HAND ARM VIBRATION

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Methods for the laboratory evaluation of HAV-related comfort of bikes

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AIM

Our work aims at summarizing our experience in tests performed for the evaluation of the HAV-related riding comfort.

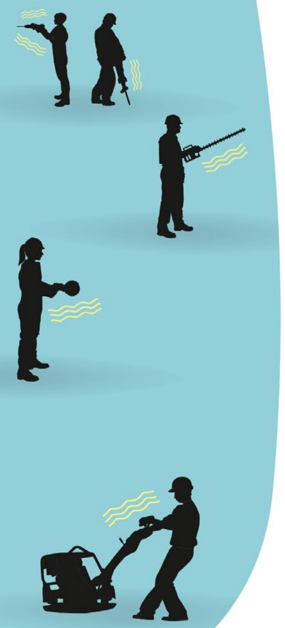
Our focus is on:

1. the experimental **setup**,
2. the identification of the **vibration stimulus** and
3. the **metrics** for the **subjective** and **objective** evaluation of **comfort**.

Introduction

- **Cyclists** are exposed to **hand-arm vibration** generated by the road (or track) irregularities and transmitted **to handlebars, pedals** and **saddle** through the bike wheels, fork and frame.
- **Vibrations limit the comfort** and bike manufacturers are looking for **solutions** to attenuate the energy transmitted at the hands, in order **to improve the riding comfort**.

Introduction



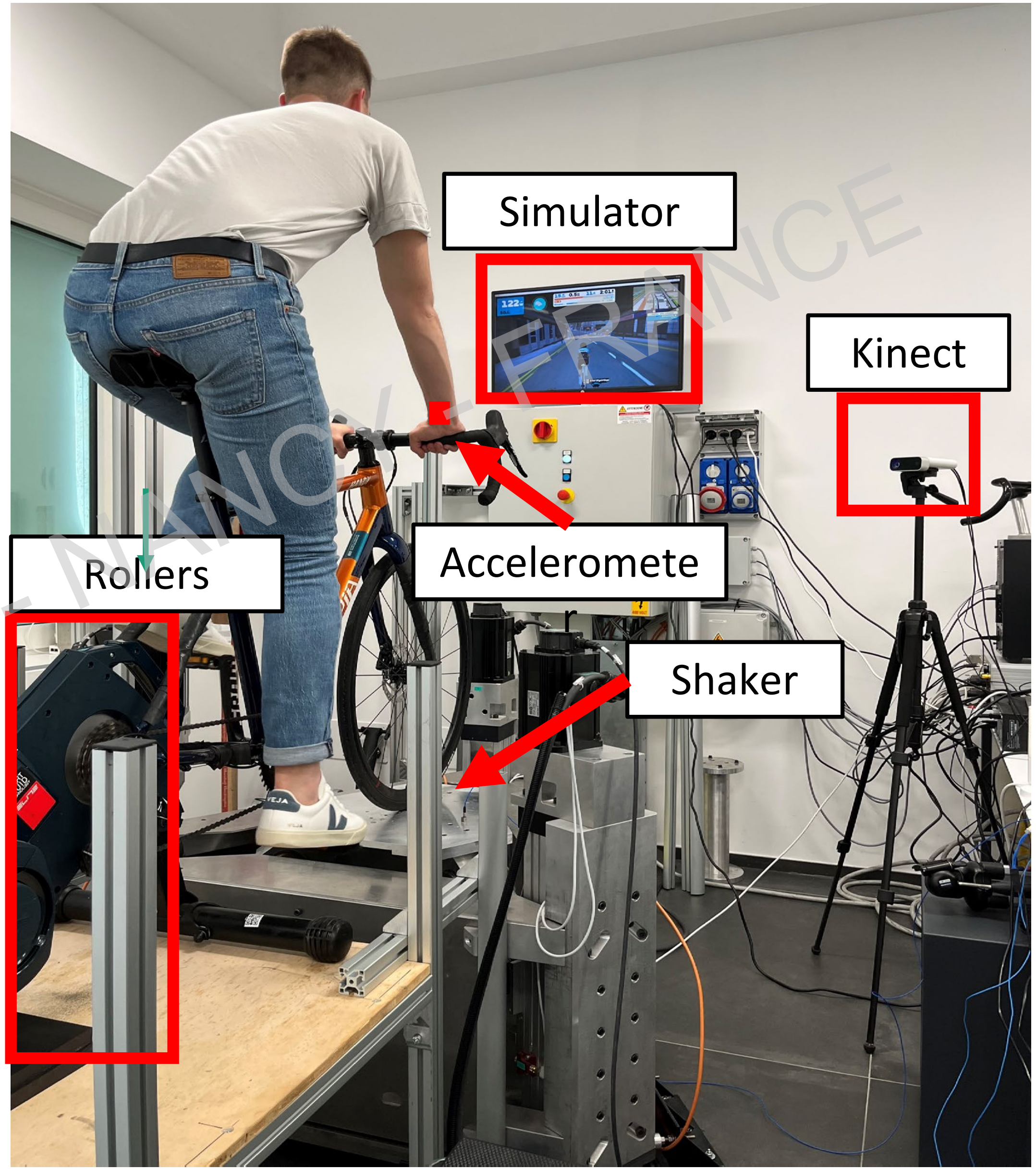
The possibility of **developing diseases seems limited**, despite the value of A(8) (as defined in the ISO 5349-1) is usually high and the exposure time limit for a 20 km/h trip on and paved street is in the order of tens of minutes [1], [2]. Were observed:

- carpal tunnel syndrome in long-distance cycling [3],
- discomfort or pain after cycling [4], [5].

[1] X. Chiementin, M. Rigaut, S. Crequy, F. Bolaers, and W. Bertucci, “Hand-arm vibration in cycling,” JVC/Journal Vib. Control, vol. 19, no. 16, pp. 2551–2560, 2013.
[2] M. Tarabini, B. Saggin, and D. Scaccabarozzi, “Whole-body vibration exposure in sport: four relevant cases,” Ergonomics, vol. 58, no. 7, pp. 1143–1150, 2015.
[3] V. Akuthota, C. Plastaras, K. Lindberg, J. Tobey, J. Press, and C. Garvan, “The Effect of Long-Distance Bicycling on Ulnar and Median Nerves: An Electrophysiologic Evaluation of Cyclist Palsy,” Am. J. Sports Med., vol. 33, no. 8, pp. 1224–1230, Aug. 2005.
[4] D. Capitani and S. Beer, “Handlebar palsy – a compression syndrome of the deep terminal (motor) branch of the ulnar nerve in biking,” J. Neurol., vol. 249, no. 10, pp. 1441–1445, 2002.
[5] L. A. Kirkwood, M. D. Taylor, L. A. Ingram, E. Malone, and G. D. Florida-James, “Elite mountain bike enduro competition: a study of rider hand-arm vibration exposure,” J. Sci. Cycl., vol. 8, no. 1, pp. 18–25, 2019.

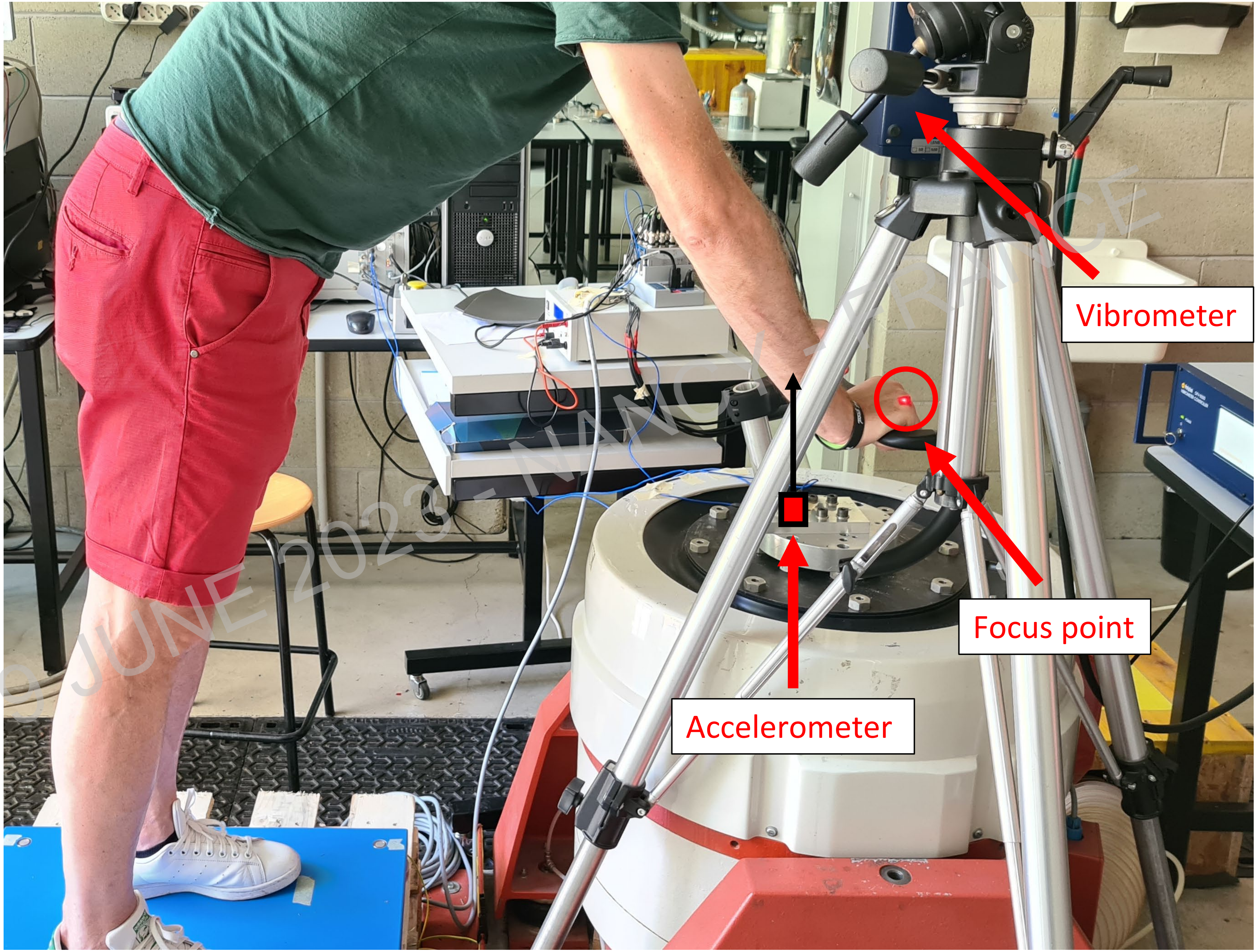
Setup 1

- The **entire bike** mounted on **smart rollers .**
- The plate of a 3D shaker supports the front wheel of the bike and imposes the **vibration along** the **vertical** and/or **medio-lateral axes**.
- The **cyclist's posture** is measured by the **Kinect 4 Azure** and **Kinect Body Tracking** (Microsoft)
- **Acceleration** is measured at the right wrist using accelerometer (PCB 333030, 100 mV/g).



Setup 2

- The **handlebar is mounted on** the head of **the shaker**.
- **Estimation of the vibration transmissibility** of different handlebars and tapes using a **vibrometer** focused on the **knuckle**.
- Ad-hoc measurements to ensure a realistic contact **force distribution** between the **handlebar** and the **feet**.



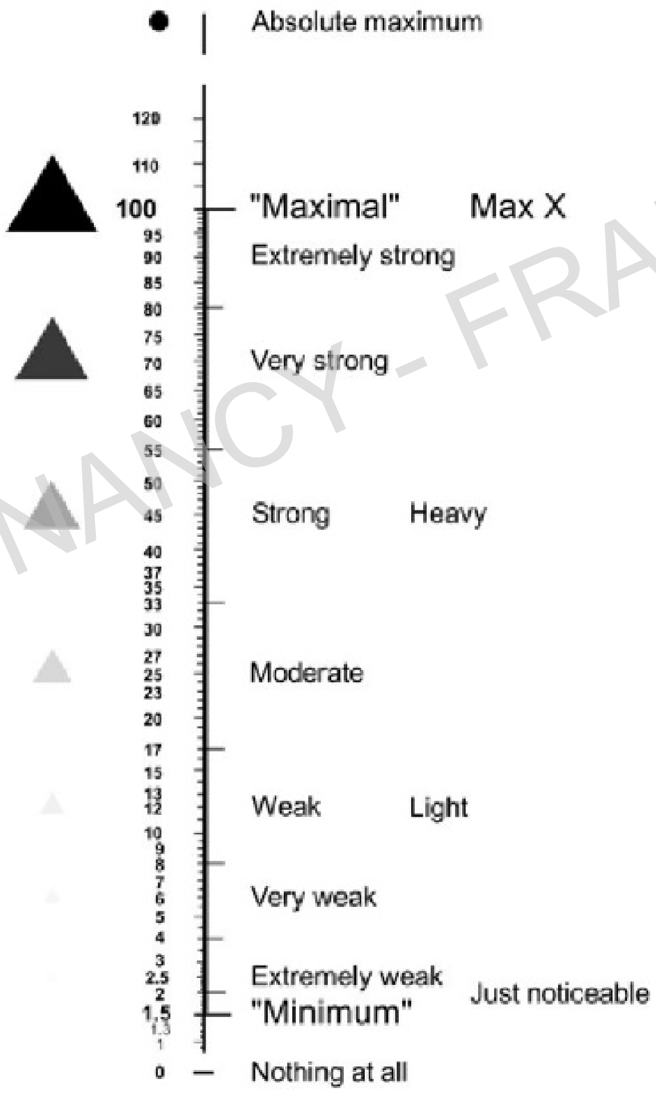
Vibration stimulus

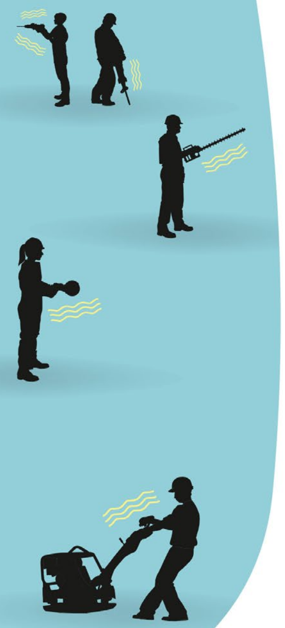
Since there are no reference vibration profiles for cycling, it is possible to adopt two approaches:

1. Reproducing the vibration measured on-field during a bike session with a PSD imposed at the vibrating platform. The vibration profile depends on tests parameters such as the speed, the terrain characteristics, the tires' pressure and cyclist's anthropometric characteristics.
2. Using harmonic or random stimuli; the RMS of the vibration stimulus usually varies between 5 and 50 m/s^2; lower values are used to simulate urban or road cycling at low speed, while higher accelerations are meant to simulate the off-road and gravel vibration.

Comfort Metrics - subjective

The perceived comfort can be evaluated at different time intervals using the CR100 scale proposed by Borg and Borg [6].





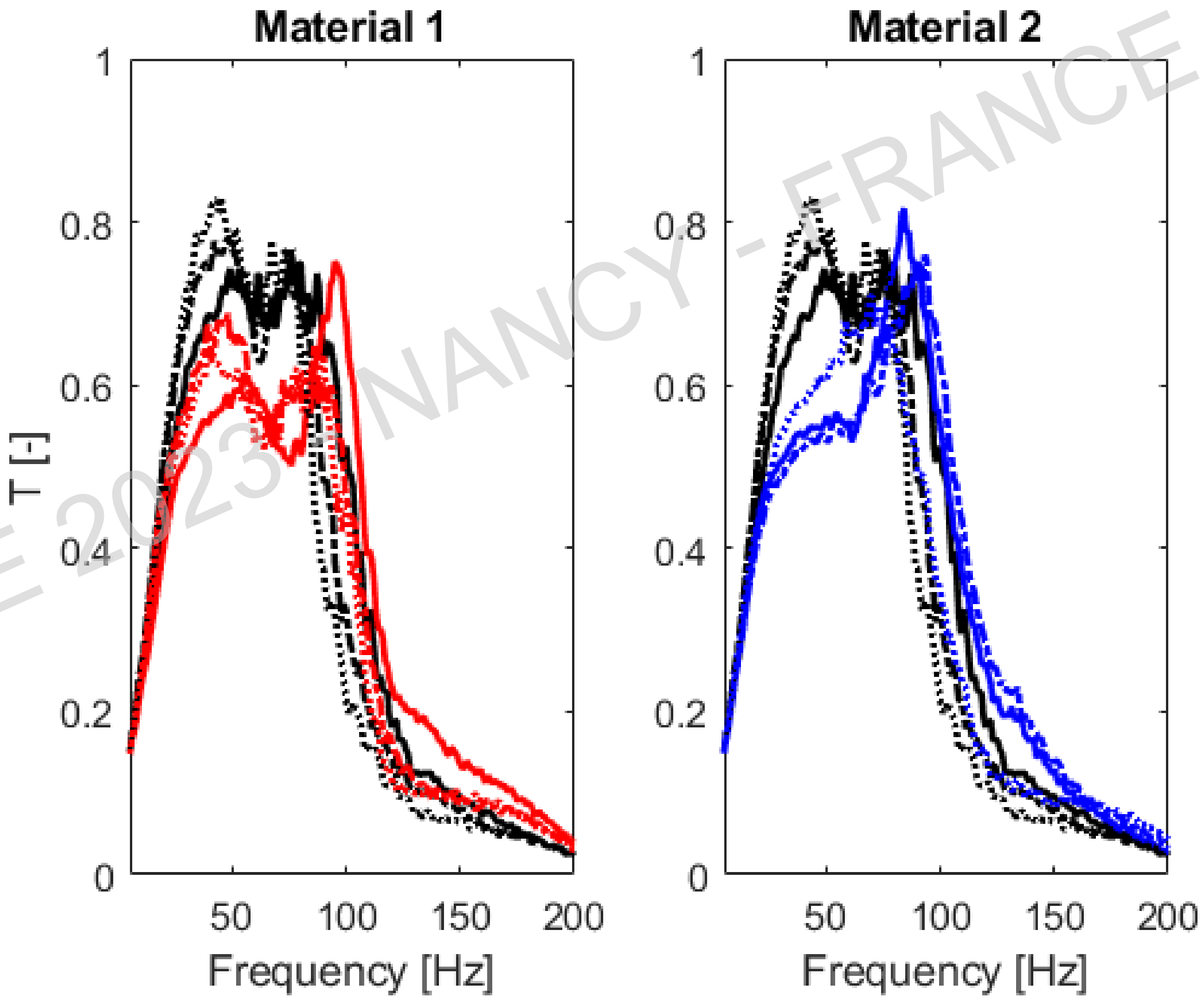
6. E. Borg and G. Borg, "A comparison of AME and CR100 for scaling perceived exertion," Acta Psychol. (Amst)., vol. 109, no. 2, pp. 157–175, Feb. 2002.

Comfort Metrics - objective

The discomfort can be quantified by the **vibration transmissibility**

$$T^{ID}(f) = \frac{r^{ID}(f)}{i(f)},$$

function of the vibration frequency f, is the ratio between the spectrum of the acceleration response $r^{ID}(f)$ and the spectrum of the vibration input $i(f)$.

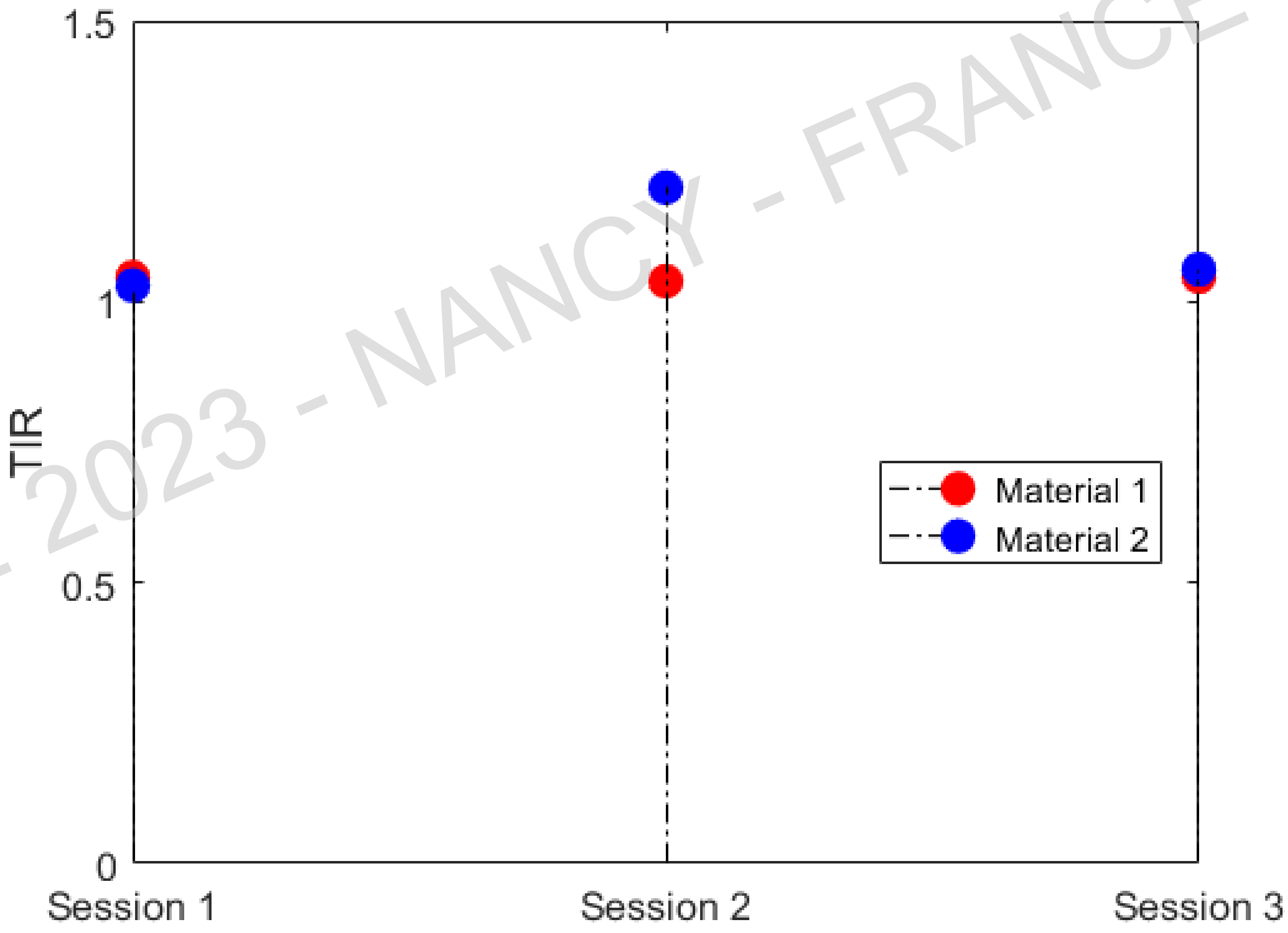


Comfort Metrics - objective

In each ID tested configuration (e.g., a specifi grip material or a high/low tire pressure)

The Transmissibility Integral Ratio (TIR) of the configuration ID can be computed as the ratio between the integral value of

$$TIR^{ID} = \frac{\int T^{ID}}{\int T^{BL}}.$$



Case study

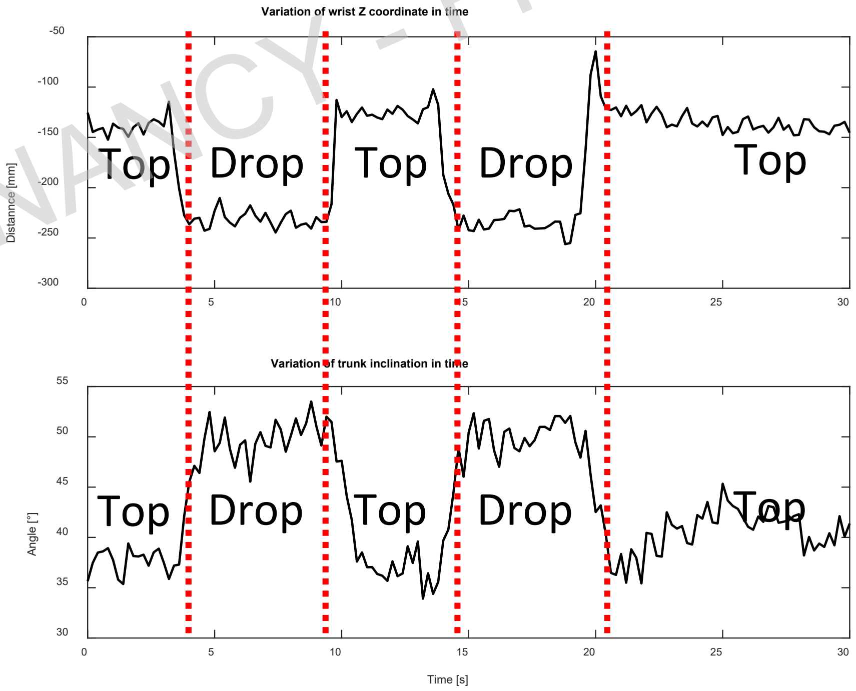
Setup and method to measure **cyclist's posture** during a training session.

Case study: change of posture

Top position

Drop position

Posture



Variation of wrist Z coordinate in time
Distannce [mm]
Top
Drop
Top
Drop
Top
Variation of trunk inclination in time
Angle [°]
Top
Drop
Top
Drop
Top
Time [s]

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