Science & Cycling
1 & 2 Juli 2015, Utrecht

GRESPI
Groupe de Recherche En Sciences Pour l'Ingénieur

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Evaluation of comfort: Acceleration transmissibility of different road bikes

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Équipe Cycliste FDJ

In 2014, a total of 15 km long cobblestones sections…

04/07/2015

TUESDAY, JULY 7TH - STAGE 4 223.5km

Seraing / Cambrai

In 2015, a total of 13 km long cobblestones sections

Introduction

Ride in cobblestones is a limit condition

A maximal condition of discomfort

Comfort can be also improved in a rough road or in usual road.

Colle delle Finestre, Giro 2015

1) Vibration exposures measured on cobblestones (125 $m.s^{-2}$ for the seat post and 98 $m.s^{-2}$ at the stem) are very important and could have health consequences for the cyclist.

2) Vibration exposure can involve an increase in muscular activation and in oxygen uptake and thus decrease gross efficiency.

These alterations decrease the performance of the cyclist

3) It is possible to reduce vibration exposure and improve comfort using specific bicycle components such as:

Wheels,
Frame,
Fork,
Tyre type
Damping systems...

The Relative Contribution of Road Bicycle Components on Vibration Induced to the Cyclist

Julien Lepine et al. 2013

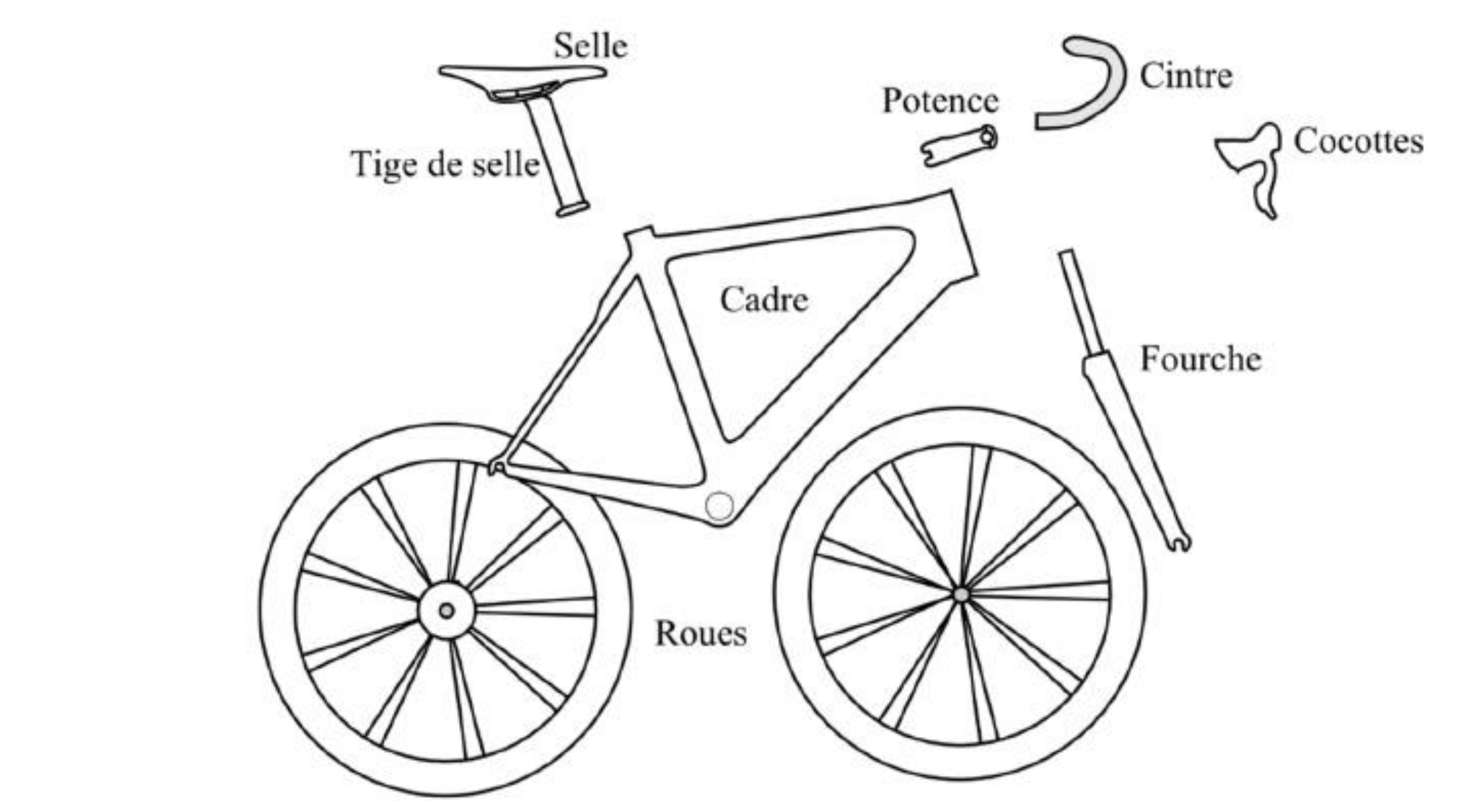


Figure : Different components of the bike that contribute to the vibration transmission

The objective of this study is to assess the relative contribution of bicycle components on the vibration at the cyclist's handlebar and seat post.

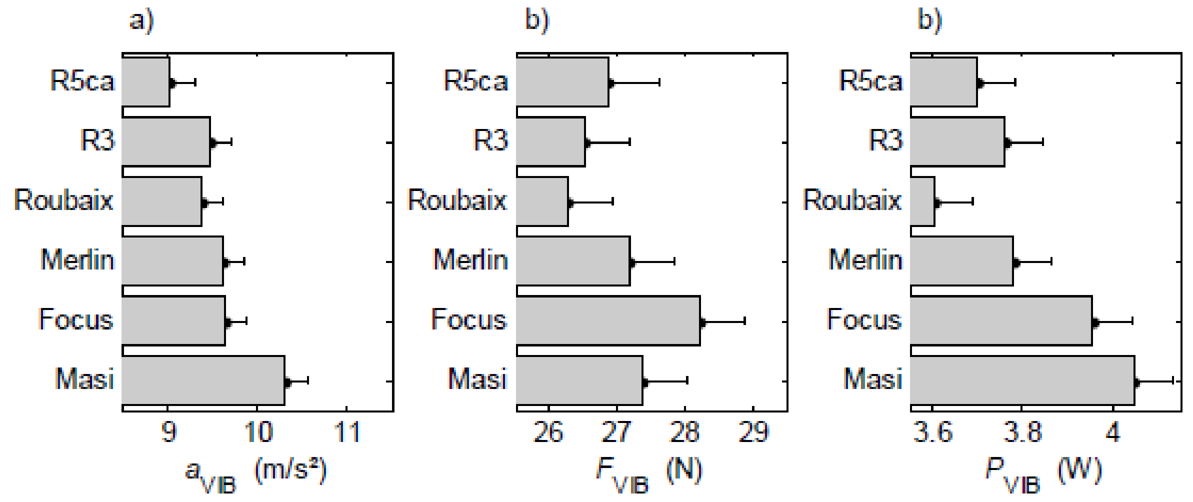


Fig. 7 Frames VIB measurements at the stem, uncertainty bars are at a confidence level of 95%

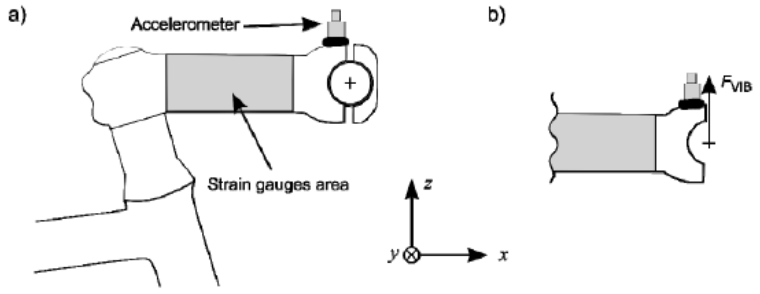


Fig. 3 Instrumented stem: (a) transducers position; (b) applied position of the measured force

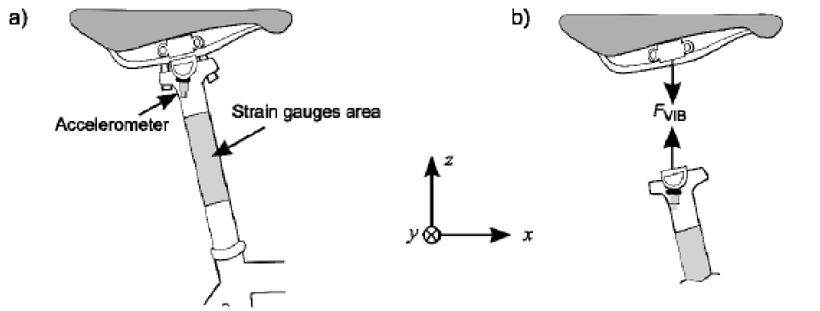


Fig. 2 Instrumented seat post: (a) transducers position; (b) applied position of the measured force

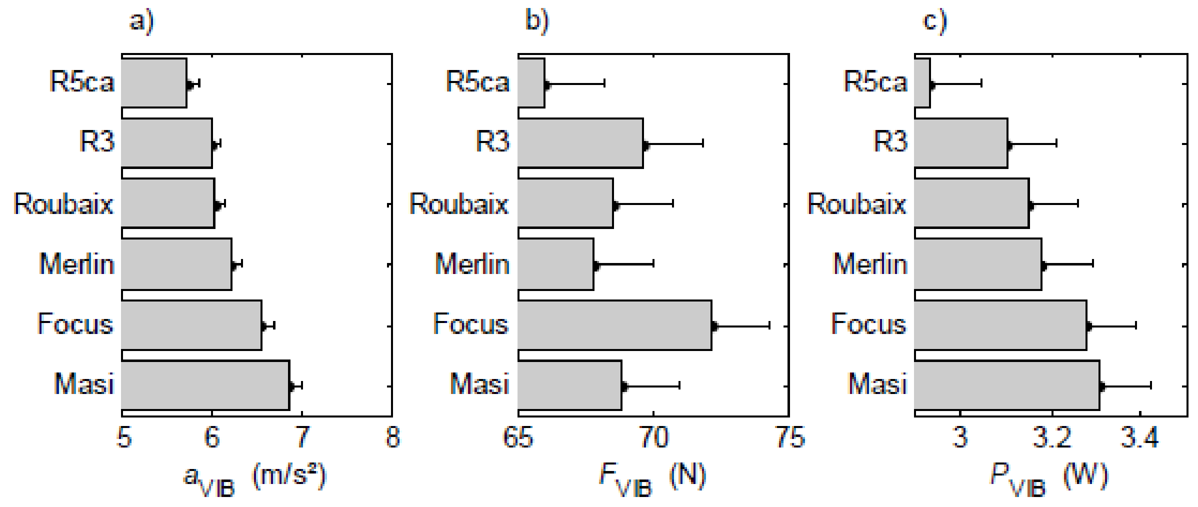


Fig. 8 Frame VIB measurements at the seat post, uncertainty bars are at a confidence level of 95%

Table 10. Component ranking contribution explaining at least 80 % of the VIB variations at 5 % significance for each measurement point

Measurement point	a_{VIB}			F_{VIB}			P_{VIB}		
		cumul %	*p*-value		*cumul %*	*p*-value		*cumul %*	*p*-value
Left Brake Hood	Fork	24	0.000	Handlebar	27	0.000	Handlebar	29	0.000
	Wheels	39	0.000	Fork	52	0.000	Fork	55	0.000
	Wheels/Frame	52	0.000	Frame	70	0.000	Frame	67	0.000
	Frame	65	0.001	Wheels/Fork	80	0.016	Wheels	78	0.000
	Frame/Handlebar	73	0.019				Wheels/Fork	83	0.006
	Fork/Handlebar	82	0.019						
Right Brake Hood	Fork	20	0.000	Handlebar	26	0.000	Handlebar	31	0.000
	Wheels	37	0.001	Fork	49	0.000	Fork	55	0.000
	Wheels/Fork	52	0.003	Fork/Frame	62	0.000	Wheels	70	0.000
	Handlebar	66	0.006	Frame	73	0.000	Frame	81	0.000
				Wheels	82	0.003			
Seat Post	Wheels	42	0.000	Wheels	30	0.000	Wheels	40	0.000
	Frame	70	0.000	Wheels/Frame	48	0.013	Frame	71	0.000
	Wheels/Frame	87	0.000				Wheels/Frame	81	0.000

The best Fork + the best Frame....

It is fundamental to take into account the Interaction Fork / Frame

Experimental Techniques (2013) © 2013, Society for Experimental Mechanics

TECHNICAL ARTICLE

A Laboratory Excitation Technique to Test Road Bike Vibration Transmission

J. Lépine, Y. Champoux, and J.-M. Drouet

Department of Mechanical Engineering, Université de Sherbrooke, Sherbrooke, QC, Canada

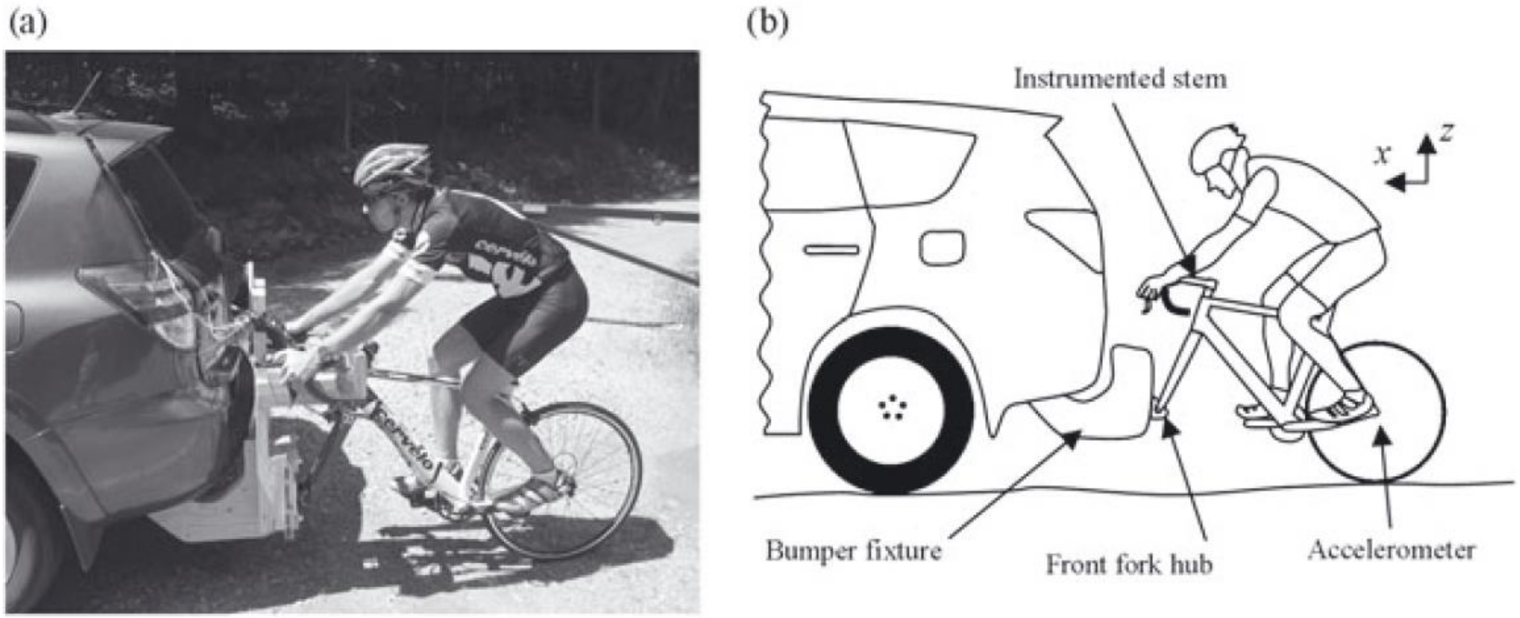


Figure 1 Road data measurement system. (a) Photographic view and (b) schematic view.

For this study, the frequency range of interest is between 8 to 100 Hz,

which corresponds to the frequency band for which the hand–arm system is more sensitive.

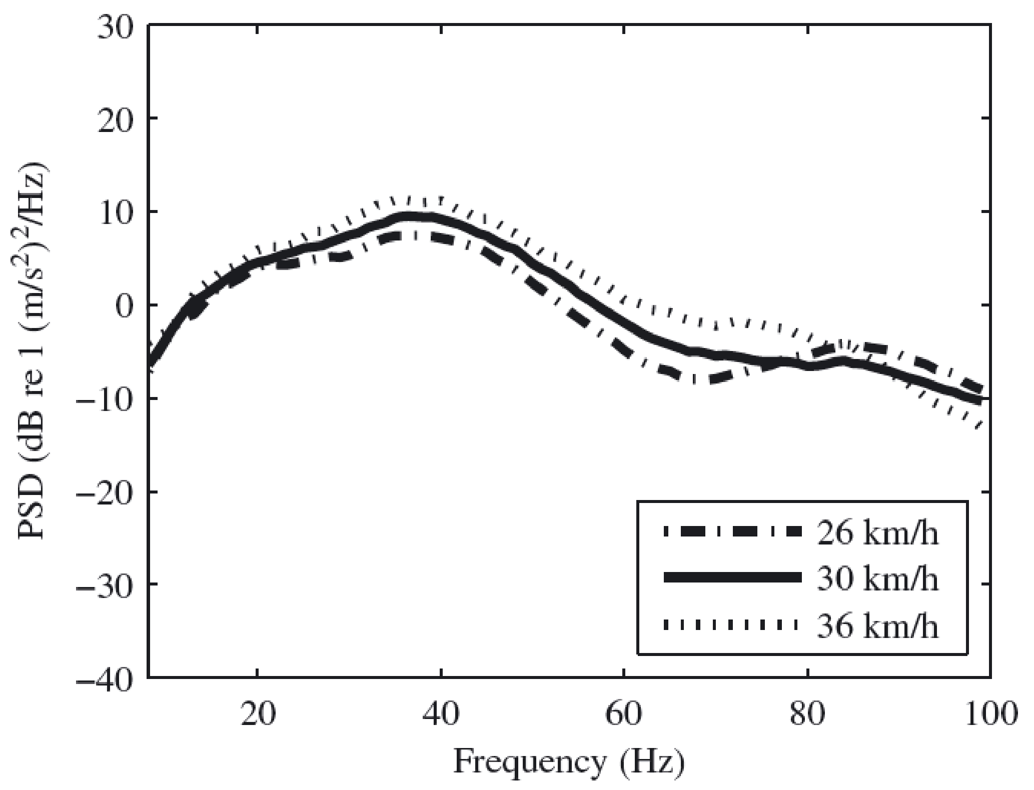


Figure 2 Average PSD for the vertical accelerations at three speeds on the road. Acceleration rms value — 26 km/h: 13.0 (m/s^2); 30 km/h: 14.6 (m/s^2); 36 km/h: 17.8 (m/s^2).

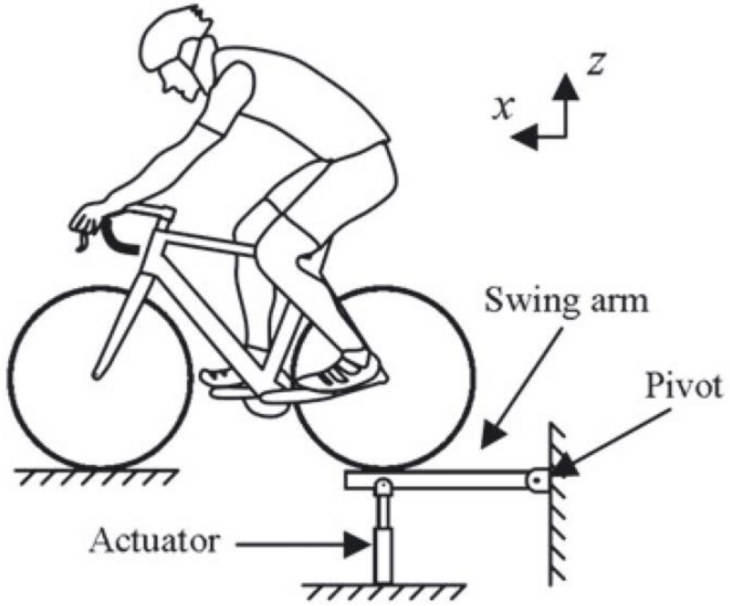


Figure 4 Schematic description of the road simulator exciting the rear wheel.

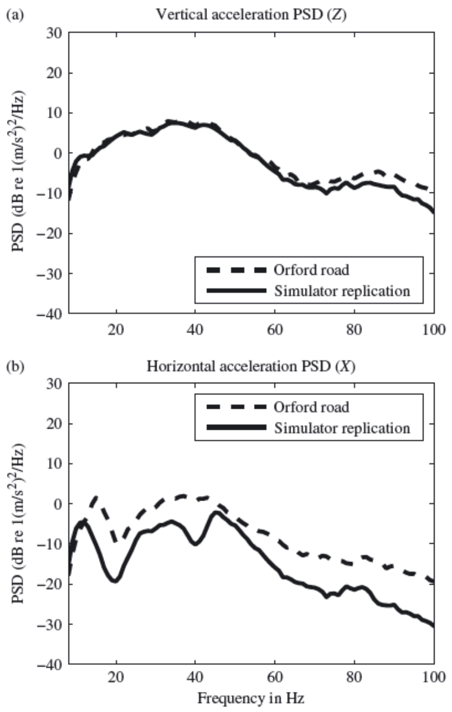


Figure 6 Comparison between the dropout acceleration PSD measured on the road and on the simulator; bike speed = 26 km/h. (a) Vertical direction (Z); road: $a_{rms} = 13.0\ m/s^2$, simulator: $a_{rms} = 12.2\ m/s^2$. (b) Horizontal direction (X); road: $a_{rms} = 6.02\ m/s^2$, simulator: $a_{rms} = 3.3\ m/s^2$.

The road and the simulator vertical acceleration PSD and the RMS values
are very similar to the curves showing an average of 1 dB difference between 8 and 75 Hz.

The discrepancy increases with frequency between 75 and 100 Hz to a maximum 5 dB.

However,
the road measurement shows that the horizontal acceleration (*a*rms = 6 $m.s^{-2}$)
is on average half that of the vertical acceleration (*a*rms =12 $m.s^{-2}$).

Our choices and methodology...

Measure the comfort from the accelerometric, EMG and subjective perceptive Measurements.

Work on the bike (type of frames, forks, configuration of frame/fork)

Bike	Damping system in the frame/bike	Road cycling usage	Manufacturer
1	On the top tube	Classic race	A
2	In the fork, the seat tube and the seat stays	Classic race	B
3	At the junction between the top and seat tubes	Classic race	C
4	Without damping system	Mountain race	B
5	Without damping system	Mountain race	A

What is the best bike to reduce the vibration dose ?

Laboratory to Ecological conditions

Measurement in the Field

Evaluation in the standardised condition in the laboratory

1) Field measurements to determine the field characteristics

2) Laboratory tests

3) Field tests : accelerometric and EMG measurements

Field Measurements

Cyclist 1,80m, 70 kg

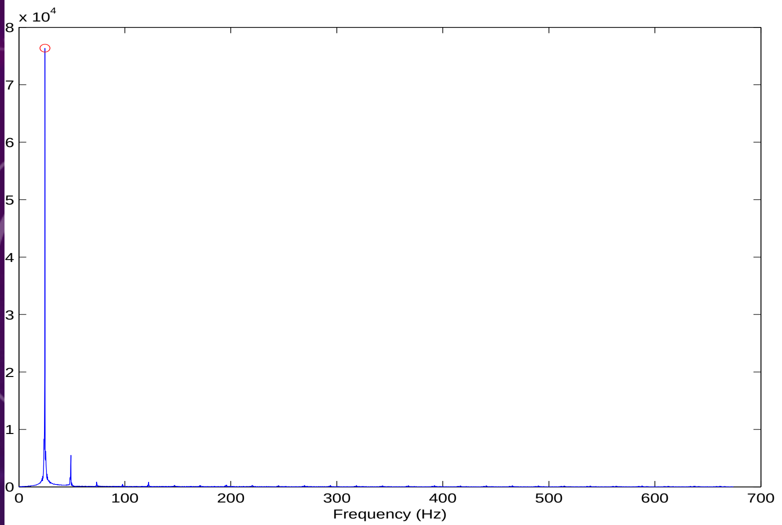
Bike, Tyres ; 5 bars

3D wireless Accelerometers : 1350 Hz

3 × Circuit of 3 km with uphill and downhill.

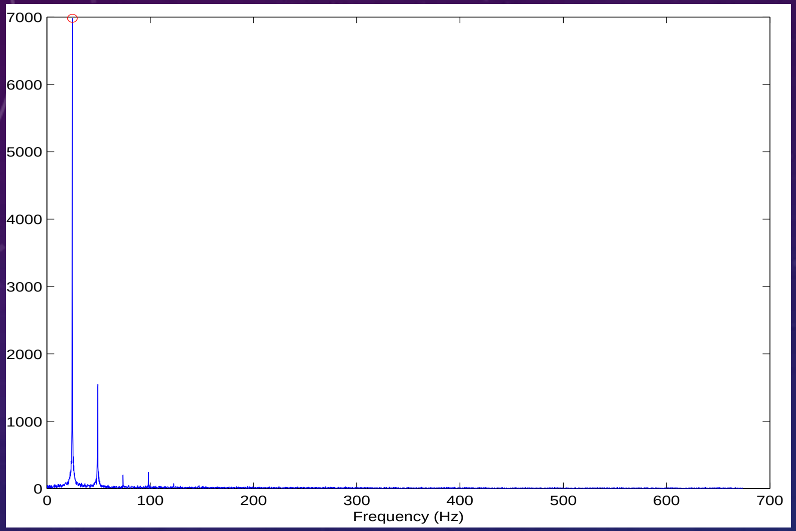
Two types of cobblestones : hight and low

Results and discussion

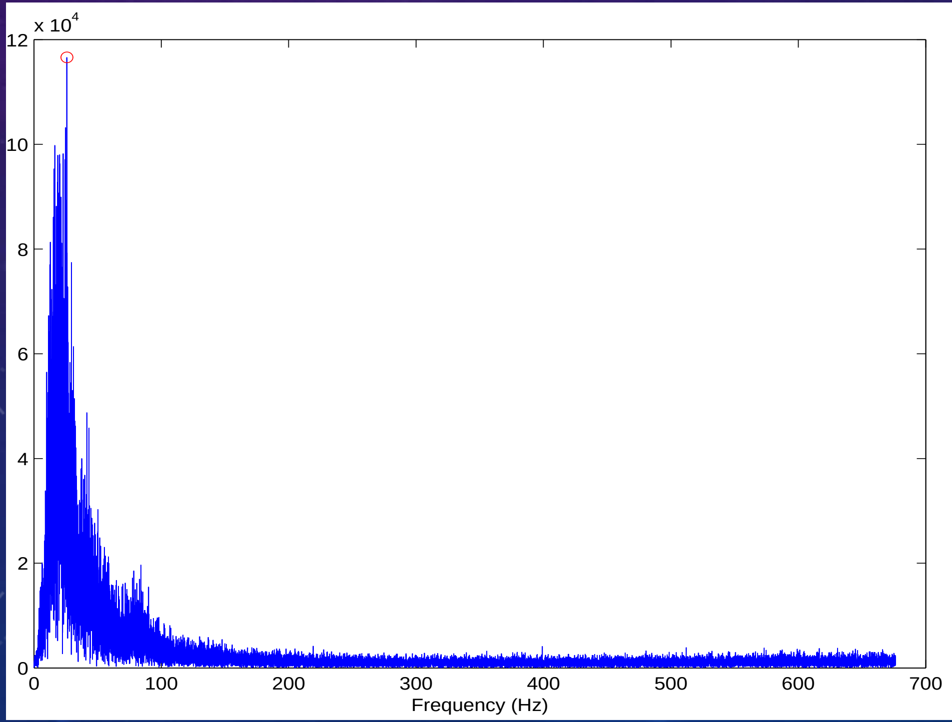


Stem : Vibration at 24Hz on Front wheel in the laboratory

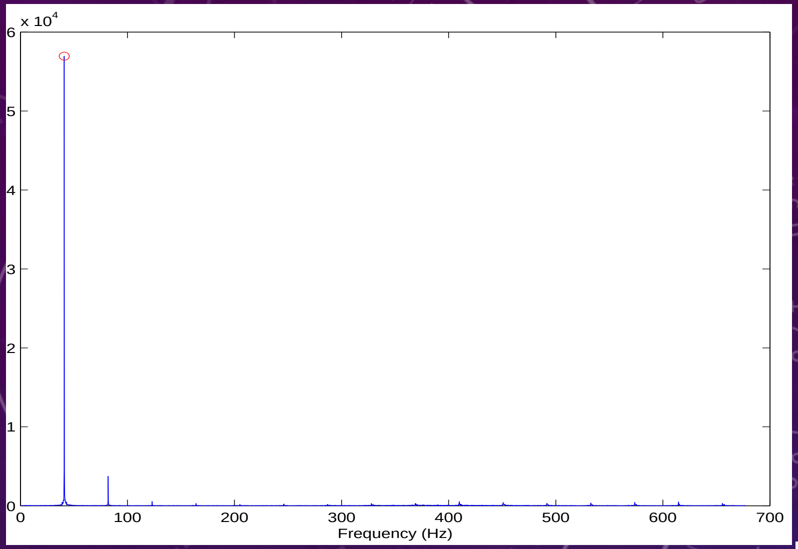
Mean speed 22 km.h $^{-1}$



Stem : Vibration at 24Hz on rear wheel in the laboratory

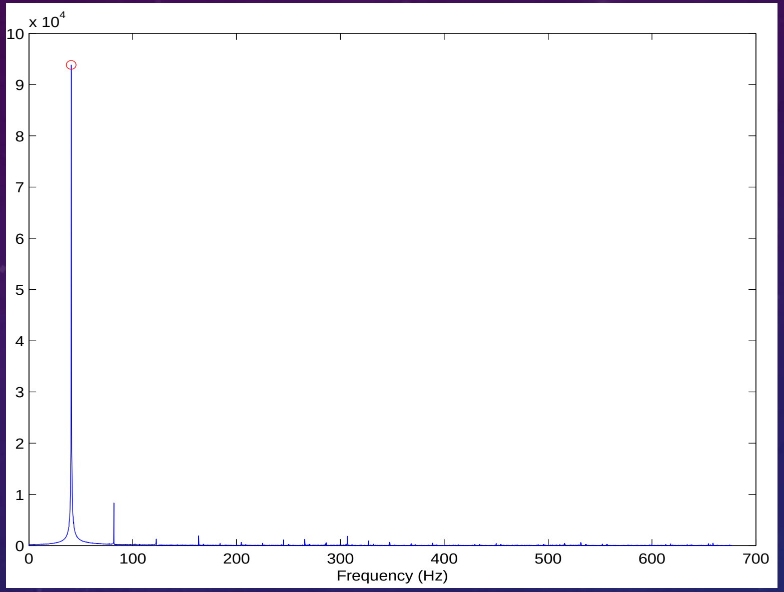


Cobblestones: Uphill section in the field. Main Frequency of 19 Hz

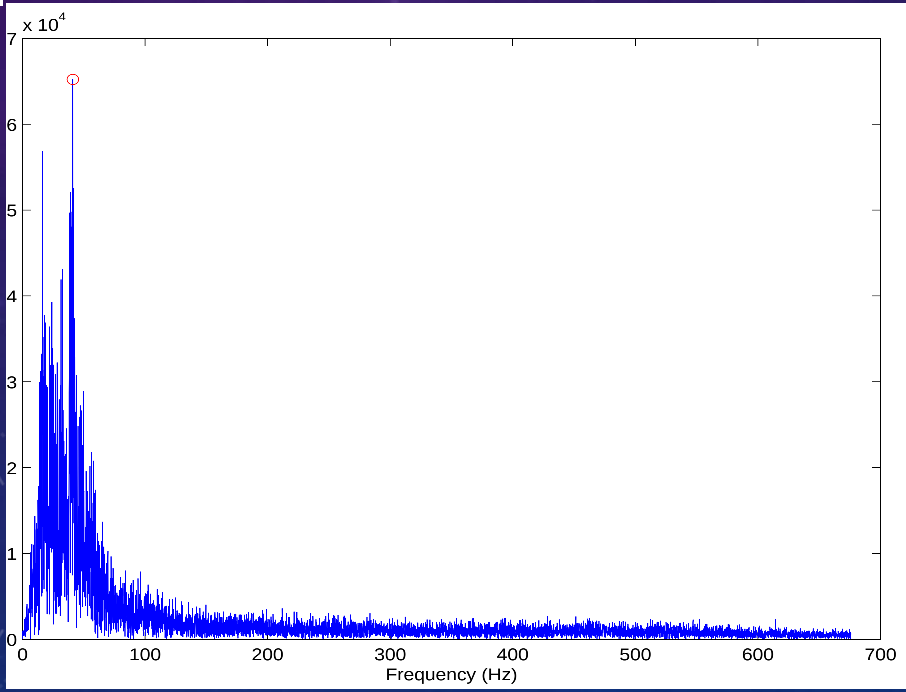


Stem : Vibration at 41 Hz on Front wheel in the laboratory

Mean speed 31.4 km.h $^{-1}$



Stem : Vibration at 41Hz on rear wheel in the laboratory



Cobblestones: Downhill section in the field. Main Frequency 30 Hz

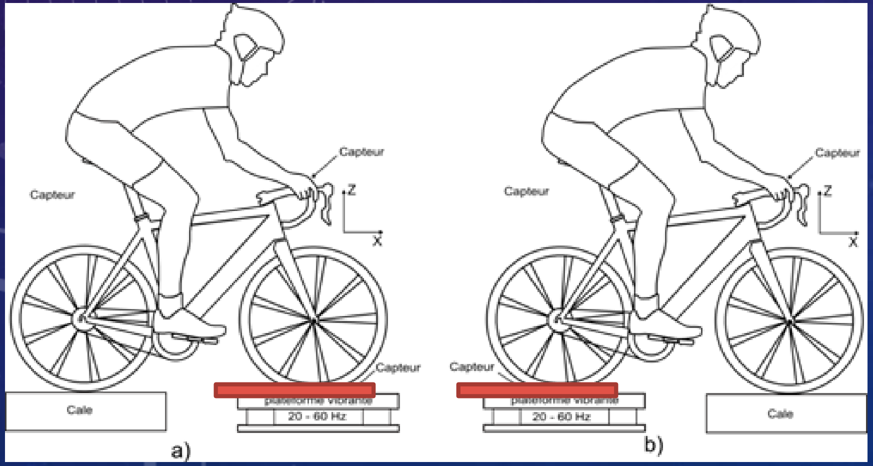
1) Field measurements to determine the field characteristics

2) Laboratory tests

3) Field tests : accelerometric and EMG measurements

Laboratory Measurements

Figure. Experimental set-up (bike without the cyclist)



Cyclist 1,80m, 70 kg

Five Bikes, Tyres ; 7 bars

3D wireless Accelerometers : 1350 Hz

Vibration generated by a Vibration force plate
from 16 to 57 Hz
Amplitude : 4 mm

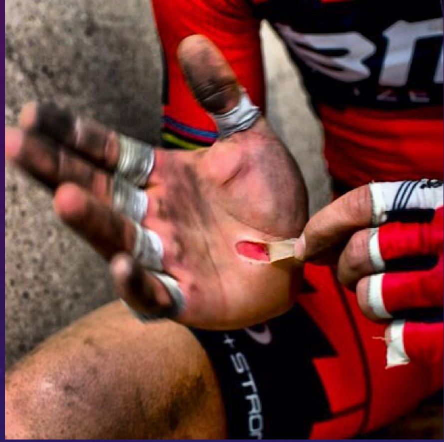
Vibration on the Front and Rear Wheel separately

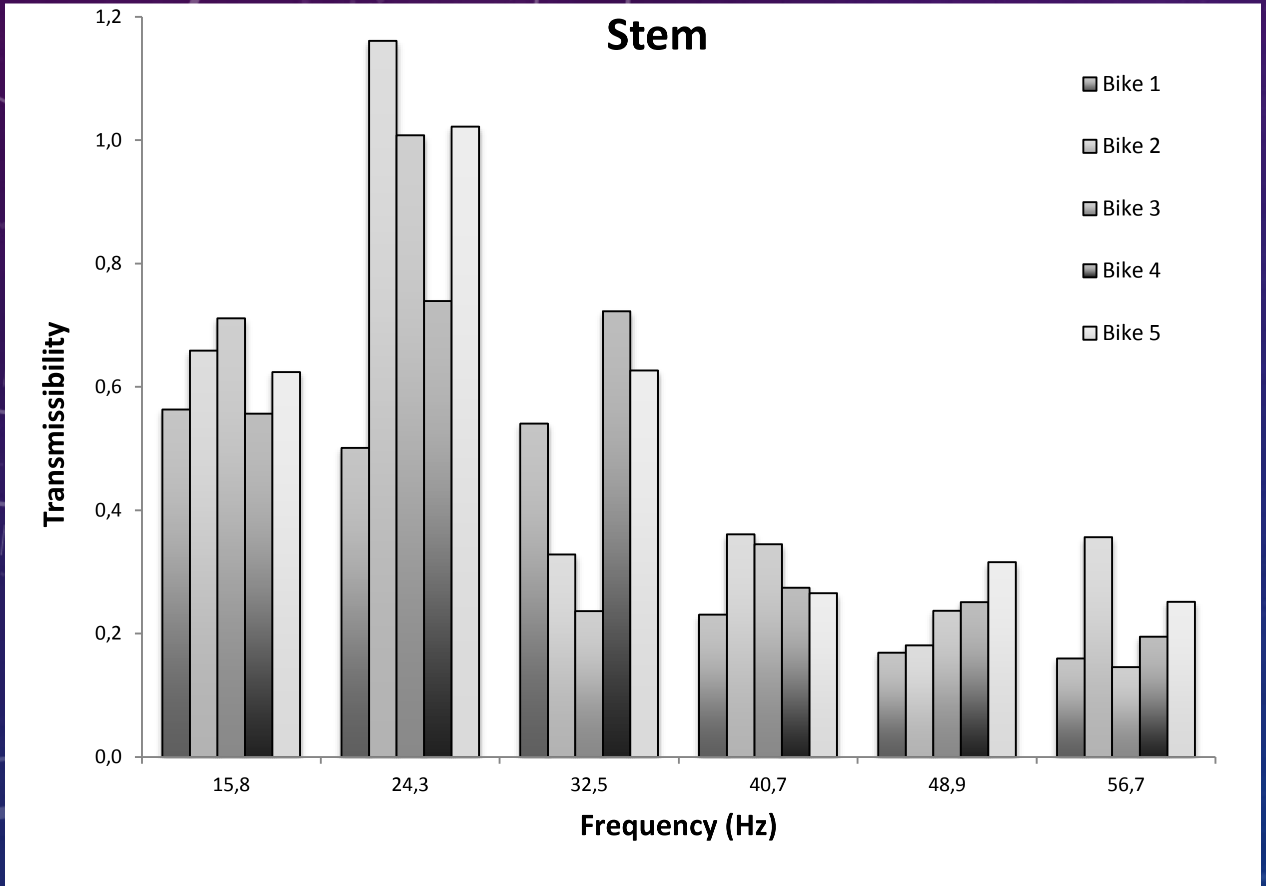
$$\textbf{Transmissibility} = \frac{RMS_{\text{stem or seat post (output)}}}{RMS_{\text{vibration plate (input)}}}$$

Laboratory results

Table: Characteristics of the five bikes studied

Bike	Damping system in the frame/bike	Road cycling usage	Manufacturer
1	On the top tube	Classic race	A
2	In the fork, the seat tube and the seat stays	Classic race	B
3	At the junction between the top and seat tubes	Classic race	C
4	Without damping system	Mountain race	B
5	Without damping system	Mountain race	A





Conclusion for Stem (higher limbs comfort):

Bike 1 was the best except at 32 Hz

Bike 3 was the best at 32 and close to bike 1 at 57 Hz

The Bikes 4 and 5 had highest values especially at 32Hz

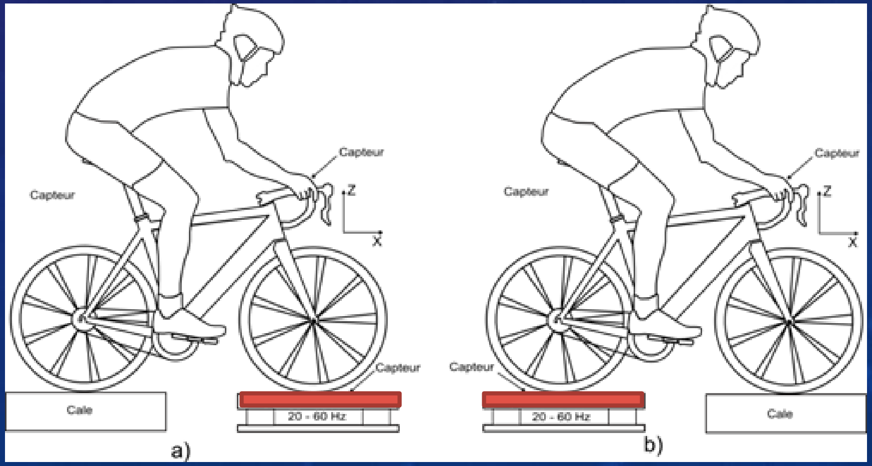


Figure: Transmissibility stem/platform (front and rear wheels) assessed on the five bikes

Laboratory results

Table: Characteristics of the five bikes studied

Bike	Damping system in the frame/bike	Road cycling usage	Manufacturer
1	On the top tube	Classic race	A
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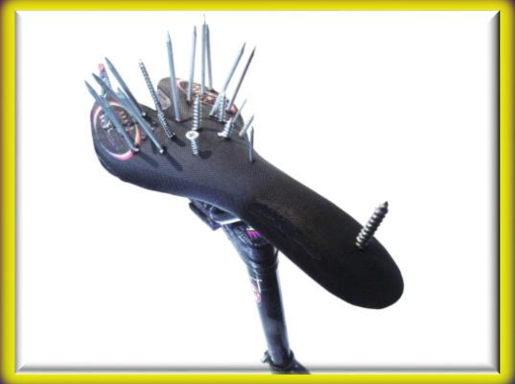
3	At the junction between the top and seat tubes	Classic race	C
4	Without damping system	Mountain race	B
5	Without damping system	Mountain race	A



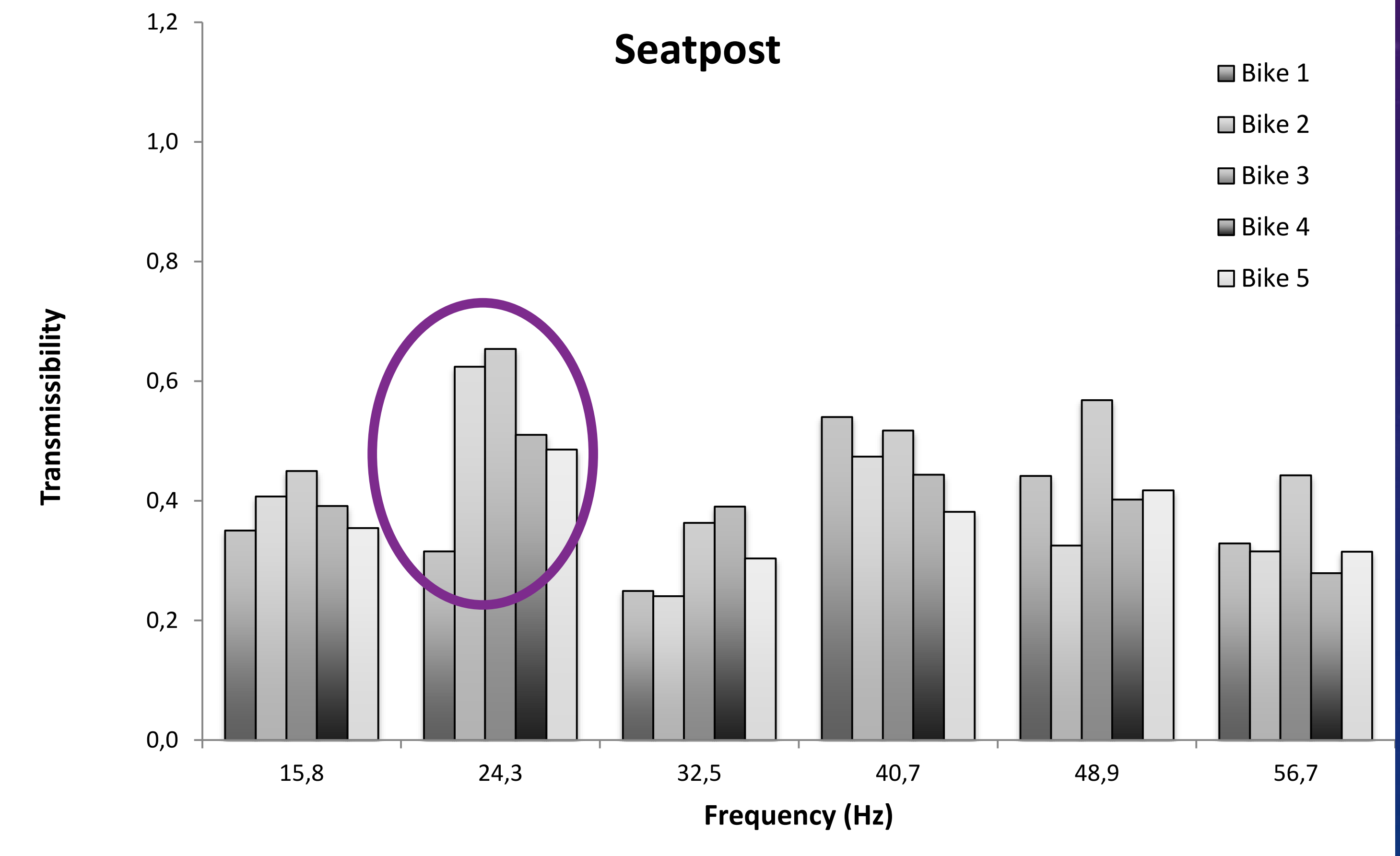


Figure: Transmissibility Seatpost/platform assessed on the five bikes

Bike 1 has lowest values for 16 and 24Hz and low for 32 Hz

Bike 2 has lowest value at 49 Hz

Bikes 4 and 5 are close to the Bikes 1 and 2 at 57 Hz

Bike 3 not optimised

Bike 5 has an interresting global behavior

For Stem + Seat Post

BEST COMPROMISE : BIKE 1

1) Field measurements to determine the field characteristics

2) Laboratory tests

3) Field tests : accelerometric and EMG measurements

Field Tests

Protocol:
Tests with two configurations of Bike 1

3 × Circuit of 3 km with uphill and downhill.

Two types of cobblestones : hight and low

Uphill and downhill, 5 and 5.5 bars

One of bike allows a lower vibration dose in the road with high cobblestones.

For other conditions in the field, No difference in vibration exposure between the two configurations of bike 1 (same design, different caracteristics for the fork and damping system).

Vibration exposure depends on the speed: RMS = 30.5 $m.s^{-2}$ at 22 $km.h^{-1}$ and RMS = 42.5 $m.s^{-2}$ at 31 $km.h^{-1}$.

Significant effect of the tyre pressure inflation.

Field results

EMG measurements

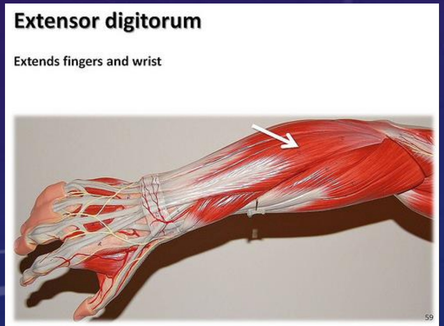
Trigno wireless, Delsys, USA.

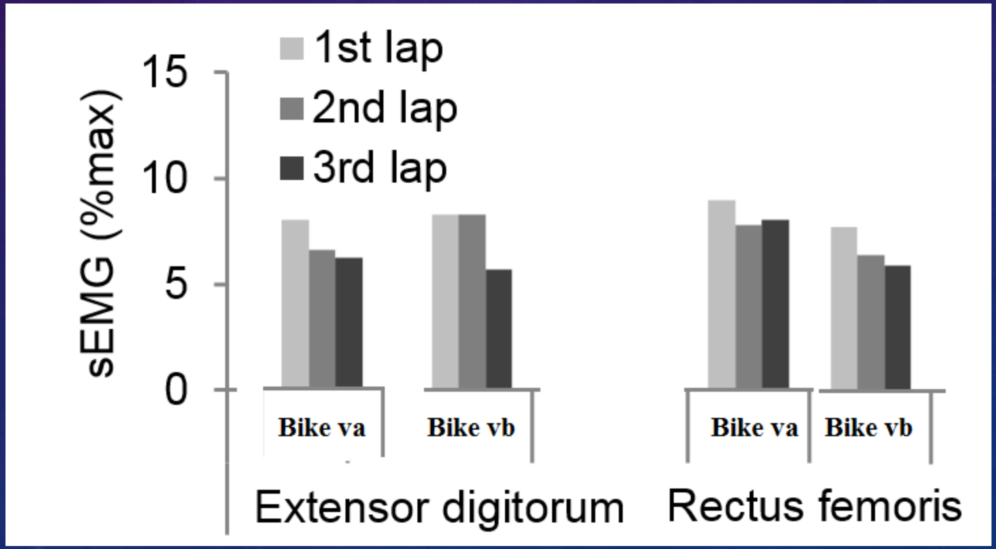
Table : Bike effect on muscular activations

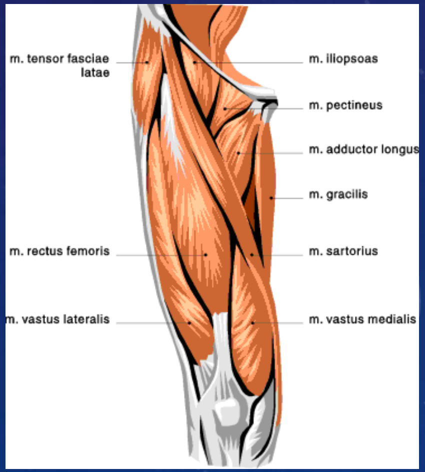
Effect		sEMG (Mean ± SD, %max) on UpH_HighC					
		ED	RF	TA	VL	All (p-value)^e	
Bike	Bike 1 va	6.0 ± 1.3	6.9 ± 1.6	27.3 ± 0.7	20.7 ± 1.0	15.2 ± 9.8	(0.761)
	Bike 1 vb	7.8 ± 1.5	6.6 ± 0.8	25.6 ± 3.2	22.2 ± 1.9	15.5 ± 9.1	

Results found for muscular activations didn't show any effect of bike configurations and settings.

ED: Extensor digitorum,
RF: Rectus Femoris,
TA: Tibialis anterior,
VL: Vastus Lateralis.







The activation of ED seemed to decrease during each condition as if the cyclist released tension from his muscle

Puel et al. 2015, ISBS, Poitiers, France

Conclusions

The methodology used is able to discriminate the behavior of different frames and forks

It is necessary to perform measurements in the laboratory and in the Field

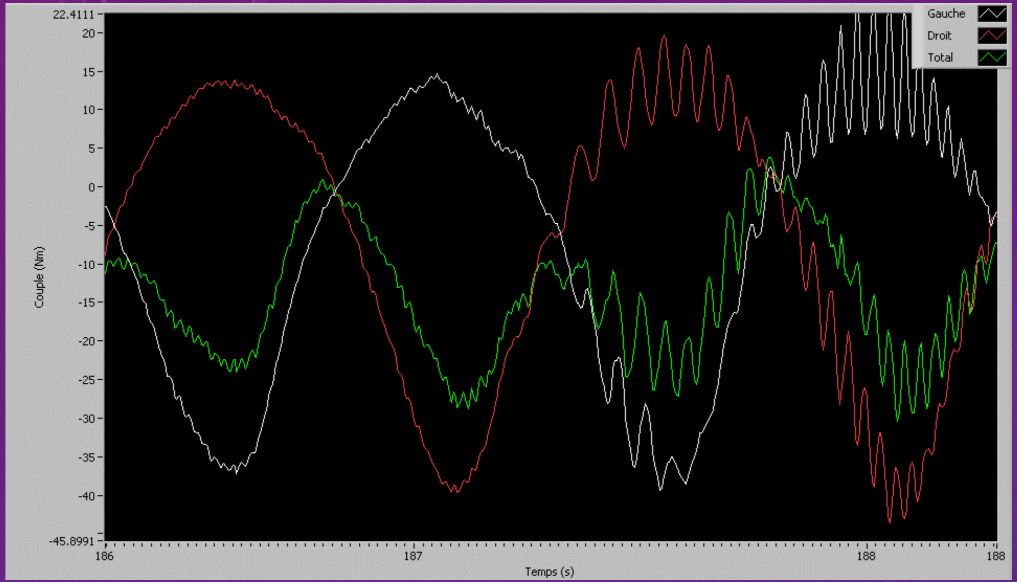
Field = ecological condition

Laboratory = standardization of the measurements

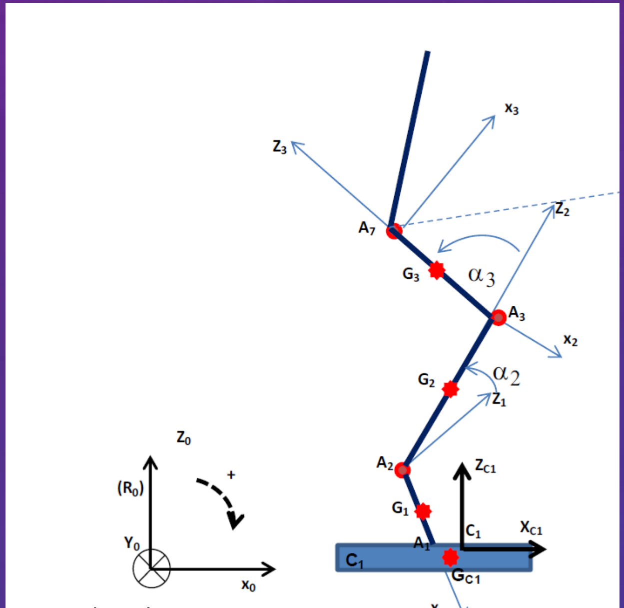
Help the coaches and the cyclists to choice his cycling equipments

Help the manufacturers to optimize conception and the design of the bike and cycling equipment

Perspectives



- Analyse the Pedaling biomechanics under vibration condition.



Bernard et al. 2015

- Biomechanical modelisation of the articular power taking into the account the external forces and the soft tissue.

Acknowledgments

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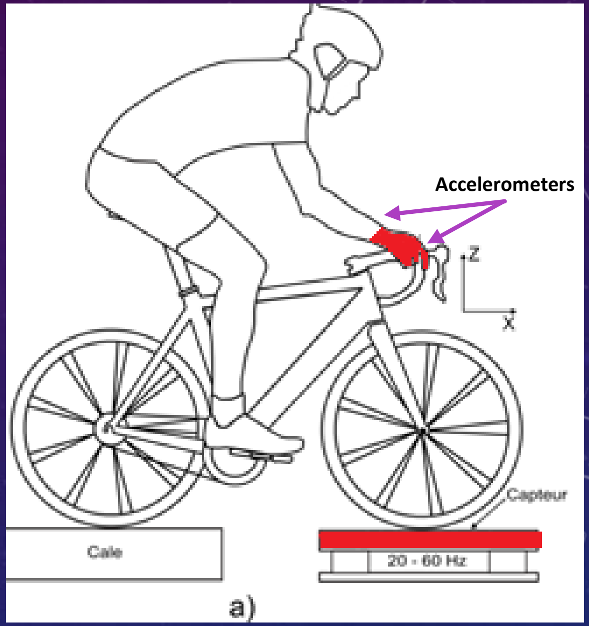
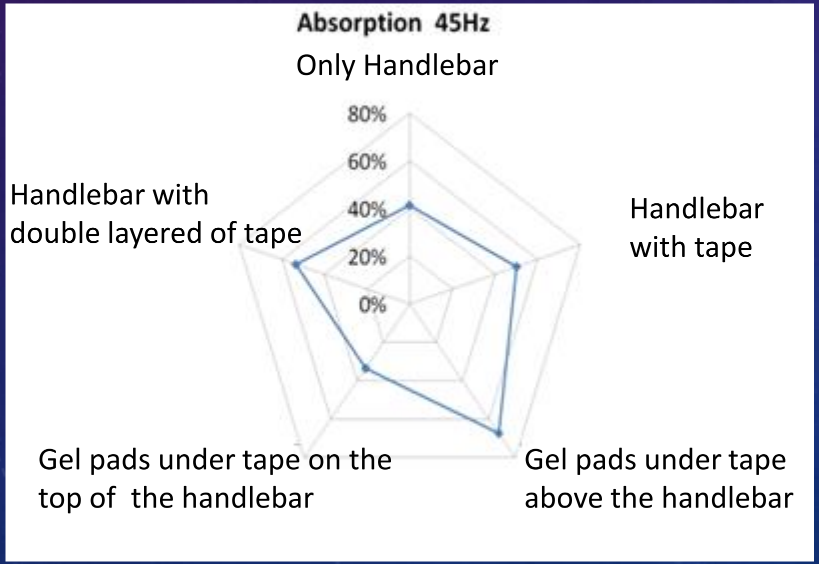
EFFECTS OF GEL PADS UNDER THE TAPE ON POINTS OF REGULAR CONTACT

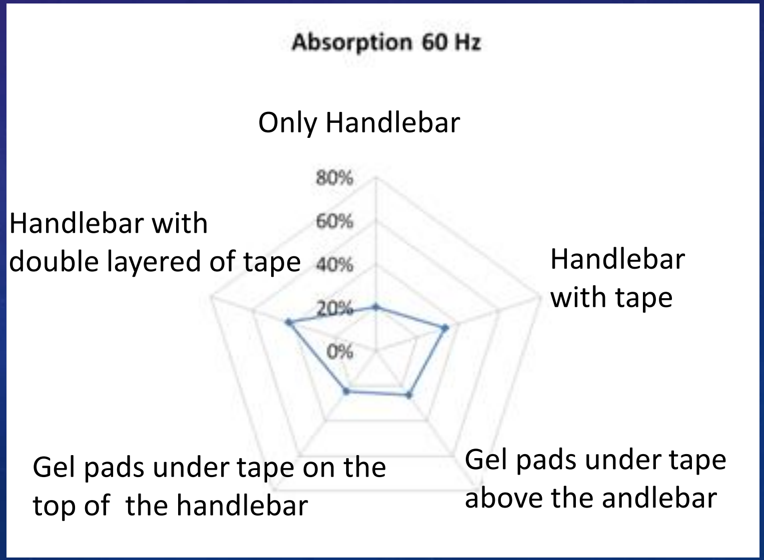
Chiementin and Bertucci, ACAPS 2013

Bar gel : Fizik's Technogel



Transmissibility Handelbar / wrist





Results

Table: Characteristics of the five bikes studied

Bike	Damping system in the frame/bike	Road cycling usage	Manufacturer
1	On the top tube	Classic race	A
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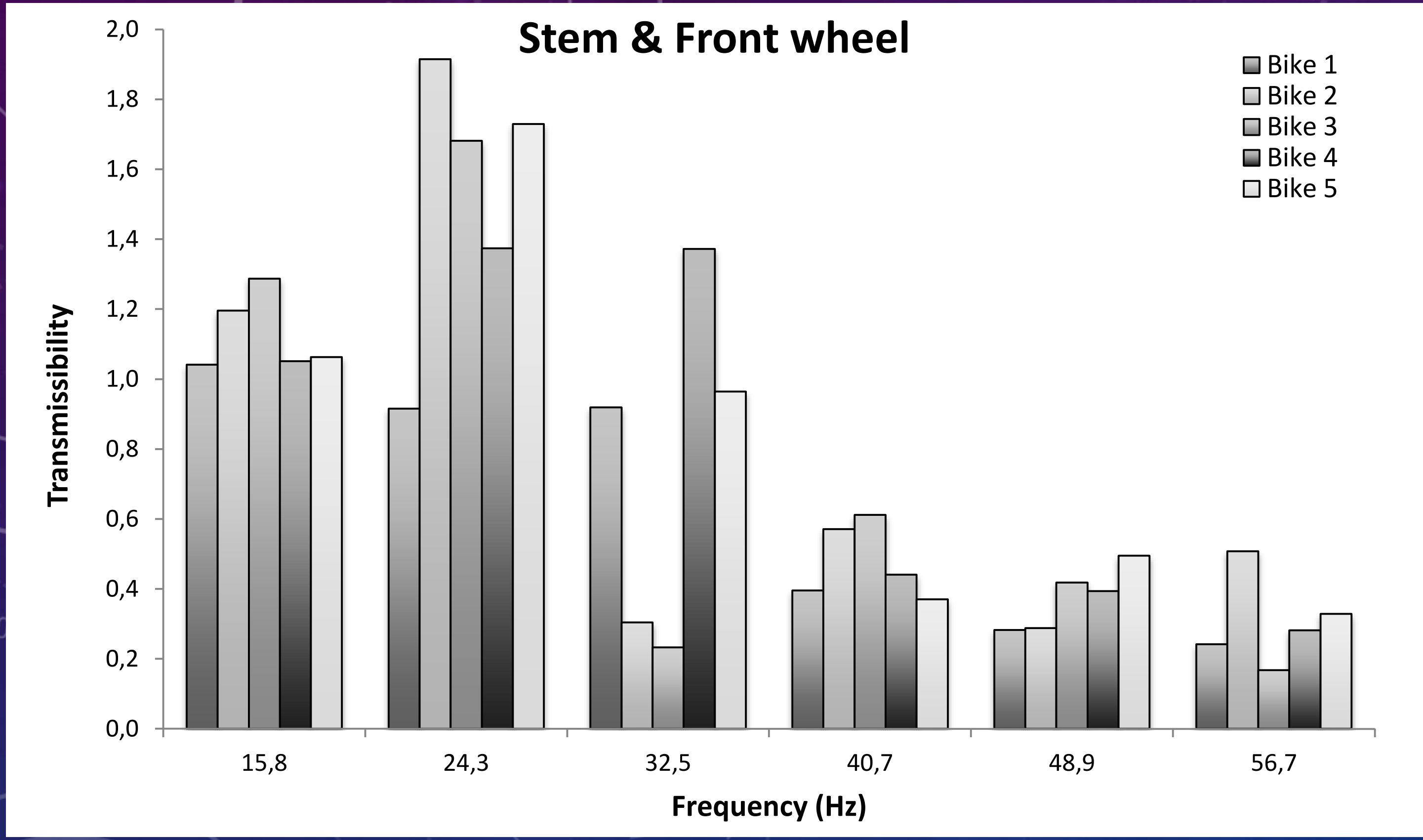
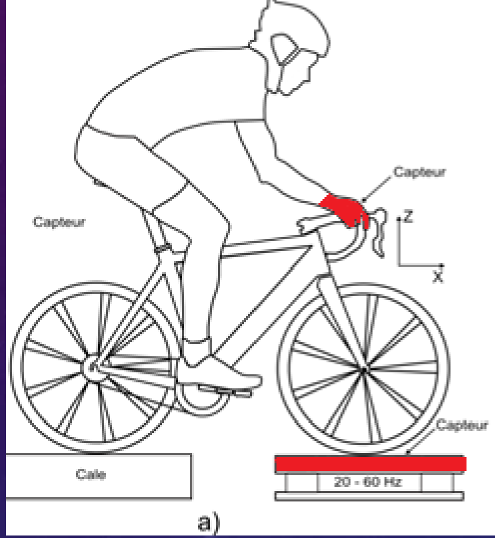
3	At the junction between the top and seat tubes	Classic race	C
4	Without damping system	Mountain race	B
5	Without damping system	Mountain race	A





Sensitivity of the methods

Behaviors differents according to the frequency

Hight value of transmissibility

Figure: Transmissibility stem/platform (Front wheels) assessed on the five bikes

Results

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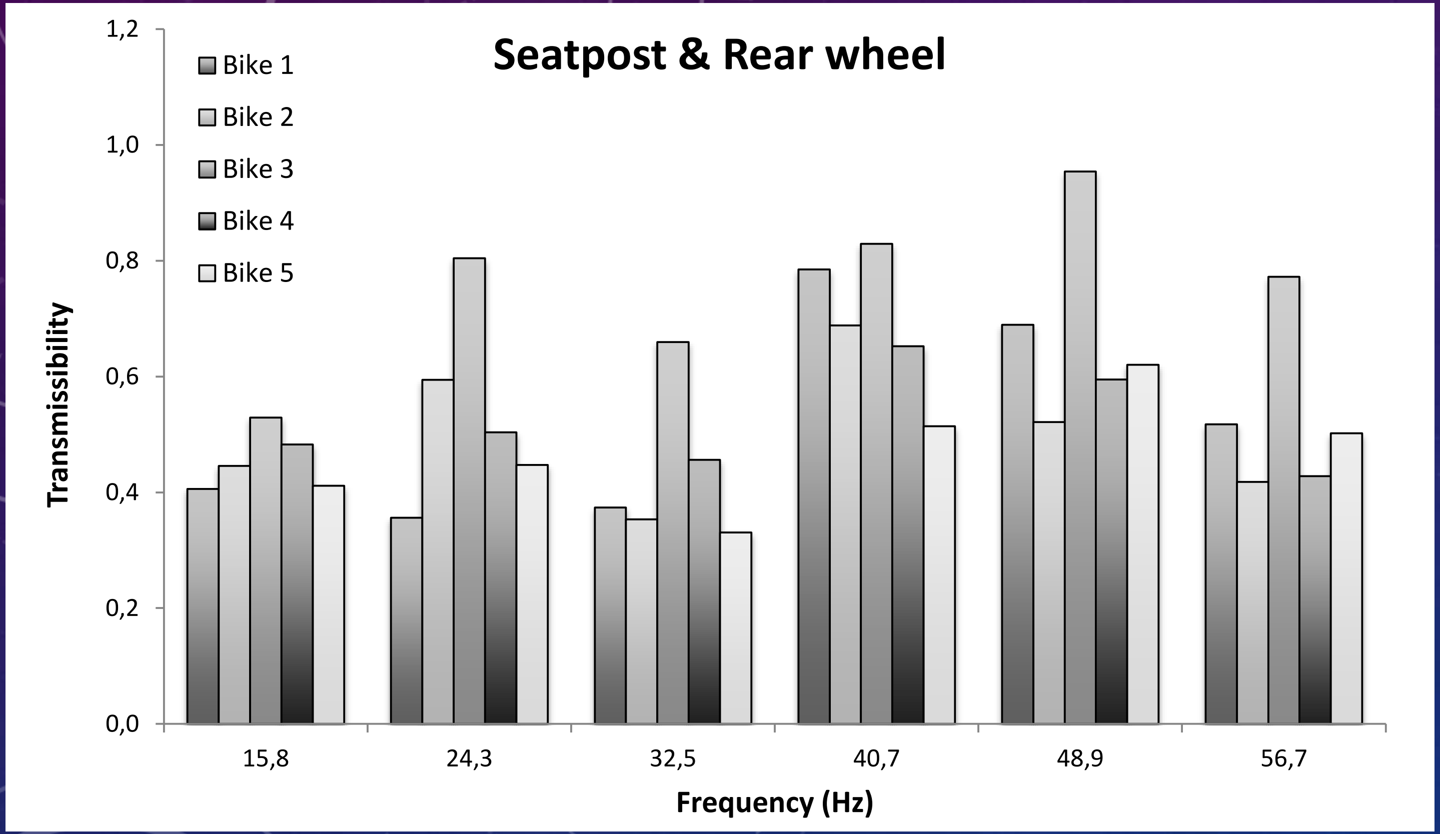

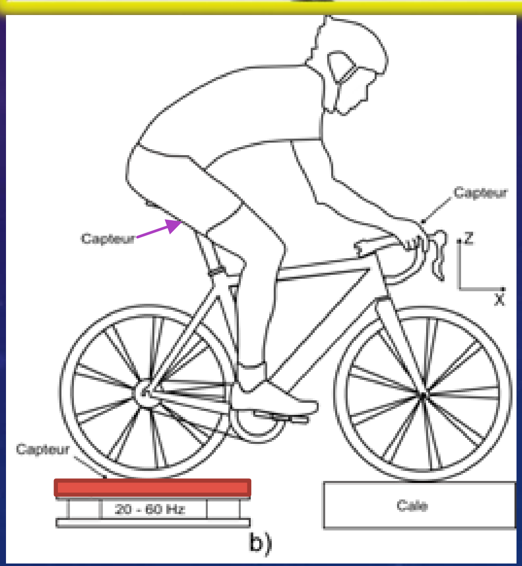

Transmissibility Values lower than for stem

Bike 3 not optimised

Figure: Transmissibility Seatpost/platform (rear wheels) assessed on the five bikes