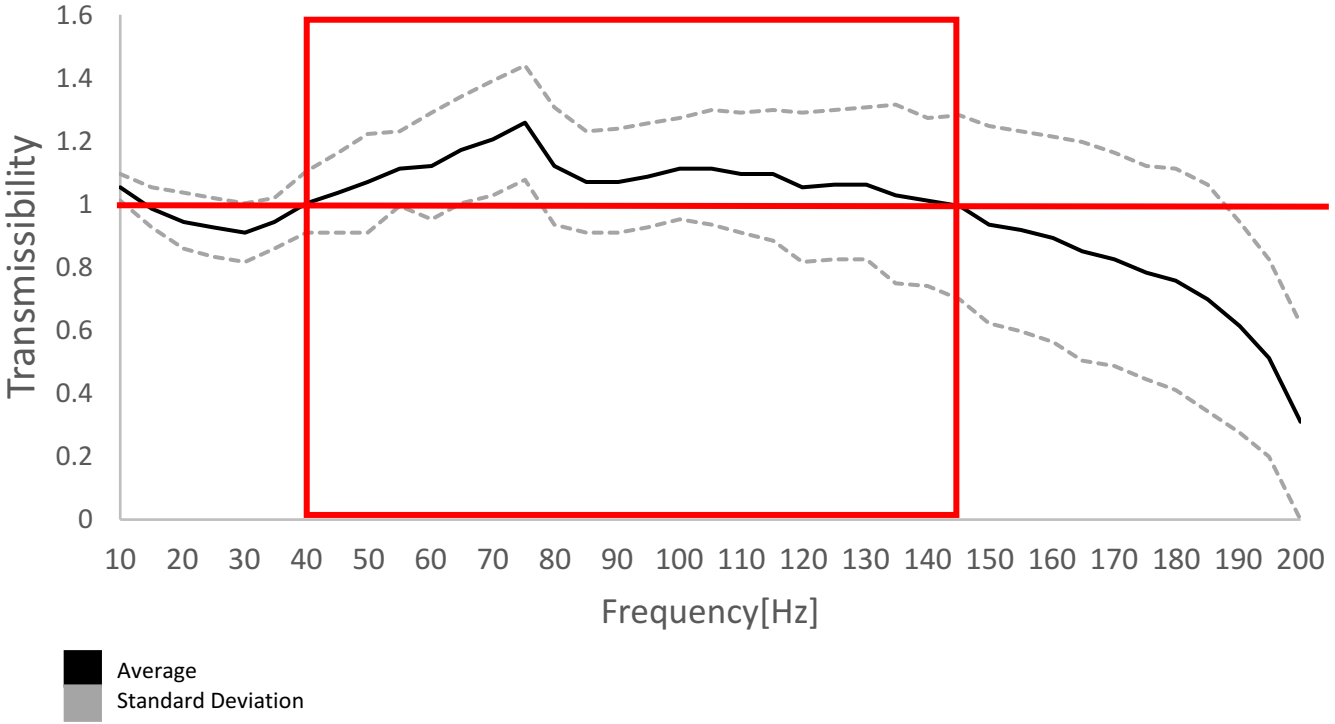
LDS V830 Electromagnetic Shaker

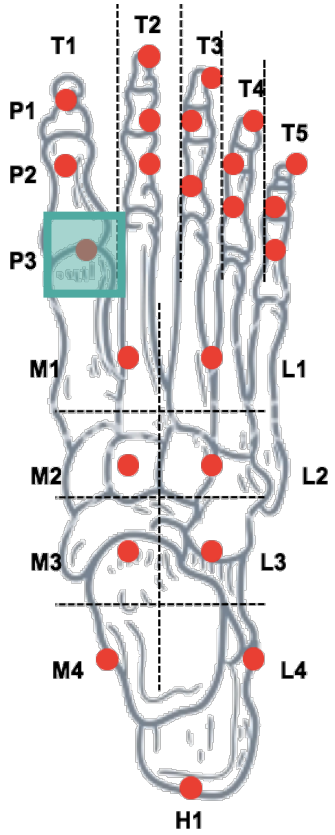
Sinusoidal Sweep Signal
Frequency Range: 10-200Hz
Vertical Magnitude: 0.5m/s^2

Accelerometer
(Bruel and Kjaer 4508B)



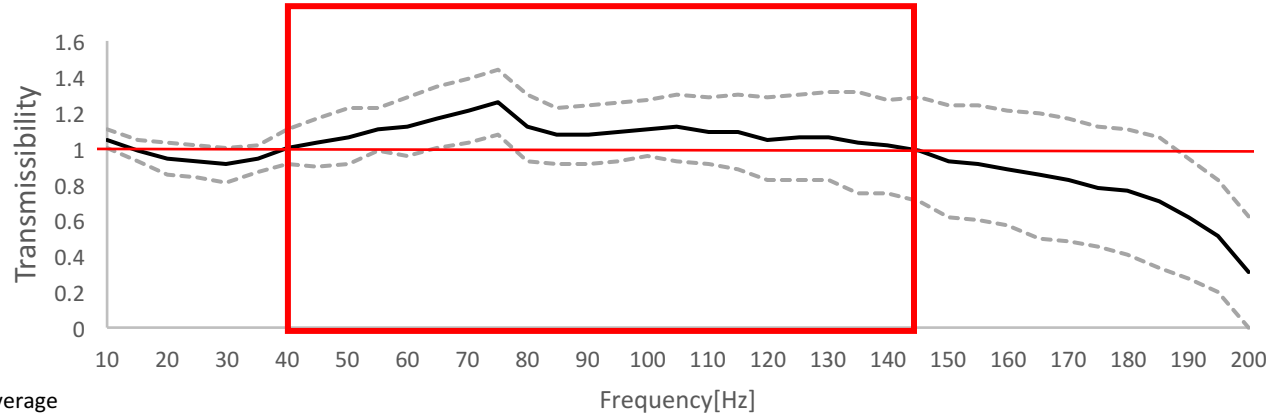
Transmissibility Results





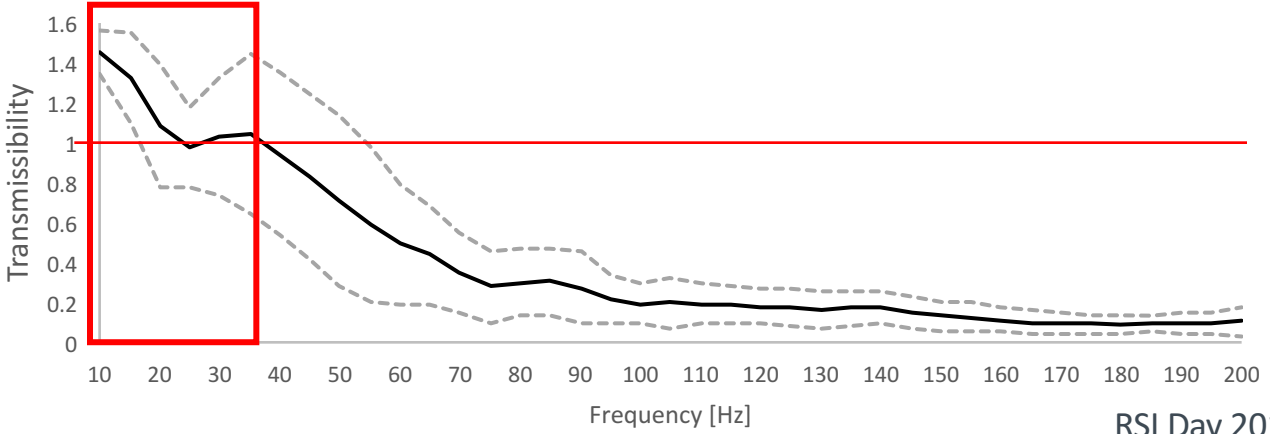
Transmissibility Results

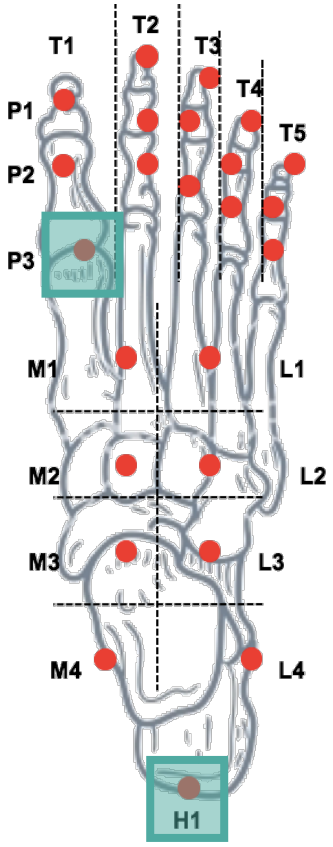
T1P3



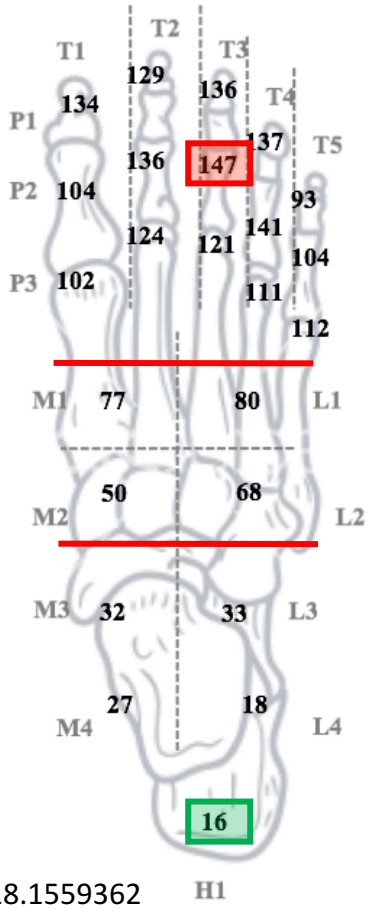
Average
Standard Deviation

H1

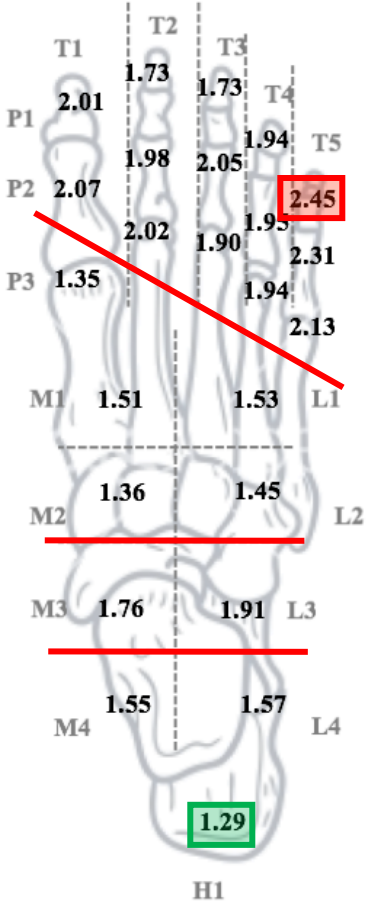




AVERAGE PEAK FREQUENCY [Hz]



AVERAGE PEAK MAGNITUDE

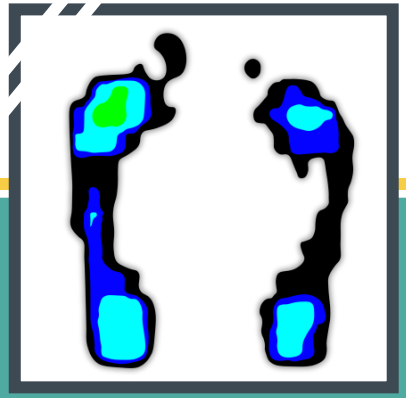


Ergonomics
DOI: :10.1080/00140139.2018.1559362

PhD Research Objectives

1

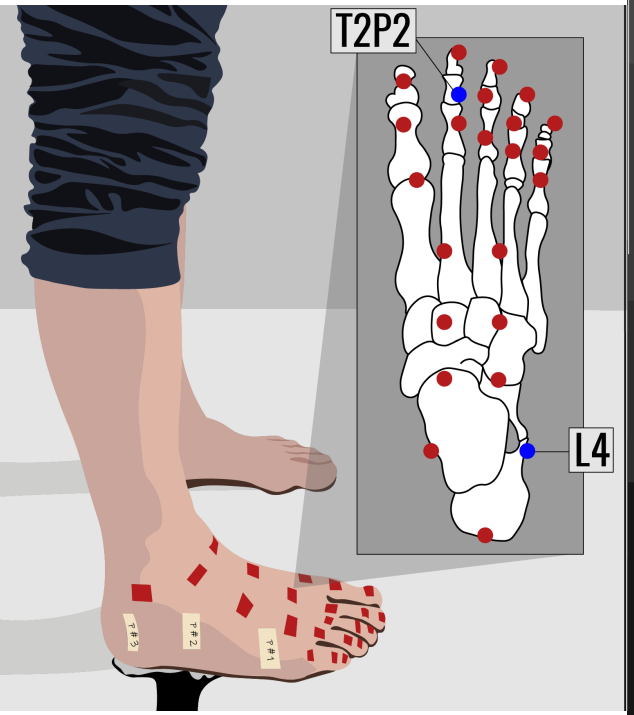
2

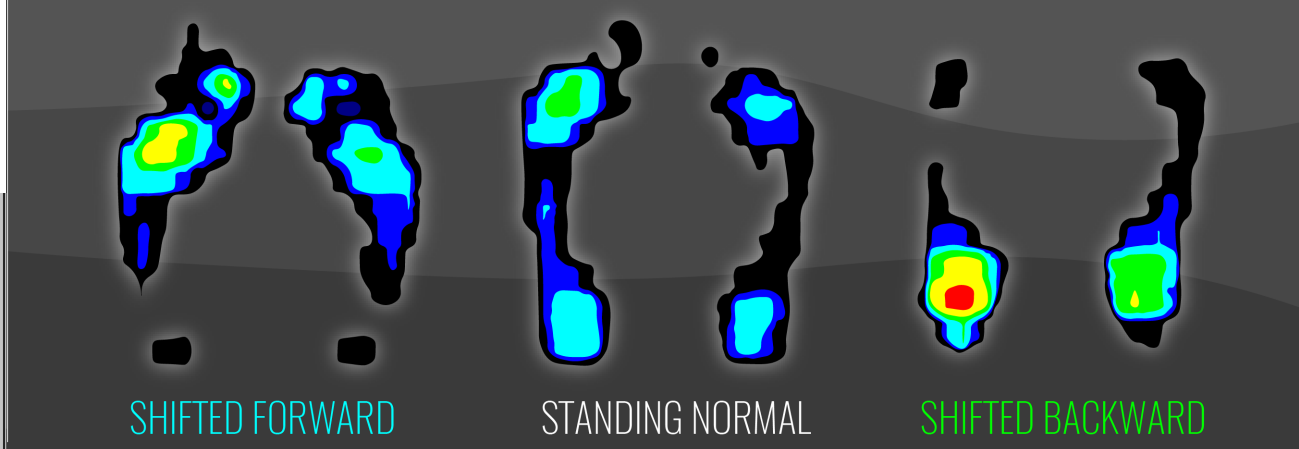


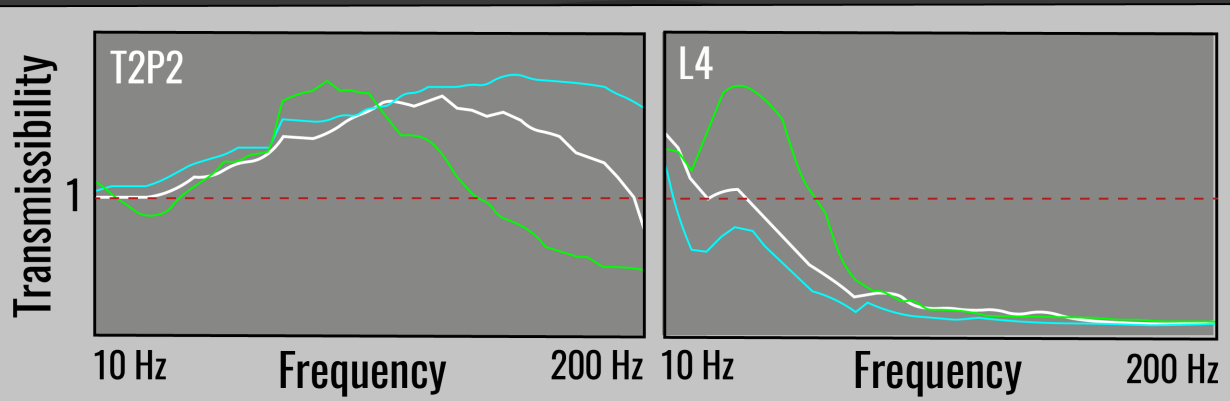
3

?

How do changes in our centre of pressure affect how vibration is transmitted through the feet?







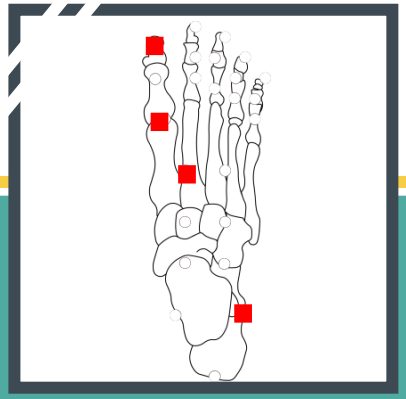
There were differences in how vibration was transmitted through the 24 locations on the foot when the centre of pressure was shifted forward or backward.

PhD Research Objectives

1

2

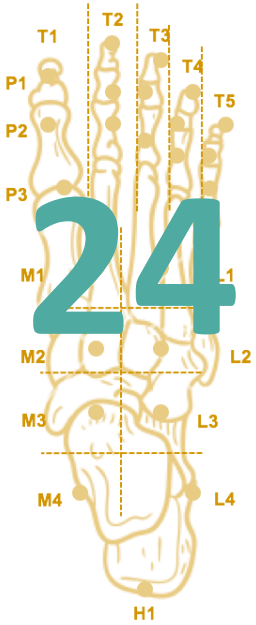
3



?

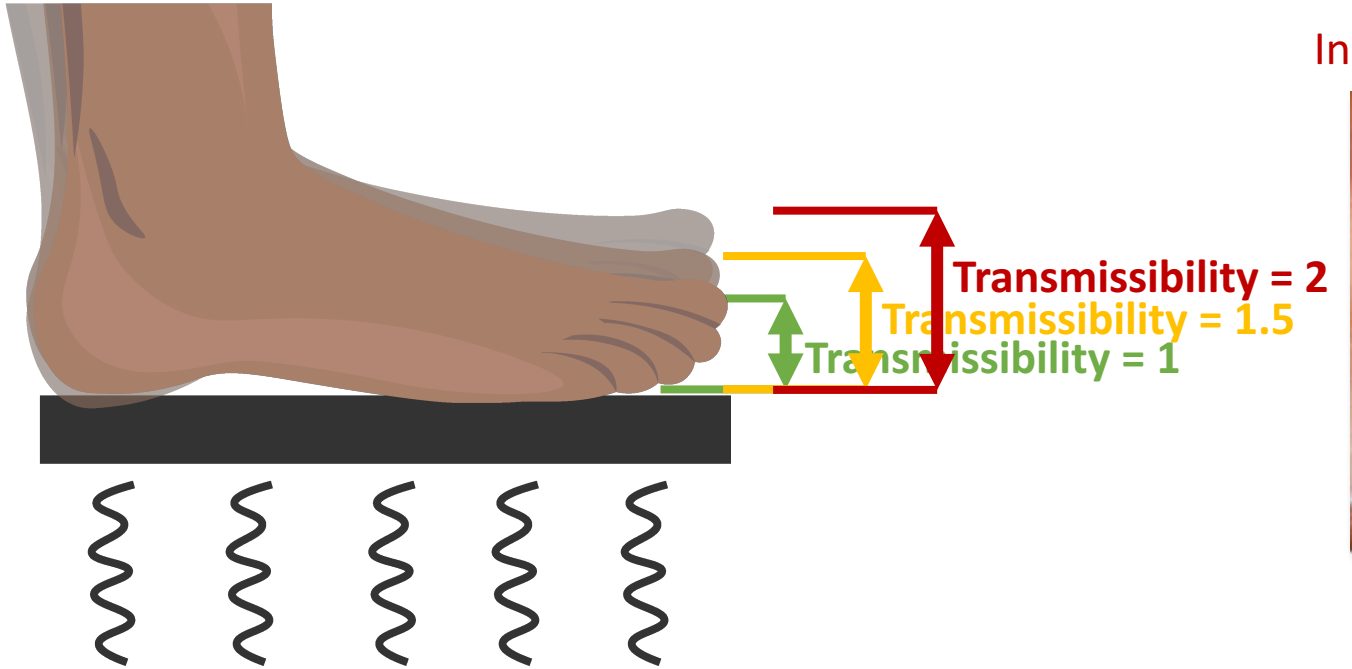
Can we reduce the number of measurements necessary to capture FTV?

Can we reduce the number of measurements necessary to capture FTV?



24 x **21** x **3** = **1512**

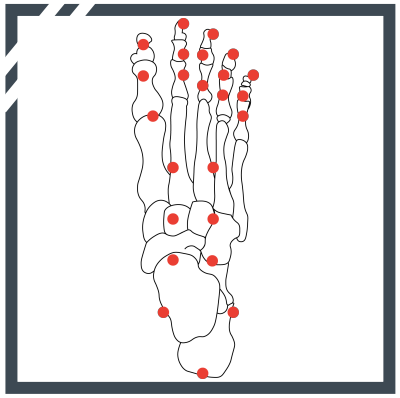
How do we infer risk from transmissibility?



Increased risk of VIWFt

What have we learned?

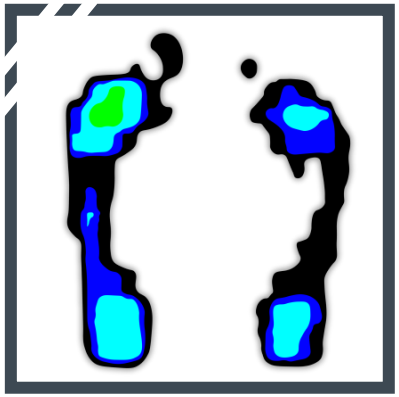
1



- How is vibration transmitted through the foot?
  - Differences in transmissibility based on anatomical location
- What frequencies affect the foot the most?
  - Toes: 93 – 147 Hz
  - Midfoot: 50 – 80 Hz
  - Ankle: 16 – 33 Hz

What have we learned?

2

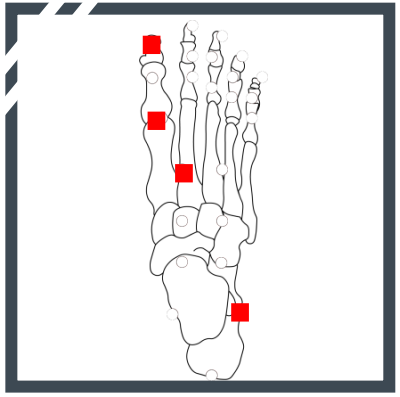


- What frequencies affect the foot the most?
- Do changes in how we apply pressure on the foot affect the transmission of vibration?

	Forward	Natural	Backward
Toes	111 – 170 Hz	93 – 147 Hz	77 – 123 Hz
Midfoot	81 – 126 Hz	50 – 80 Hz	39 – 74 Hz
Ankle	11 – 33 Hz	16 – 33 Hz	33 – 43 Hz

What have we learned?

3



- How many measurements are required to capture the foot's response to vibration?
  - Regardless of COP position: 4

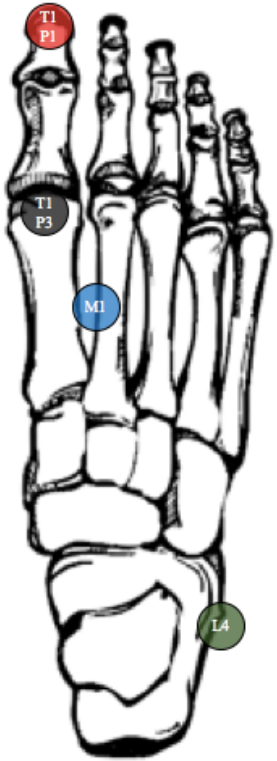
- Where should we be taking measurements on the foot?
  1. Nail bed of first toe
  2. Distal head of first metatarsal
  3. Middle of second metatarsal
  4. Lateral malleolus

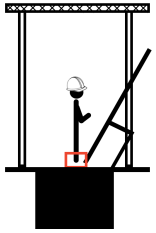
What does this mean?

Laboratory (Researcher)

Decrease Exposure Time

- Test different conditions using the same participants
- Design engineering – solutions development
- Increase success with ethics applications





Field (Ergonomist)

Maximize Risk Analysis

- Only measure at known locations for increased risk
- Potential for a new standard for evaluating FTV, instead of grouping with standing WBV

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Questions?

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