VIBRATION EXPOSURE ON COBBLESTONE SECTORS DURING PARIS-ROUBAIX : a single case study

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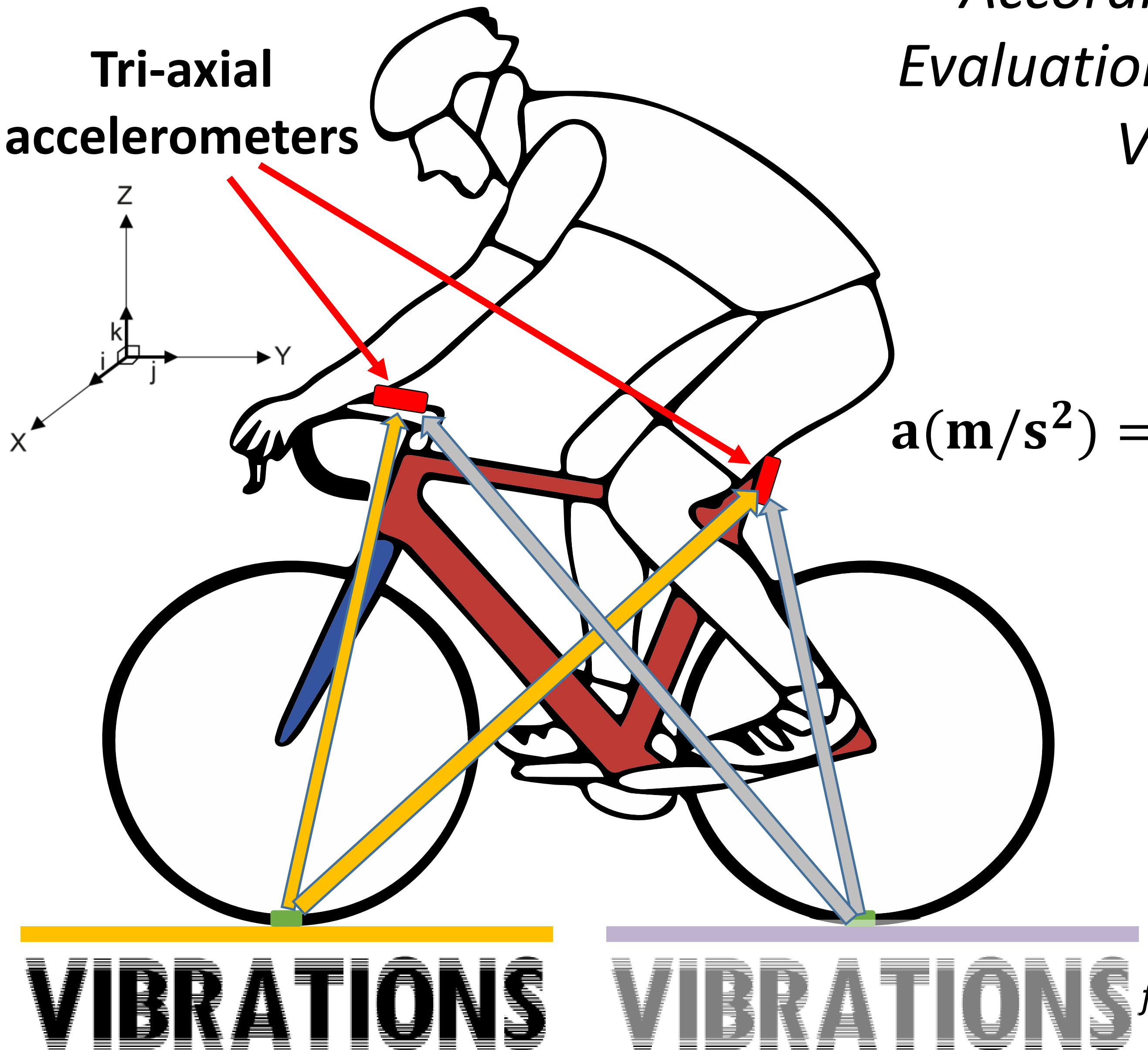
INTRODUCTION

MEASUREMENT OF VIBRATIONS

According to the European Directives for Evaluation of human exposure to whole Body Vibration (ISO 2631-1; 1997)



$$\mathbf{a(m/s^2)} = \sqrt{(\mathbf{k_x RMS_x})^2 + (\mathbf{k_y RMS_y})^2 + (\mathbf{k_z RMS_z})^2}$$

Weight coefficient

$k_x = 1{,}4$

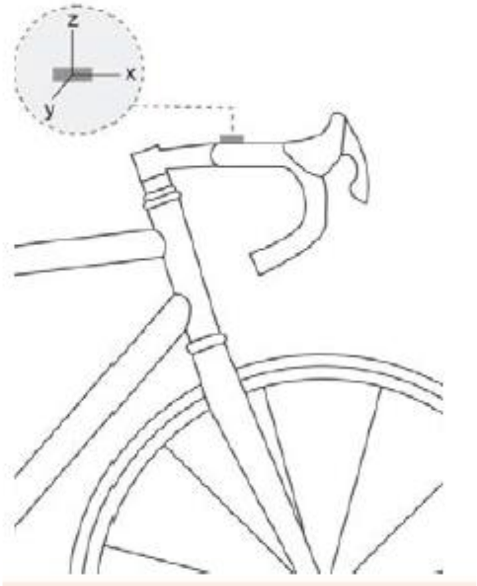
$k_y = 1.4$

$k_z = 1$

Illustration adapted from Lépine et al. 2014

WHICH FACTORS DETERMINE VIBRATION EXPOSURE?

Arpinar-Asvar et al. (J Sports Sci & Med, 2013)



Speed = 20 km/h

Table 2. Individual un-weighted rms acceleration values.

	Stem Acceleration ($m \cdot s^{-2}$ rms)	Smooth asphalt x	Smooth asphalt z	Concrete Stone x	Concrete Stone z	Rough Road x	Rough Road z
MTB	Subject 1	1.08	1.58	3.71	4.74	6.75	10.10
	Subject 2	1.89	2.22	4.14	5.19	7.60	9.37
	Subject 3	1.75	2.56	4.14	7.04	6.23	10.76
	Subject 4	1.40	1.66	3.60	4.18	7.16	7.86
	Subject 5	1.55	2.37	3.30	5.30	6.00	10.17
	Mean	1.53	2.08	3.78	5.29	6.75	9.65
	SD	.32	.44	.36	1.07	.66	1.12
RB	Subject 6	2.84	3.21	10.69	9.97	16.24	19.12
	Subject 7	3.58	3.85	8.60	9.42	13.15	13.68
	Subject 8	3.69	4.43	9.54	11.12	18.31	27.31
	Subject 9	4.37	4.21	7.61	8.52	13.71	18.12
	Subject 10	3.08	3.38	10.25	11.75	18.06	23.58
	Mean	3.51	3.82	9.34	10.16	15.[illegible]9	20.36
	SD	.59	.52	1.25	1.30	2.40	5.24

x 2

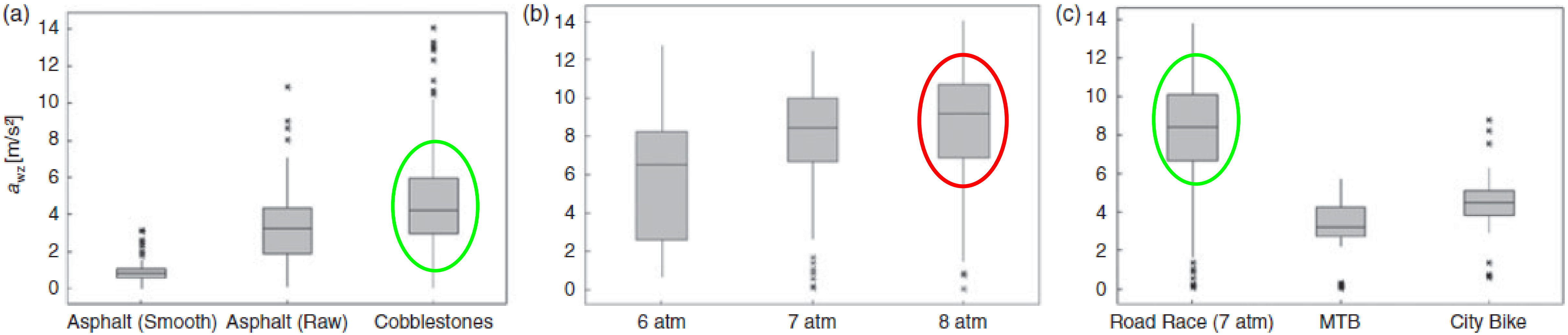
x 6

- Higher RMS with road bikes vs MTB
- RMS ↗ with road roughness

WHICH FACTORS DETERMINE VIBRATION EXPOSURE?

Tarabini et al. (Ergonomics, 2015)

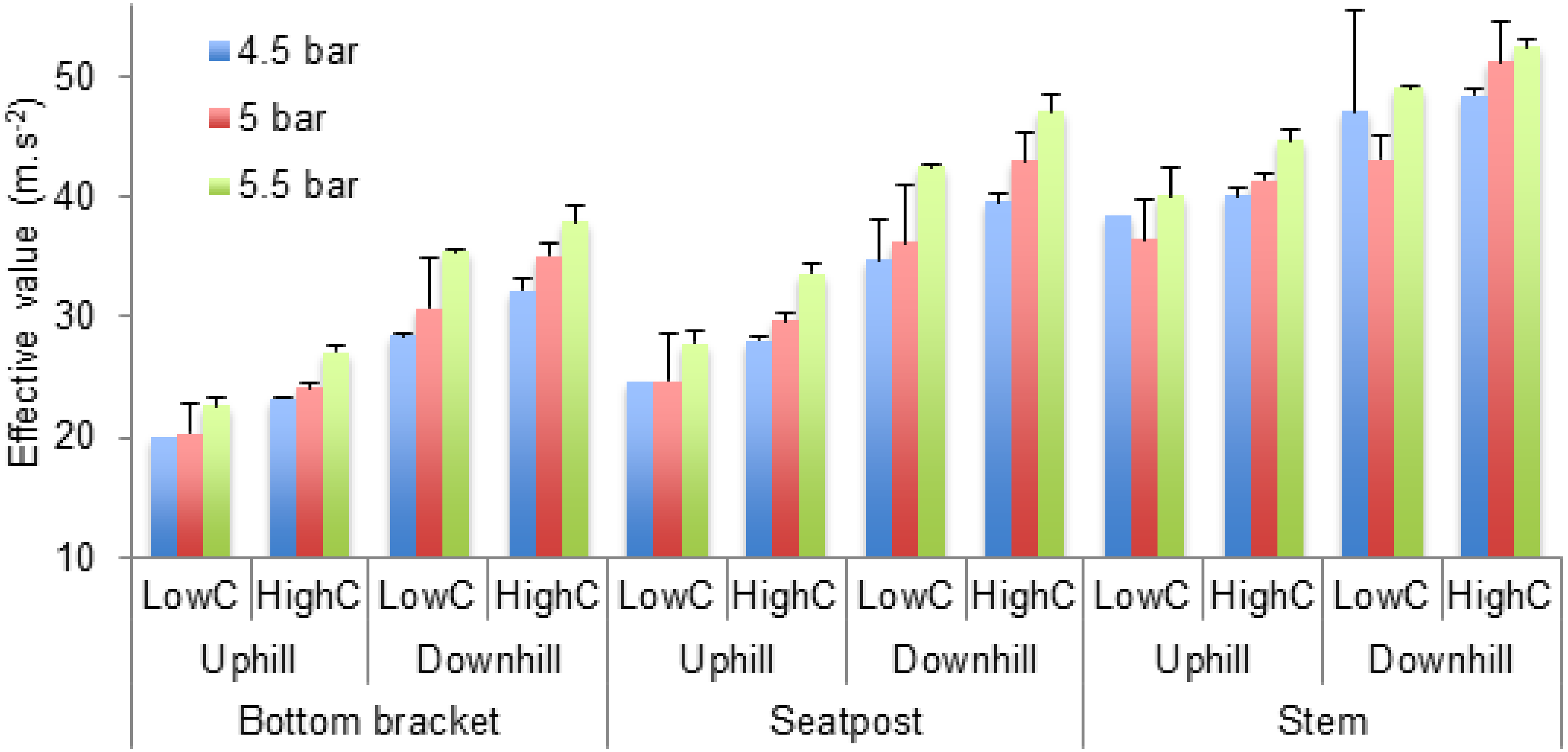
Speed ?



- RMS ↗ with tyre pressure

Puel, Duc, Grappe & Bertucci (2015)

Speed ~31 km/h (downhill)
~ 22 km/h (uphill 3-4%)



- RMS ↗ with speed
- $RMS_{stem} > RMS_{seatpost} > RMS_{bottom\ bracket}$

OBJECTIVES OF THIS STUDY

- **To measure vibrations** at the stem and at the seatpost in “Paris-Roubaix” cobblestone sectors

- **To quantify vibration levels** for the whole body (seatpost) and hand-arm system (stem) according to the European Directives (ISO 2631)

- **To compare vibration exposure** in road cycling on cobblestones with standards for workers

METHOD / Design

- One competitive male cyclist (1.80 m; 68 kg) participated to "Cycling for All Event" of UCI – 139 km race

PARIS ROUBAIX Challenge

11.04.2015

- 18 cobbles sectors = 31 km (22% total race distance)

  → data analysed over **15 cobblestone sectors**

  3 **

  6 ***

  4 ****

  2 *****

km	Départ/Start: Roubaix	
29	Rumegies	
46	Tro[illegible]erg ***** (crossed out)	Muddy !
52	Wa[illegible]mes *** (crossed out)	Crash !
57	Hornaing	
58	Hornaing à Wandignies ****	
65	Warlaing à Brillon ***	
69	Tilloy à Sars-et-Rosières ****	
75	Beuvry à Orchies ***	
80	Orchies ***	
86	Auchy à Bersée ****	
91	Mons-en-Pévèle *****	
97	Mérignies à Avelin **	
100	Pont-Thibault à Ennevelin ***	
106	Templeuve	
107	Templeuve - Moulin de Vertain **	
113	Cysoing à Bourghelles ***	
116	Bourghelles à Wannehain ***	
118	Camphin-en-Pévèle ****	
120	Carrefour de l'Arbre *****	
123	Gr[illegible] ** (crossed out)	Too smooth !
130	Willems à Hem **	
139	Vélodrome de Roubaix	

METHOD / Material

Tri-axial HIKOB- Fox accelerometer

Garmin EDGE 800

Hub PRO SL+ PowerTap

Technical characteristics of the bike	
Frame	**Carbon** fact 8 K Roubaix *(Specialized)*
Fork	**Carbon** fact 8 K Roubaix *(Specialized)*
Transmission	Centaur 12 x 25, 10 speeds *(Campagnolo)*
Crankset	Chorus Ultratorque 34 x 50 *(Campagnolo)*
Breaks	Centaur Aluminium *(Campagnolo)*
Wheels	RR.1.1. **Aluminium** *(DT Swiss)* Rim height : 21 mm
Tyres	Roubaix Pro 7**00-25c** *(Specialized)* **5 bar pressure**
Handlebar	WC **Aluminium** *(Ritchey)* **Gel pads tape** Roubaix *(Specialized)*
Stem	World Cup **Carbon** *(Massi)*
Saddle	Phenom *(Specialized)*
Pedals	Xpresso 2 *(Time)*
Weight	8.2 kg

METHOD / Measures

$f_{sampling} = 1\ Hz$

- ❖Power Output (PO, W)
- ❖Pedalling cadence (PC, rpm)
- ❖Heart Rate (HR, bpm)
- ❖Speed (km/h)

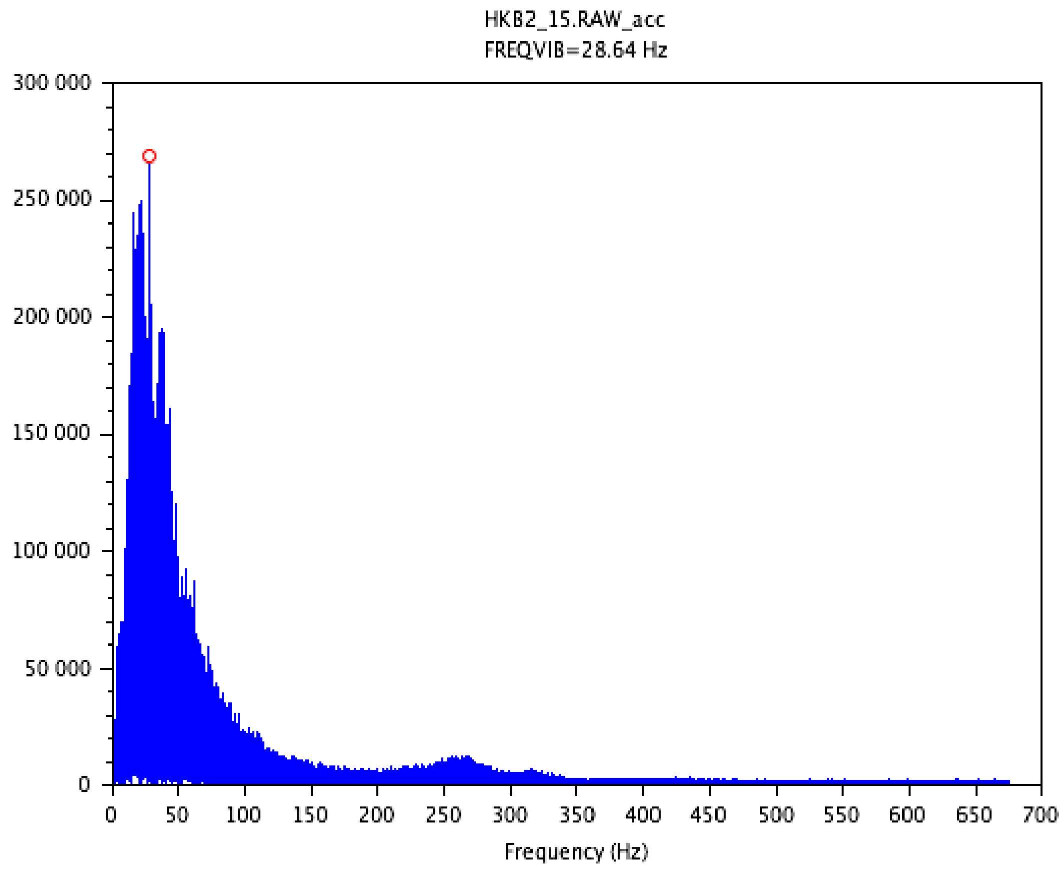
$f_{sampling} = 2000\ Hz$

- ❖Tri-axial Accelerations

→ data analysis only on Z axis

METHOD / Measures of vibration level

- principal **vibration frequency** (f_{vib}, Hz)
  - *Spectral analysis (FFT)*



- **Effective value** (RMS, m/s²)
  - *Procedure ISO 2631-1 (1997)*

$$\mathbf{RMS_z = \left[\frac{1}{T}\int_0^T a_z^2(t).\,dt\right]^{\frac{1}{2}}}$$

METHOD / Measures of vibration exposure

❖ **Acceleration equivalent level** (A(8), m/s²)

represent the equivalent acceleration energy as it varies over a working day

$$\mathbf{A(8)} = \sqrt{\frac{1}{T_0}\sum_{i=1}^{n} RMS_i^2 \times T_i}$$

Ti = cobblestone sector time (h)

T_0 = reference time (8h)

❖ **Vibration Dose Value** (VDV, m/s$^{1.75}$)

More sensible to peak acceleration

$$\mathbf{VDV} = \left[\int_0^T a_z^4(t).\,dt\right]^{\frac{1}{4}}$$

$$VDV_{total} = \left[\sum VDV_i^4\right]^{\frac{1}{4}}$$

→ *Cumulative measurement (dose) of the vibrations encountered during all cobblestone sectors (i)*

METHOD / Measures of vibrations exposure

$$T_{ELV}(min) = (8 \times 60) \times \left(\frac{ELV_{threshold}}{RMS}\right)$$

Exposure Limit Value (ELV)

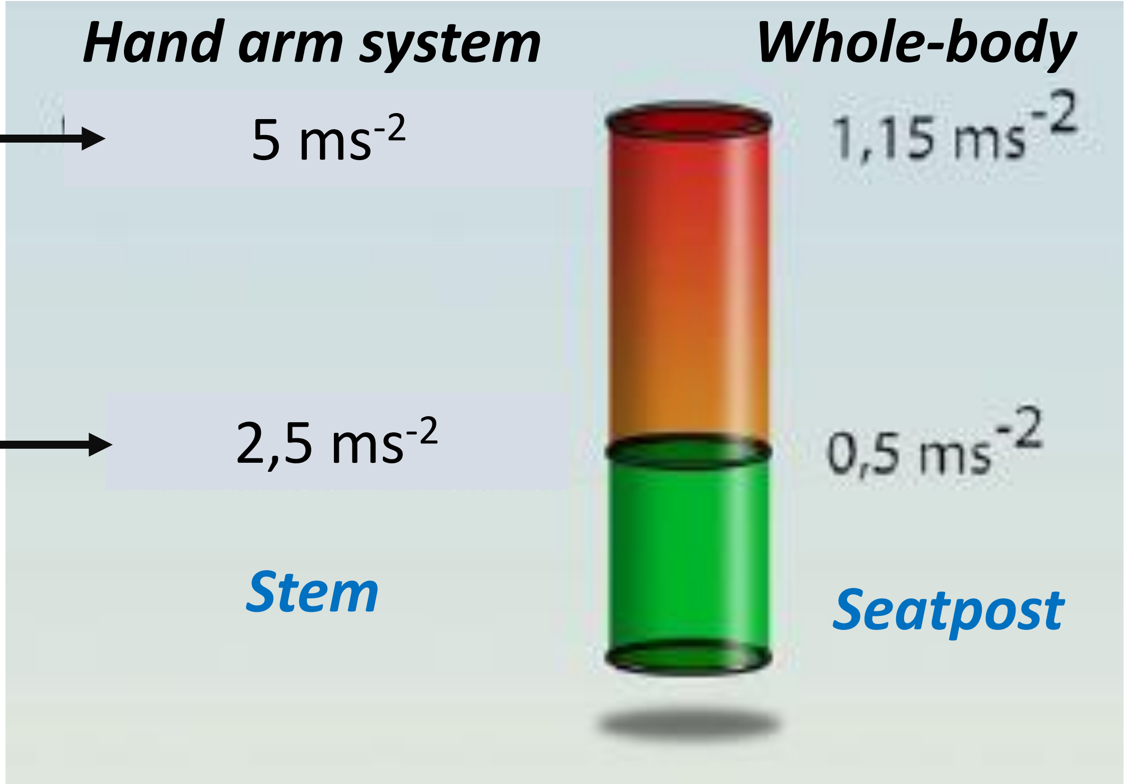
Workers must not to be subjected

Exposure Action Value (EAV)

Employers are required to take action to control exposure

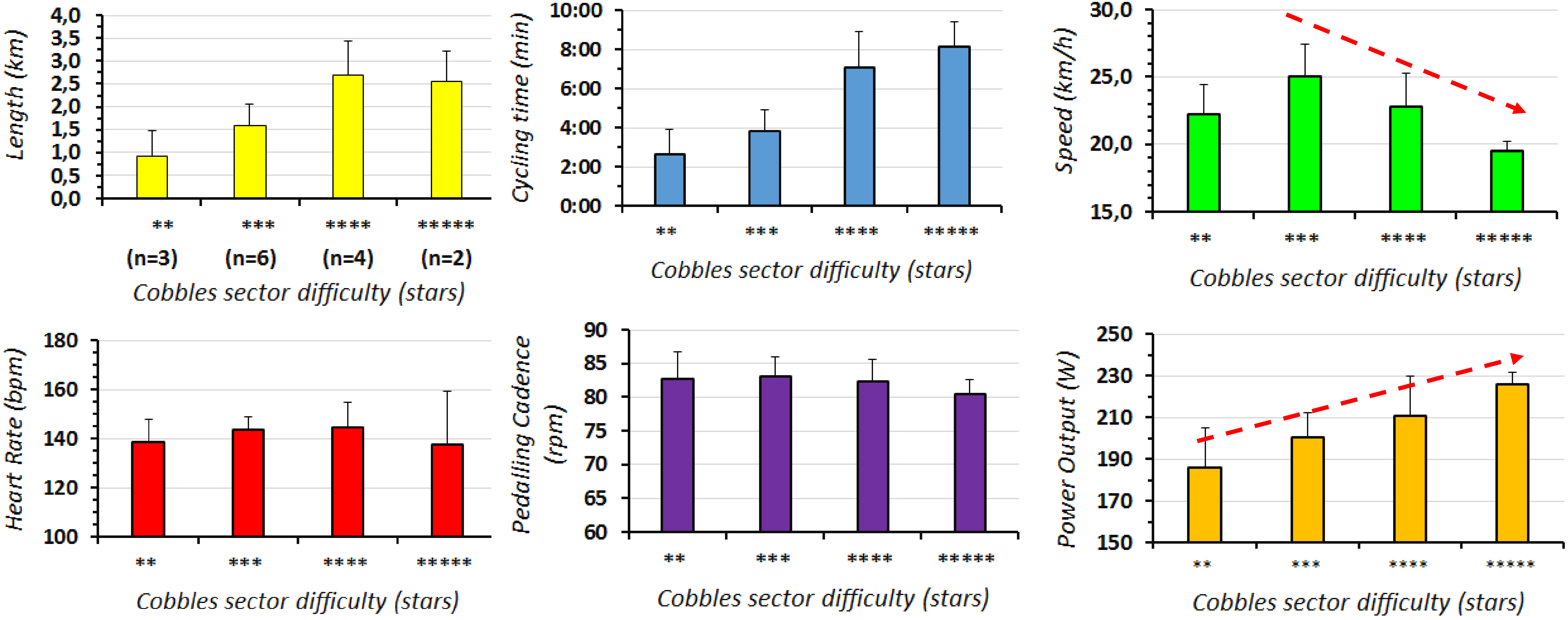
$$T_{EAV}(min) = (8 \times 60) \times \left(\frac{EAV_{threshold}}{RMS}\right)$$

Thresholds of exposure regarding amount of vibration during any single 8-hour daily exposure



European directive 2002/44/EC

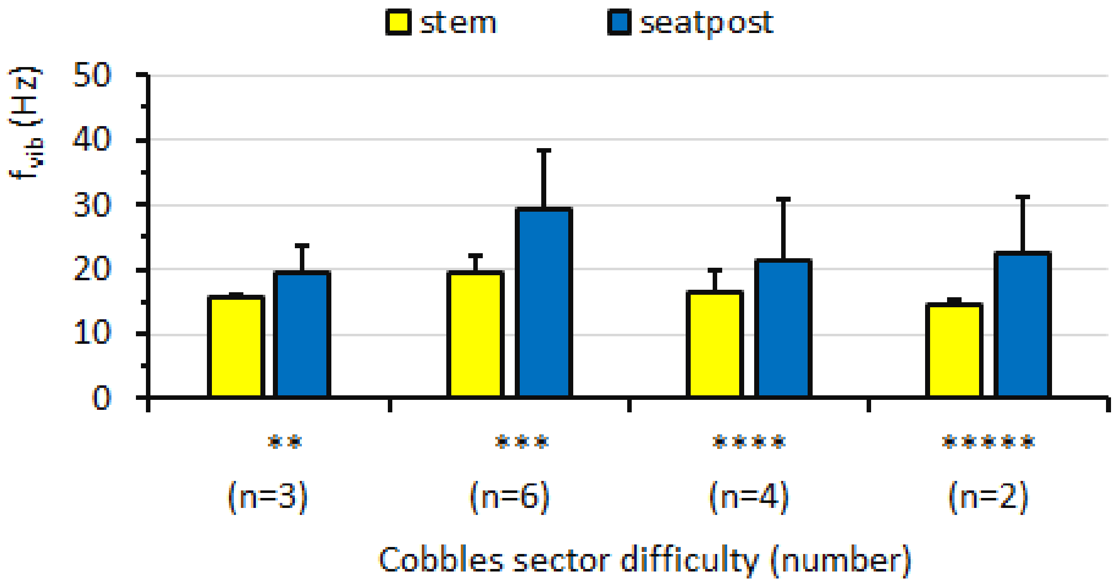
RESULTS

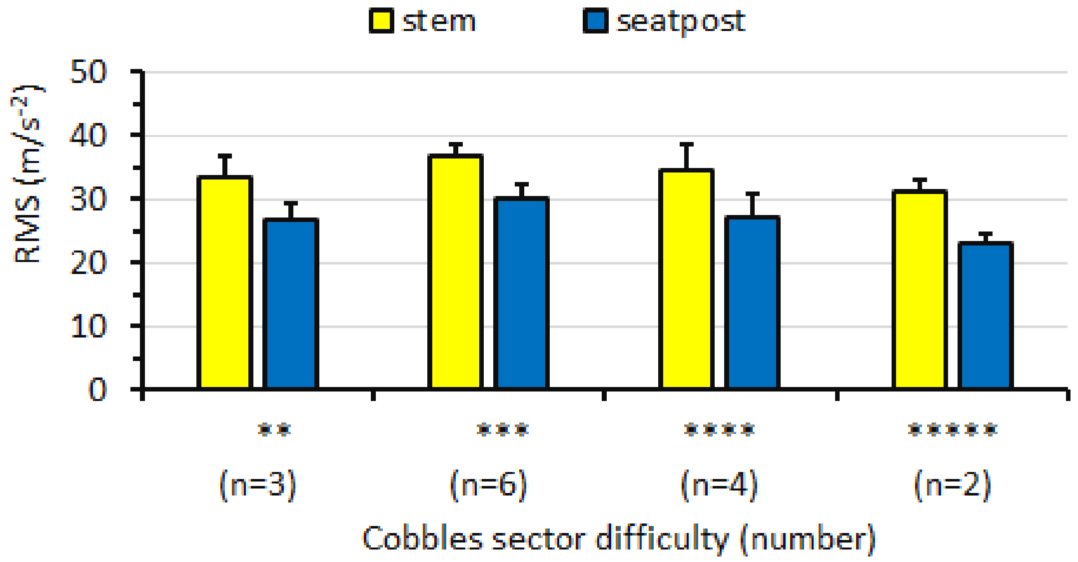


- PO increased on the hardest cobbles sectors while speed decreased

↳ **Lower mechanical efficiency ?**

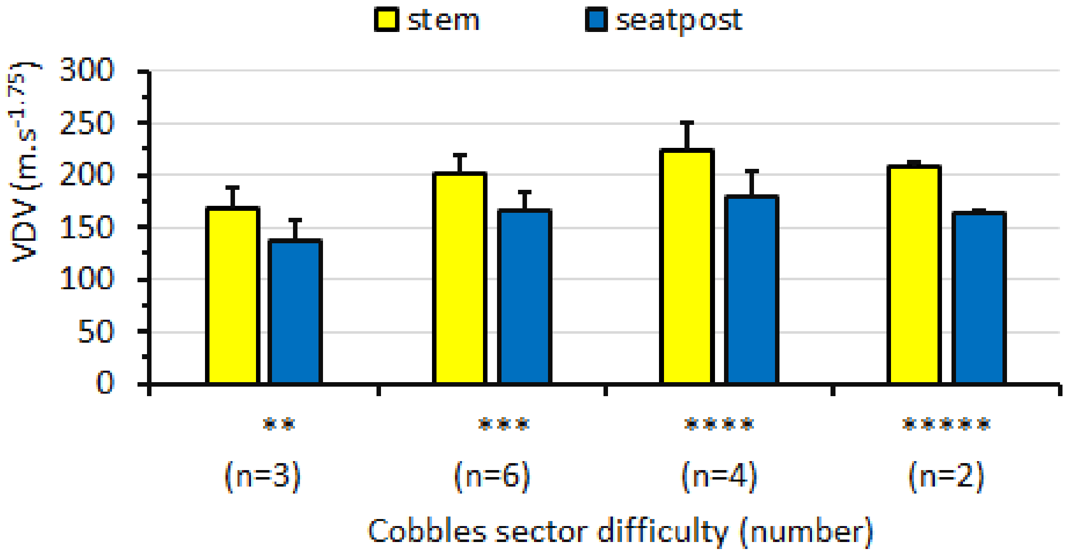
RESULTS



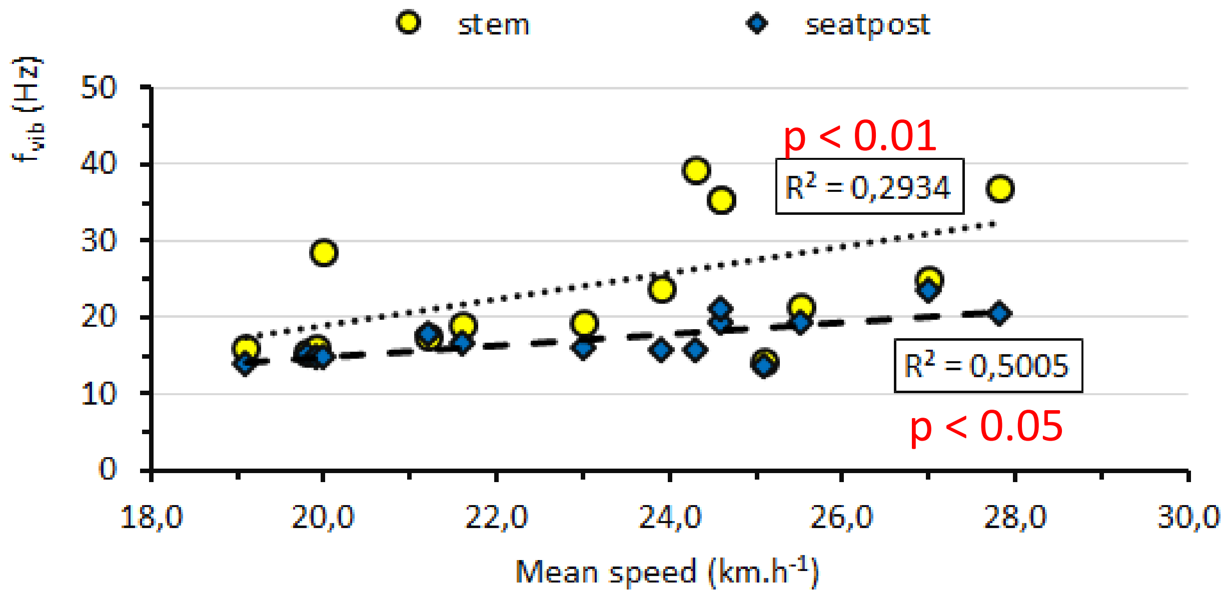


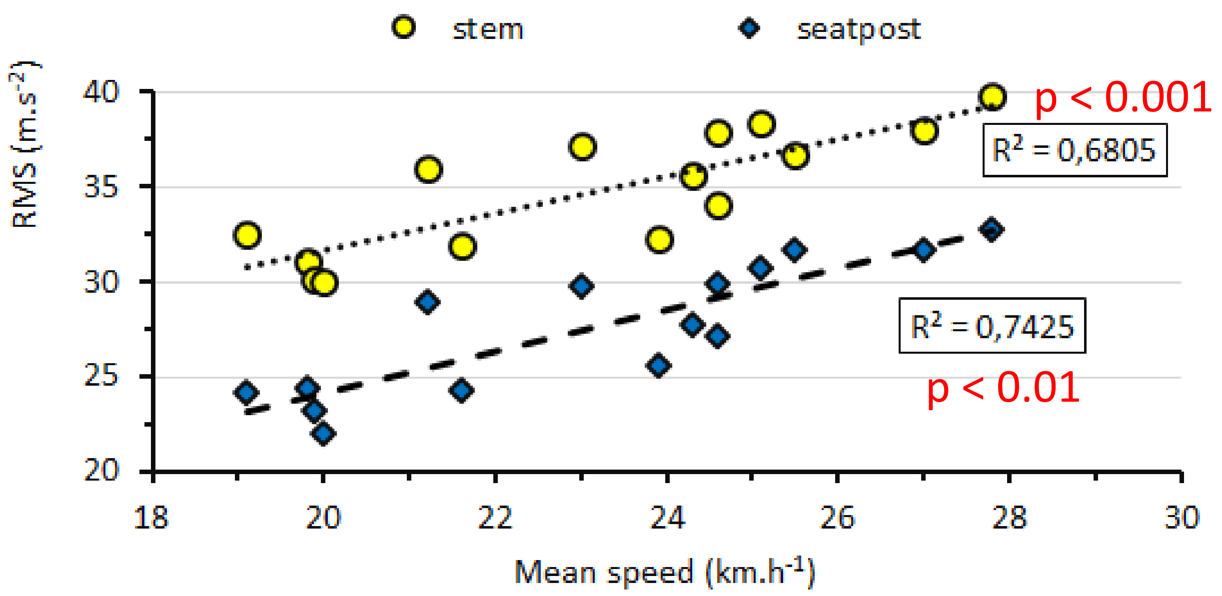
- ➢Higher Vibration frequency at seatpost
- ➢ Higher RMS and VDV at stem

↳ agree with Puel et al. (2015)



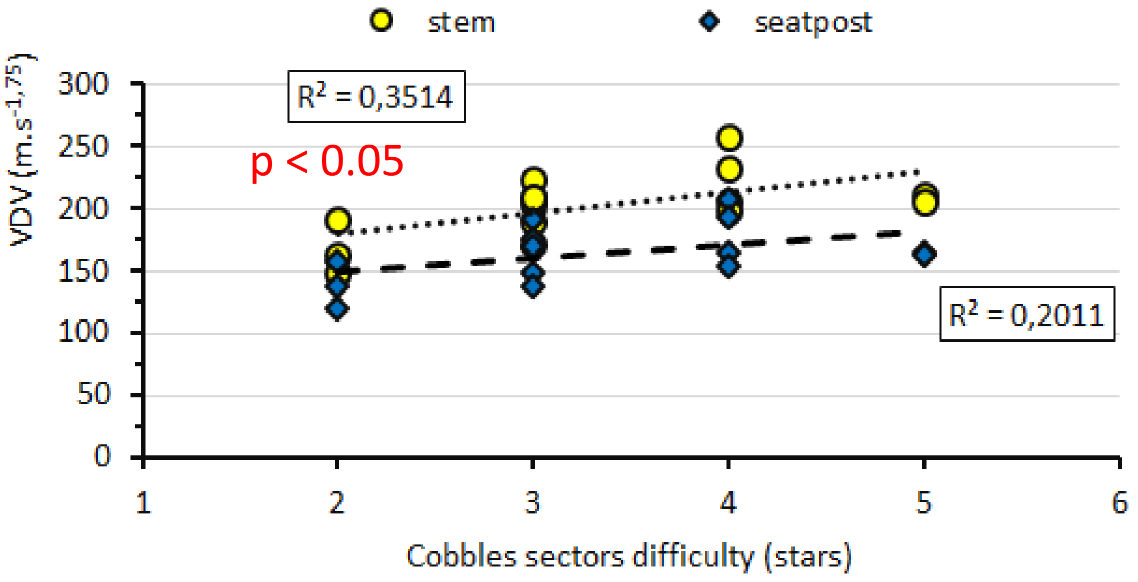
RESULTS





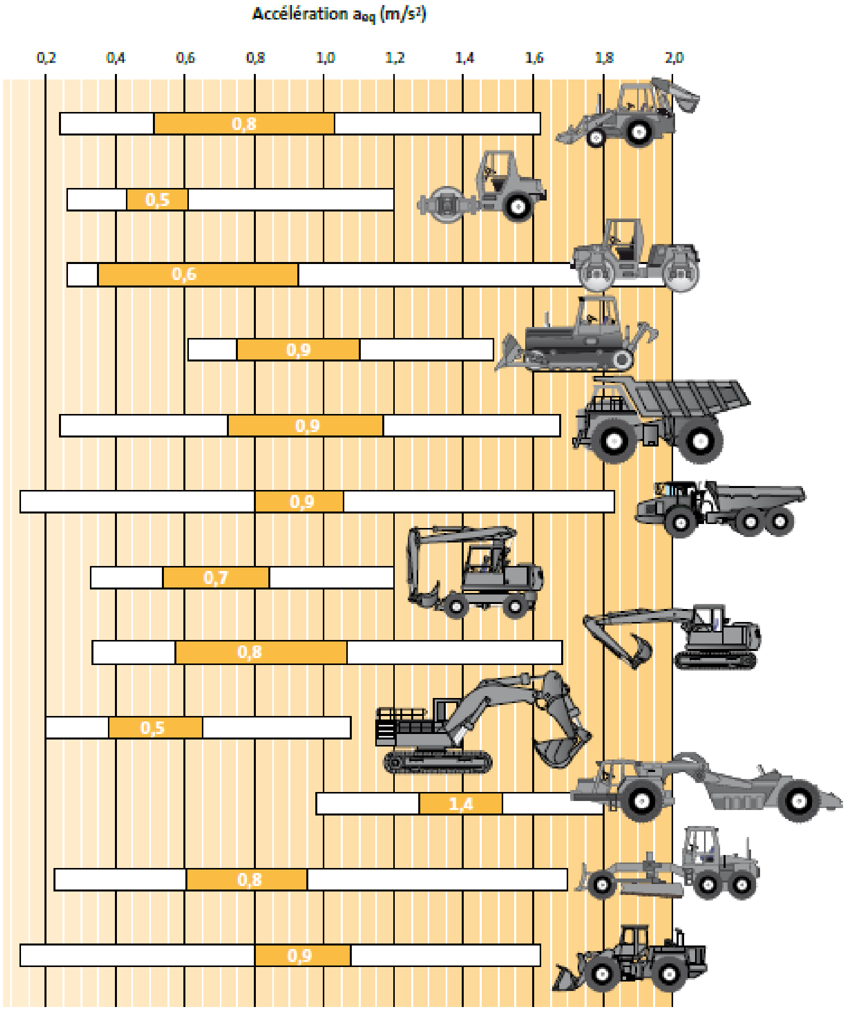
Significant positive correlations between:

- Speed & Vibration frequency
- Speed & RMS
- cobbles sectors difficulty & VDV



RESULTS

	Seatpost	Stem
Acceleration Equivalent Level (A8)	10.8 $m.s^{-2}$	13.7 $m.s^{-2}$
Vibration Dose Value $_{(1h15)}$	330 $m.s^{-1,75}$	406 $m.s^{-1,75}$
Time to reach Exposure Action Value (min)	0.2 ± 0.1	2.5 ± 0.5
Time to reach Exposure Limit Value (min)	0.9 ± 0.2	10.2 ± 1.9



for all heavy plant : A (8) < 2 m/s²

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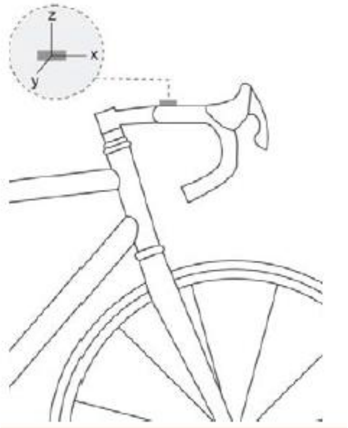
Time to reach Exposure Limit Value (min)	0.9 ± 0.2	10.2 ± 1.9

Largely inferior to the cobbles sector mean time (5 ± 2 min)

Table 2. Characteristic values

Speed (km/h)	A(8) (m/s^2)	T_{limit} (min)
5	3.30	138
10	7.14	29
15	9.46	17
20	13.03	9
25	12.9	9
30	14.14	7.5
35	14.11	7.5



Chiementin & Bertucci (Journal of Vibration & Control, 2012)

	VDV_z ($m/s^{1.75}$)	T(EAV) (min)	T(ELV) (min)
Kitesurf	65 (1 h)	4	20
Alpine ski	95 (2 h)	1.5	8
Snowboard	210 (2 h)	3	17
Road bike	50 (2 h)	7	40
Mountain bike	25 (2 h)	15	80
City bike	26 (2 h)	13	70

Tarabini et al. (Ergonomics, 2015)

CONCLUSION

- Vibrations measured over 15 cobblestone sectors of Paris-Roubaix in "racing" conditions were characterised by

↗ with speed
- ✓ **Highest** vibration frequency at seatpost
- ✓ **Highest** vibration level (RMS) at stem

↳ **Professional road cycling are probably subjected to higher vibration level !**

↳ *Next step !*

- Vibration exposure increased with cobblestone sector difficulty and largely exceeded the daily vibration dose encountered by workers

↳ **Need to take action to limit exposure for health by optimizying bicycle-rider interface**

Thank You!

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