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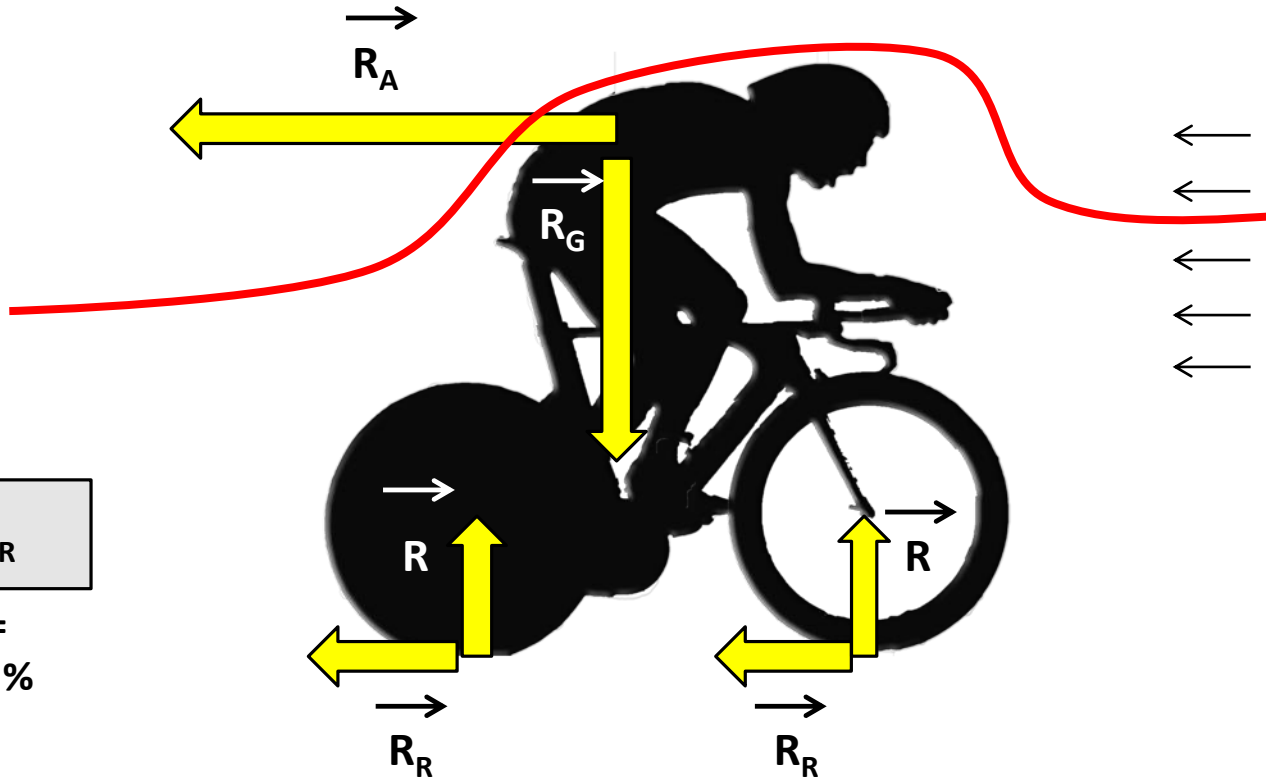
The head movements degrade the aerodynamic drag according to the time-trial duration

A. Bouillod[1,2,3], L. Garbellotto[3], P. Acco[3], E. Brunet[2], G. Soto-Romero[3,4] & F. Grappe[1,5]

[1] EA4660, C3S Health - Sport Department, Sports University, Besancon, France; [2] French Cycling Federation, Saint Quentin en Yvelines, France;
[3] LAAS-CNRS, Université de Toulouse, CNRS, Toulouse, France; [4] ISIFC, Université de Franche-Comté, France;
[5] Professional Cycling Team FDJ, Moussy le vieux, France

Total resistive forces opposing motion



$$R_T = R_A + R_G + R_R$$

$$= \quad = \quad =$$

90 % 0 % 10 %

$$R_A = AC_d \times 0.5 \times \rho \times V^2$$

Debraux et al., 2011

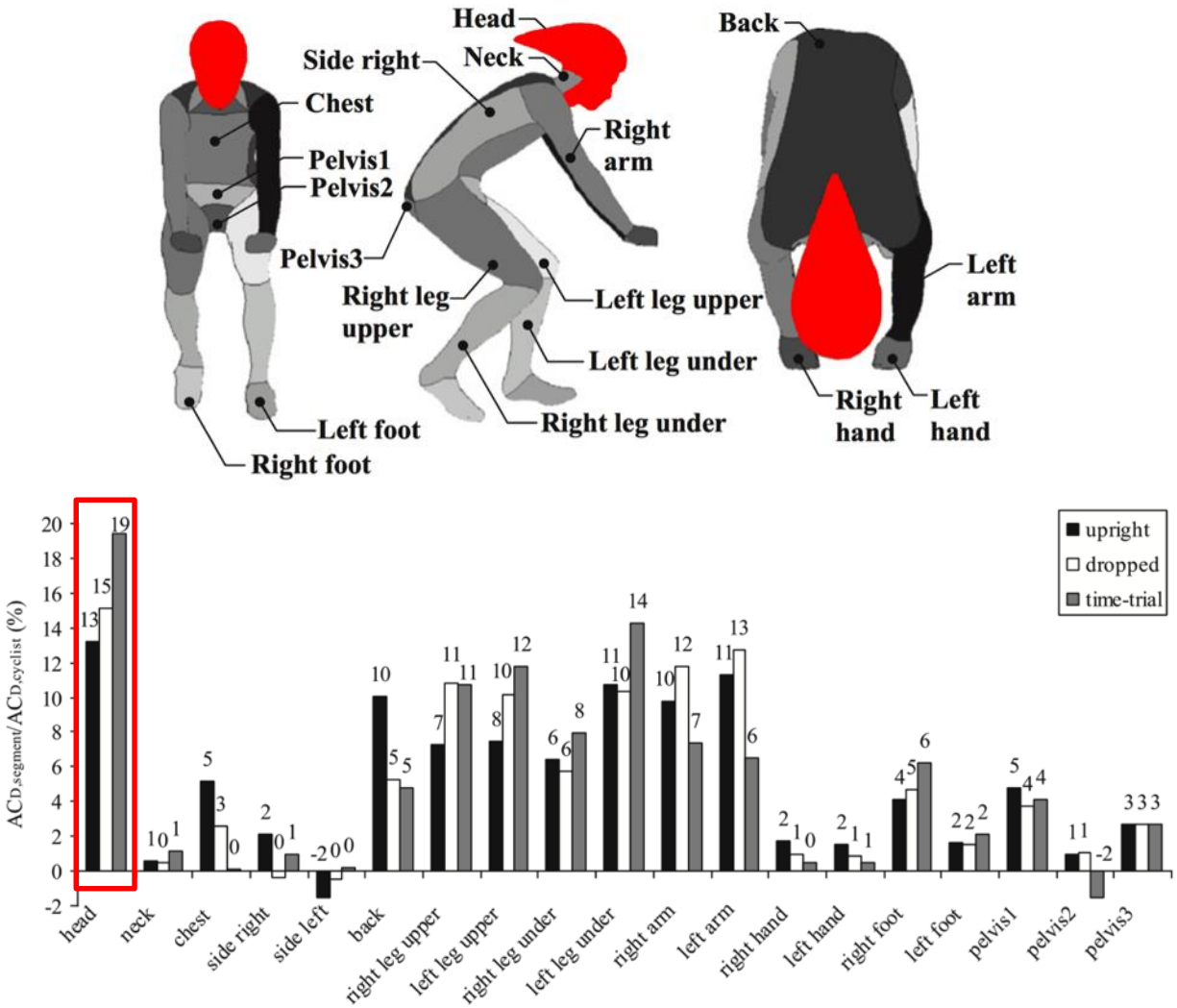
ATHLETE = 70 % R_A

Importance of cycling position

Oggiano et al., 2008

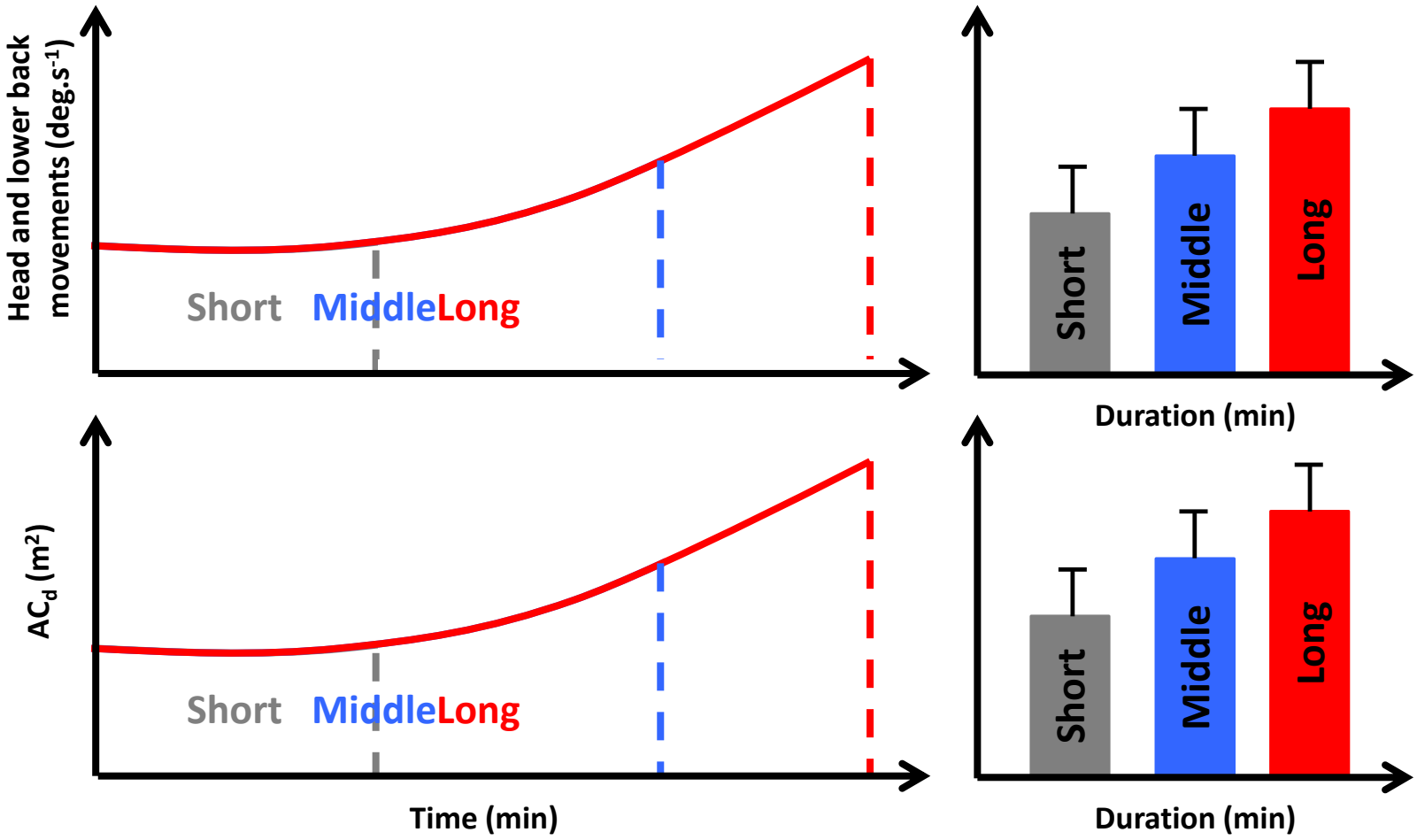
R_A

BICYCLE = 30 % R_A



Percentage of drag area for the individual body segments at wind speed of 60 km/h (Defraeye et al., 2011)

Effect of time-trial duration on head and lower back movements

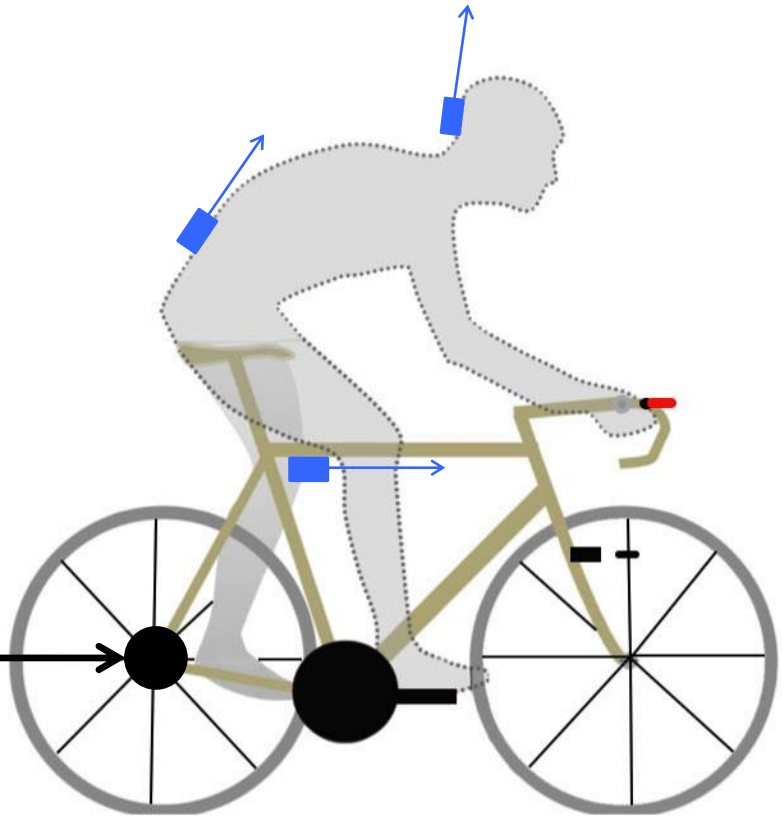


Participants & materials

9 elite road cyclists

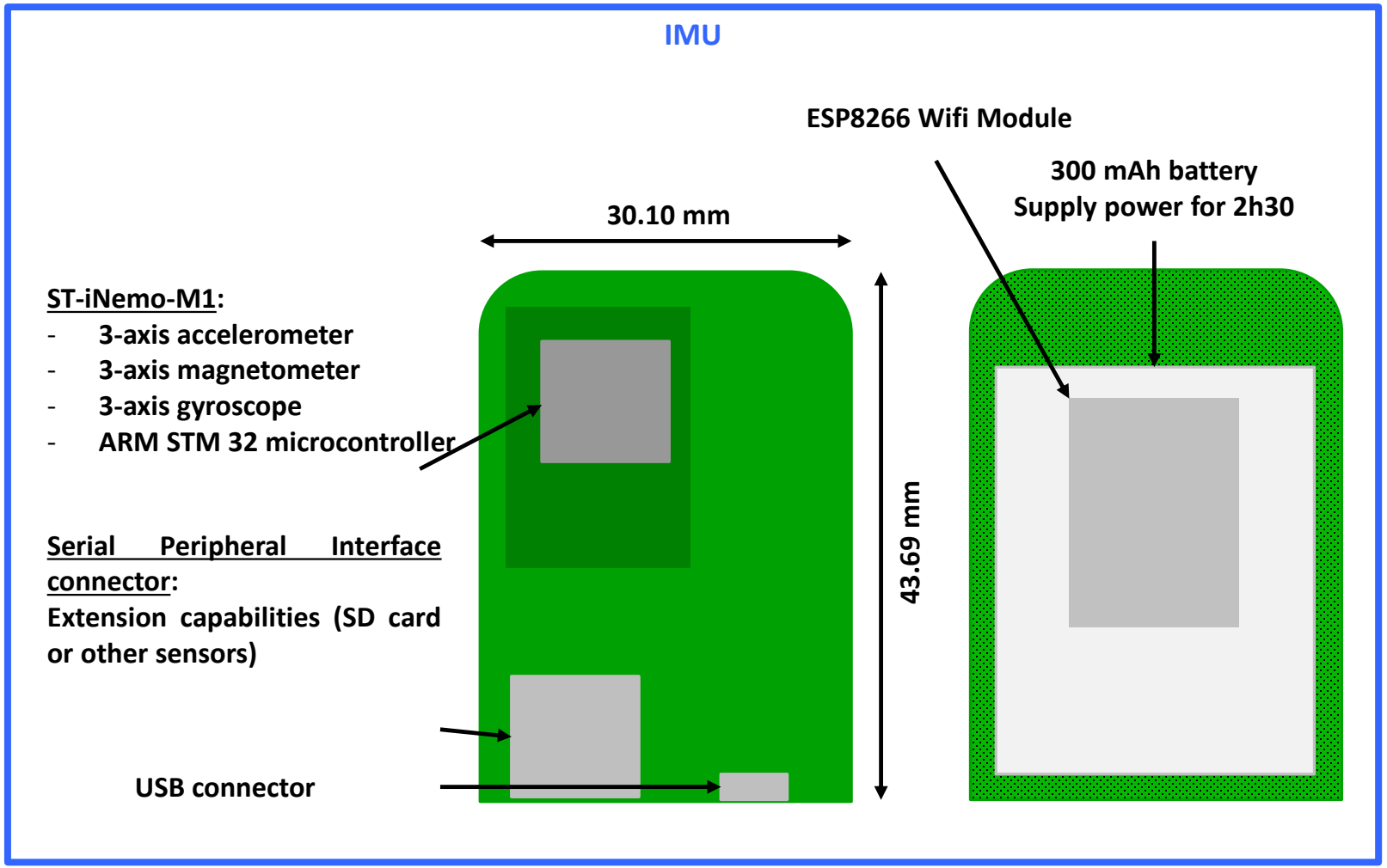
Kestrel

Powertap

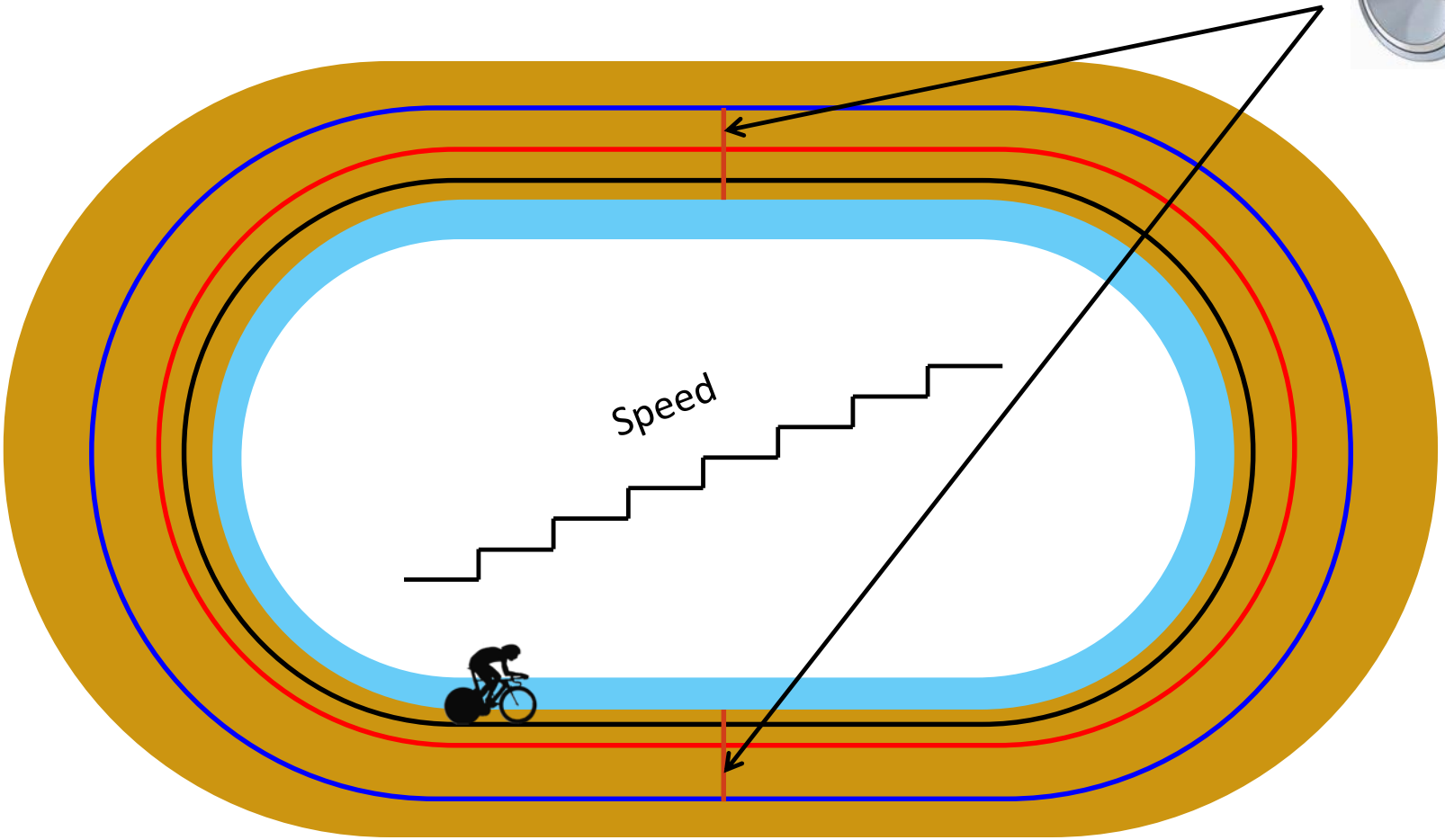


IMU

Inertial Measurement Unit

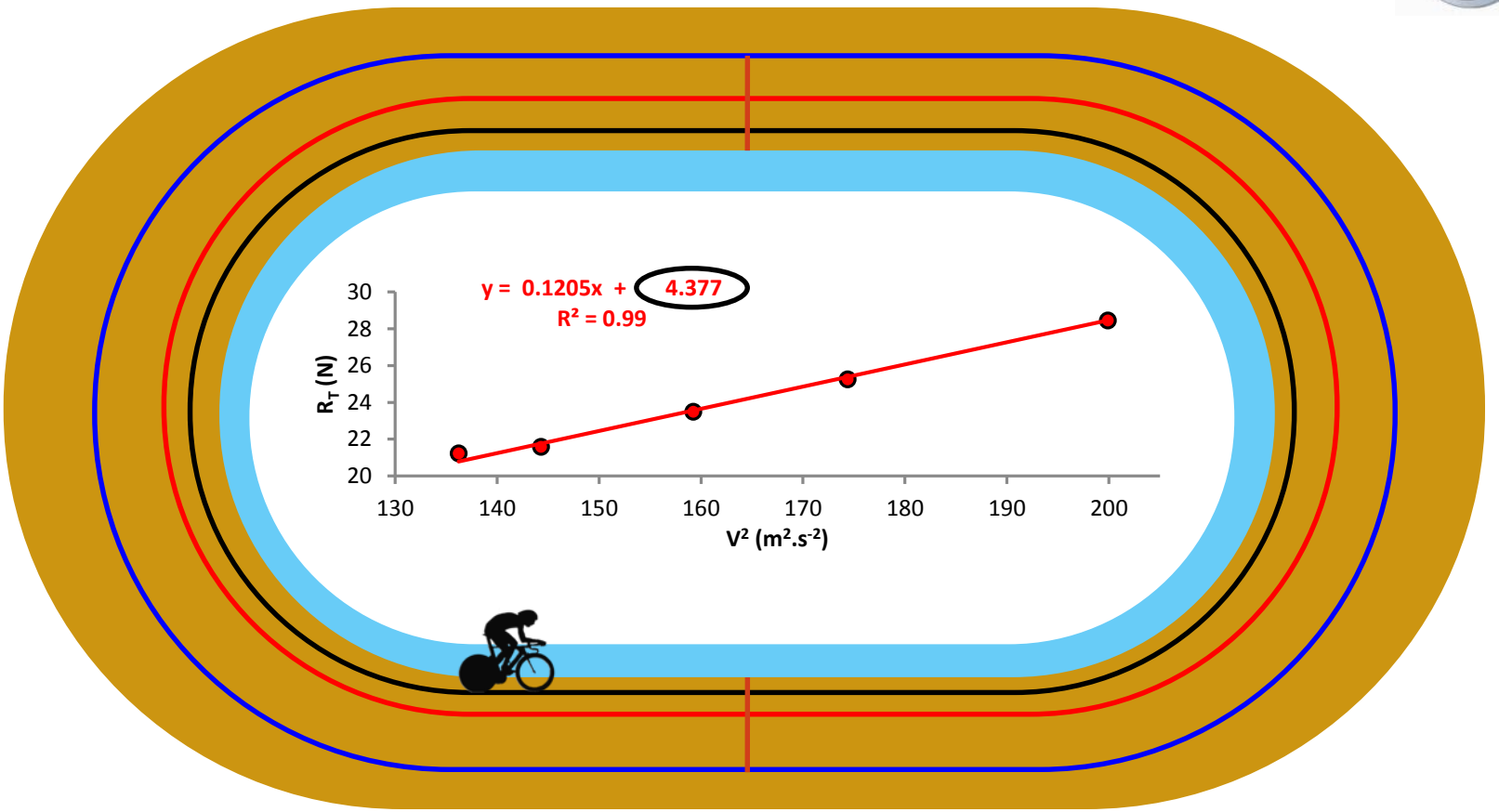


Discontinuous incremental exercise



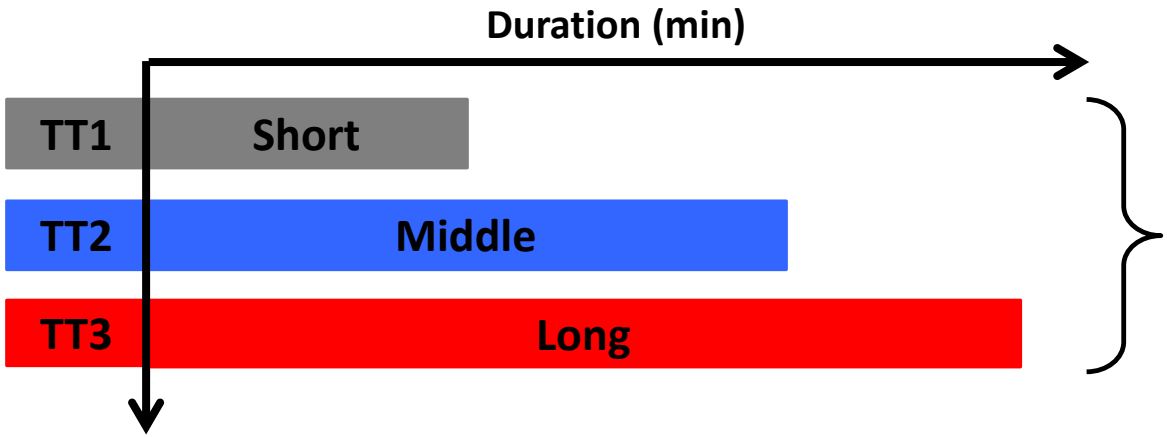
Grappe et al., 1997

Discontinuous incremental exercise



$b = R_R$

TT tests



Randomized order

Categories	TT1	TT2	TT3
U17 Men / U19 Women	3	8	15
U19 Men / U23 Women	4	10	20
U23 + Elite Men / Elite Women	5	15	30

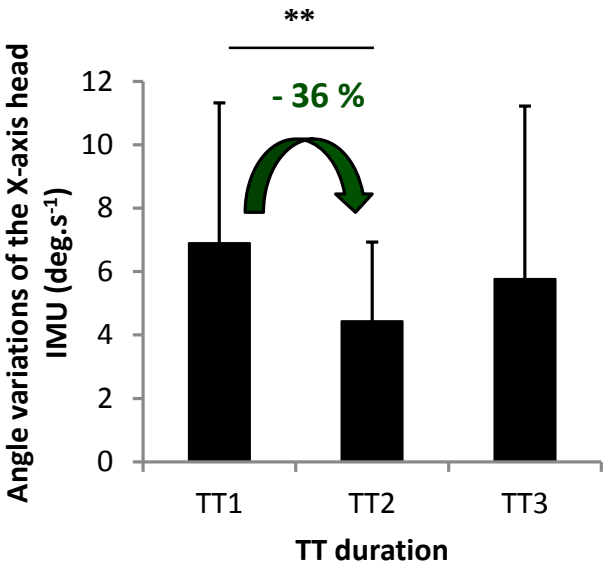
Kestrel

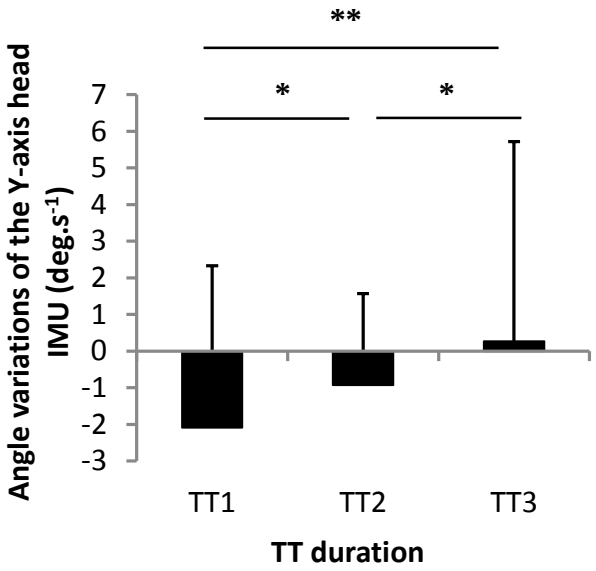
Powertap

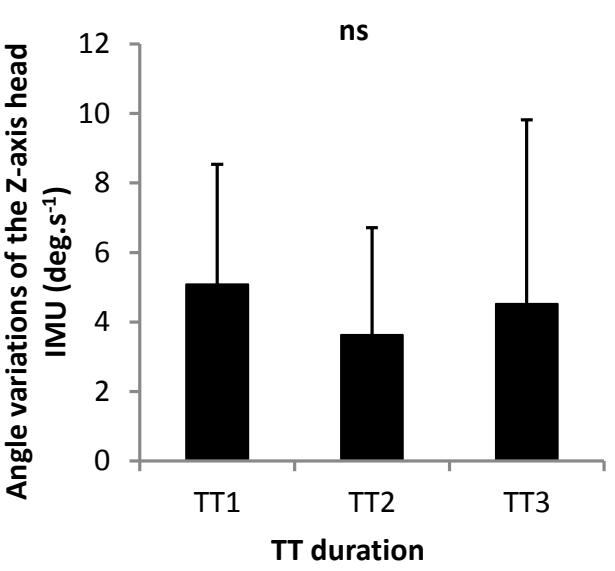
$$AC_d = \frac{PO - V \times Rr}{0.5 \times \rho \times V^3}$$

DIE

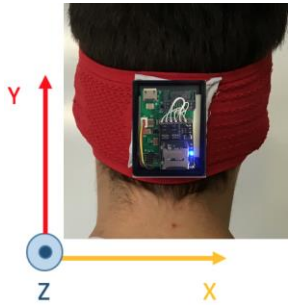
Effect of duration



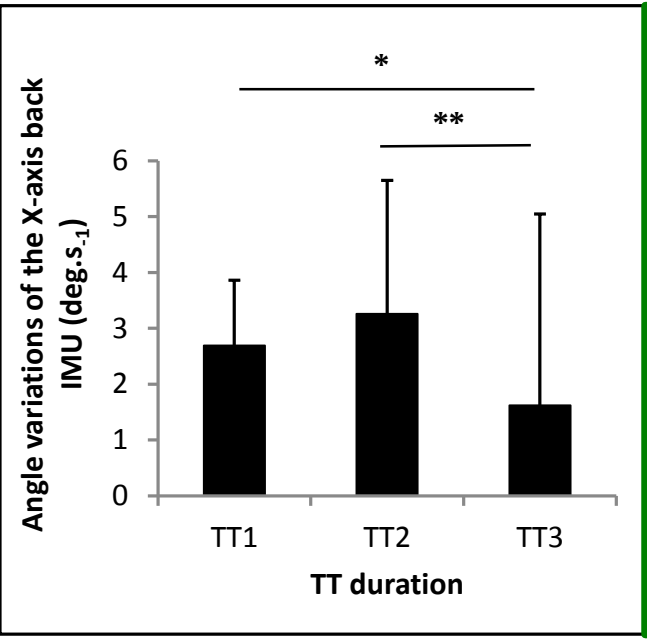


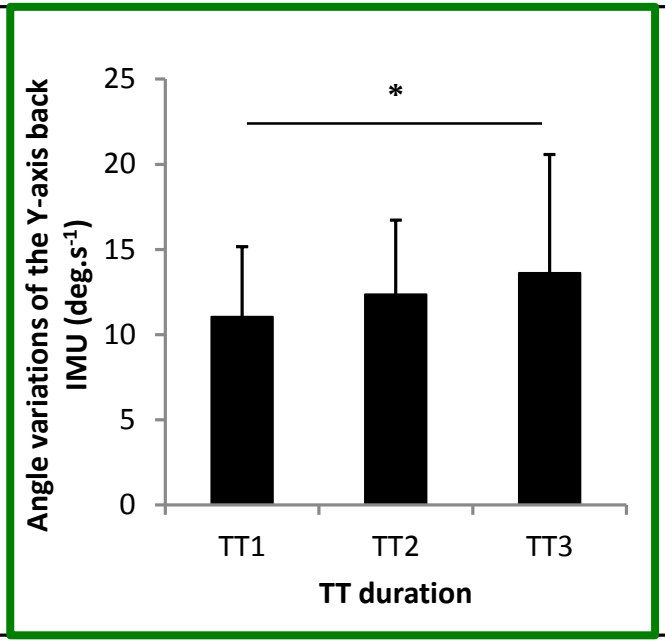


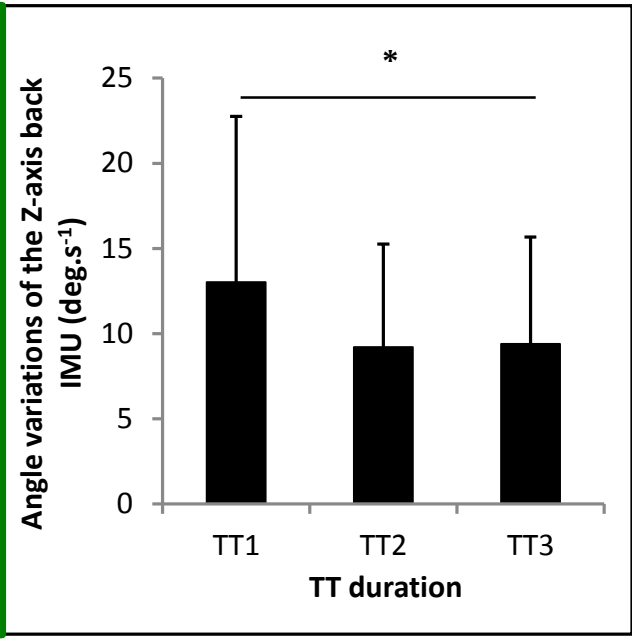
↗ in angle variations of the X and Z axes head IMU for the TT1 and TT3



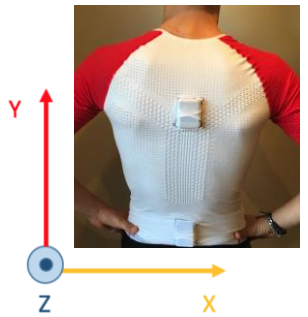
Effect of duration





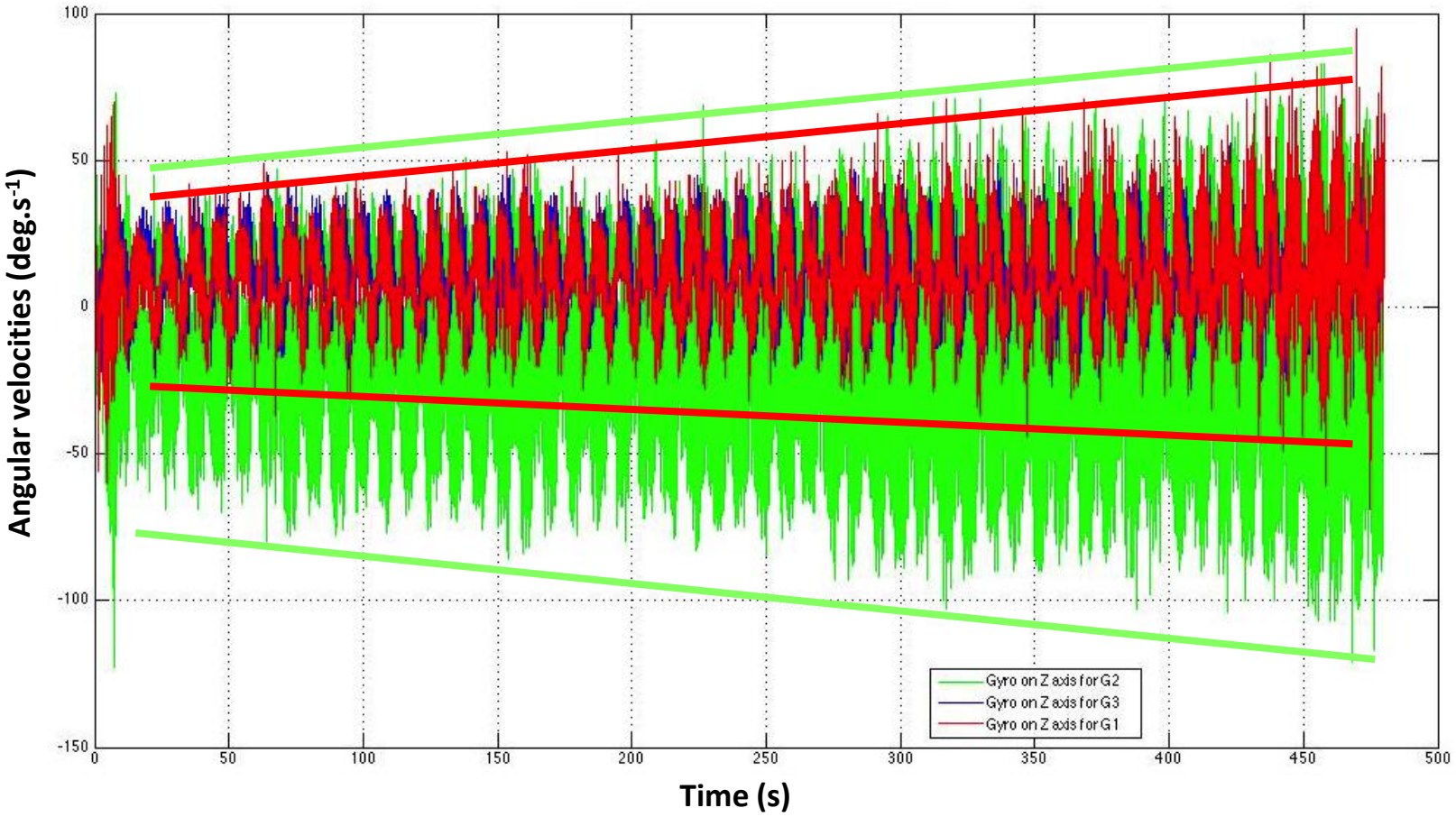


↗ in angle variations of the Y-axis lower back IMU

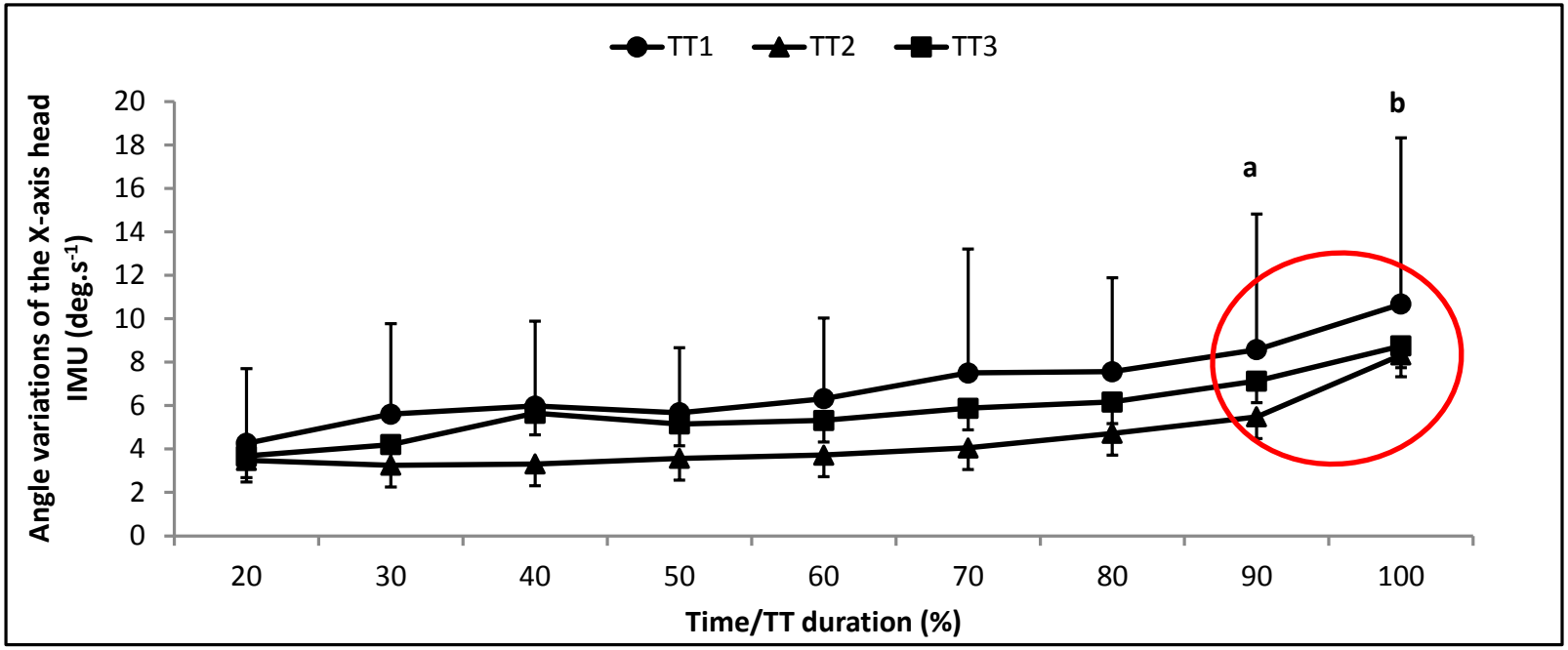


Effect of time

Example : Z axis Gyroscope comparison between 3 gateways

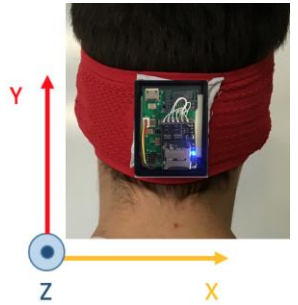


Effect of time



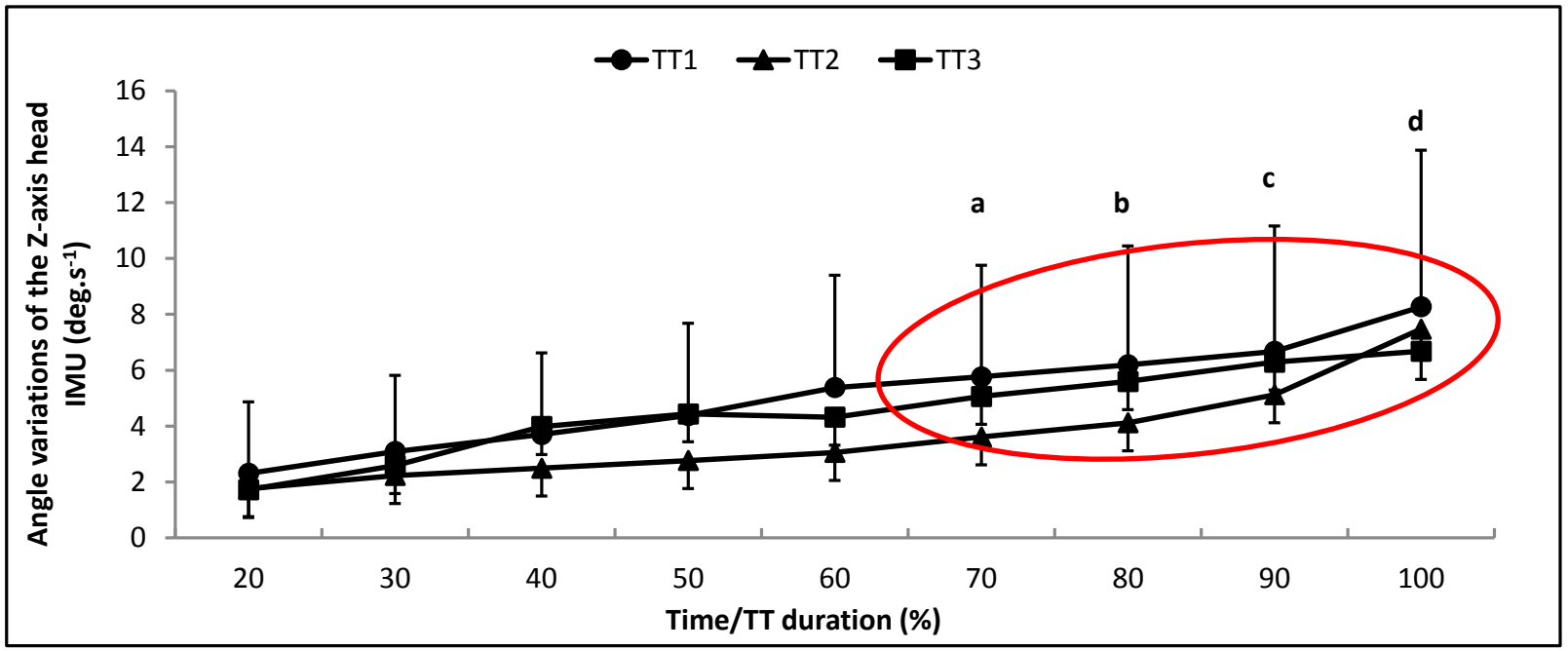
[a] *Significant difference between the 20th and 30th tenth ($p < 0.05$)*

[b] *Significant difference between all tenth except for the 90th tenth ($p < 0.05$)*

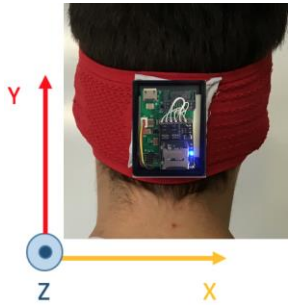


↗ in angle variations of the X-axis head IMU according to time

Effect of time

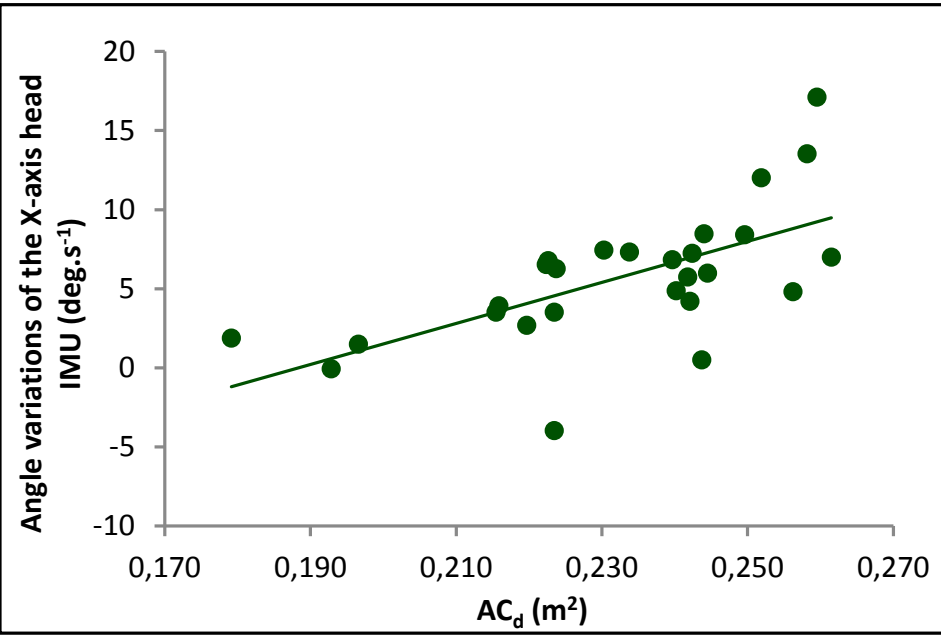


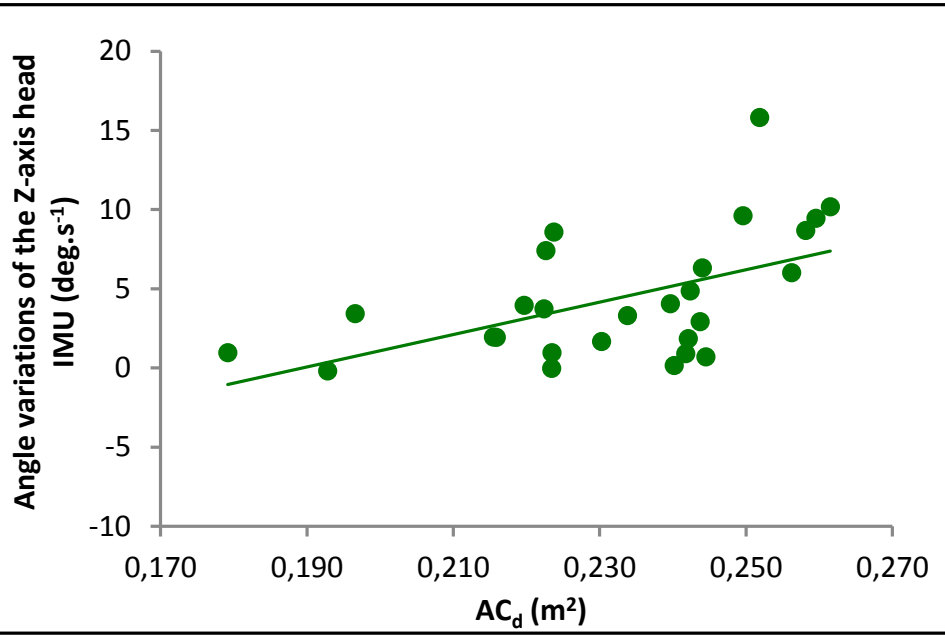
[a] *Significant difference between the 20th tenth (p < 0.05)*
[b] *Significant difference between the 20th and 30th tenth (p < 0.05)*
[c] *Significant difference between the 20th, 30th and 40th tenth (p < 0.05)*
[d] *Significant difference between all tenth except for the 80th and 90th tenth (p < 0.05)*



↗ in angle variations of the Z-axis head IMU according to time

Relationship between AC_d and angle variations of the X and Z axes head IMU





Angle variations of the X-axis head IMU

$y = 129.87x - 24.476$

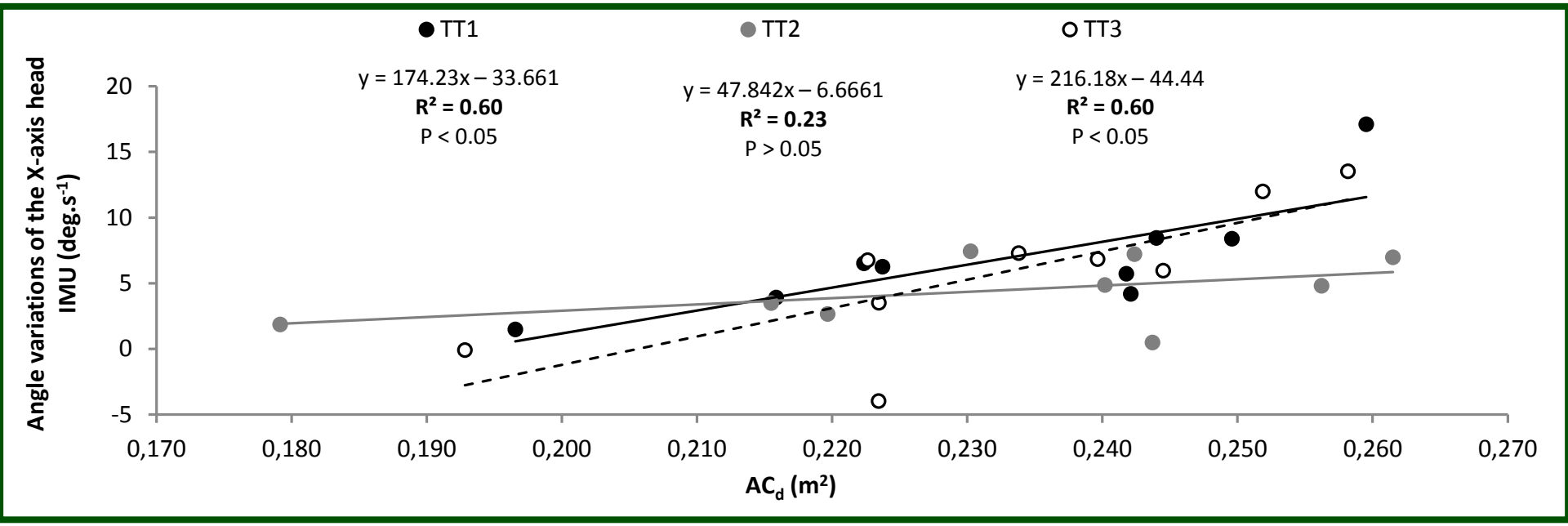
$R^2 = 0.40$ ($p < 0.001$)

Angle variations of the Z-axis head IMU

$y = 102.29x - 19.36$

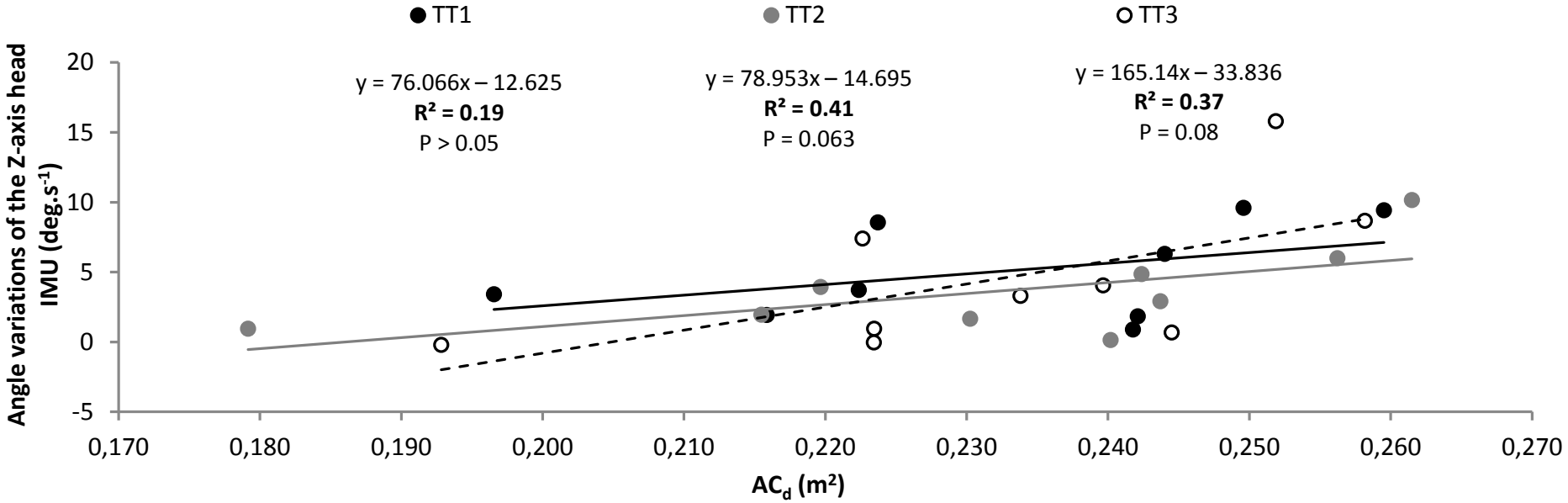
$R^2 = 0.29$ ($p < 0.05$)

Relationship between AC_d and angle variations of the X-axis head IMU in each TT



The more the angle variations of the X-axis head IMU ↗ the more the AC_d ↗

Relationship between AC_d and angle variations of the Z-axis head IMU in each TT



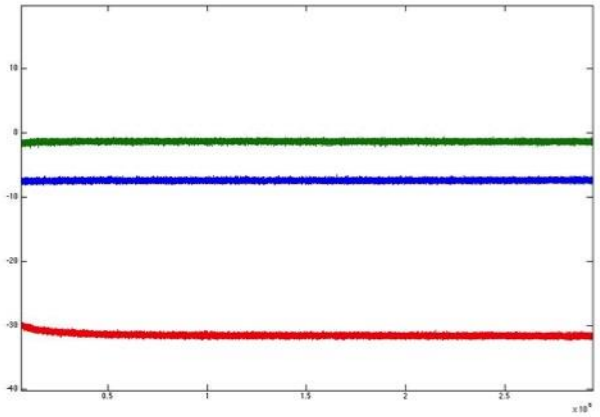
The more the angle variations of the Z-axis head IMU ↗ the more the AC_d ↗

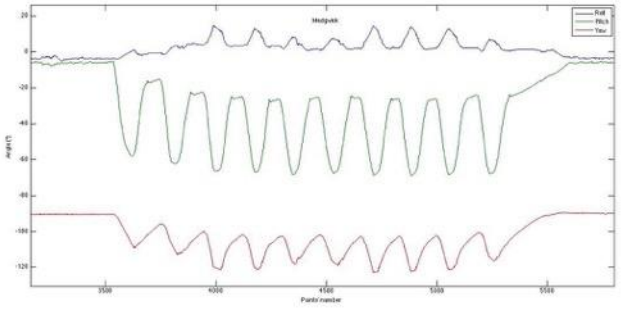
Effects of duration and time

- AC_d significantly correlated with angle variations around X and Z axes of the head IMU
- Results in accordance with Defraeye *et al.* (2011) -> drag value highly influenced by the head (19 % in TT position)
- Angle variations around X and Z axes of the head IMU ↗ over time
- Fatigue accumulation = ↗ in head movements
- ↗ in head movements = ↗ in ACd = ↘ in PO/AC_d ratio = ↘ in performance during flat TT (Peterman *et al.*, 2015)
- IMU = useful tool to detect small changes in TT position and optimise the performance by reducing head movements.
- Future investigation : degradation of the TT position in competitions
- Full body IMU system to make kinematic measurements on the field

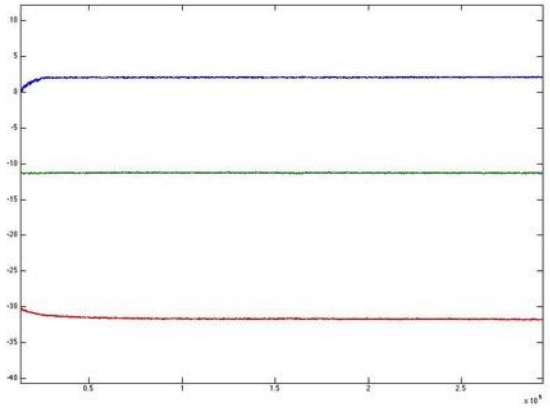
Validation of a fusion algorithm to compute reliable Roll, Pitch and Yaw

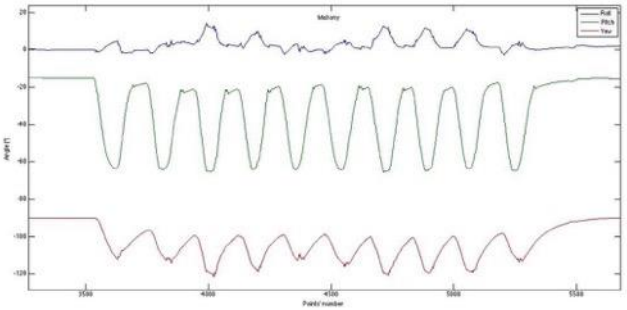
Madgwick



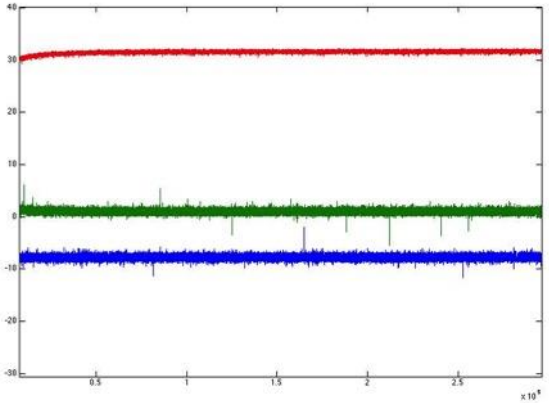


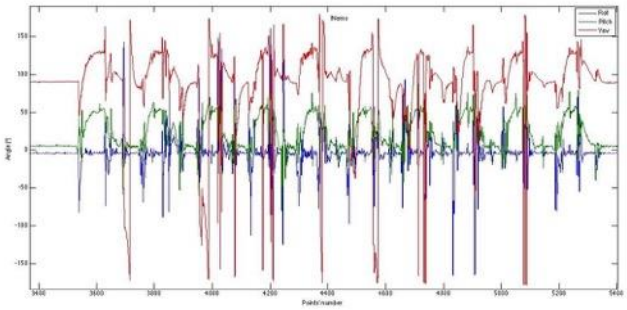
Mahony





iNemo





THANKS FOR YOUR ATTENTION

anthonybouillod@gmail.com
@ABouillod

1. Debraux P, Grappe F, Manolova AV, Bertucci W (2011) Aerodynamic drag in cycling: methods of assessment. Sports biomechanics / International Society of Biomechanics in Sports 10: 197-218
2. Defraeye T, Blocken B, Koninckx E, Hespel P, Carmeliet J (2011) Computational fluid dynamics analysis of drag and convective heat transfer of individual body segments for different cyclist positions. Journal of biomechanics 44: 1695-1701
3. Peterman JE, Lim AC, Ignatz RI, Edwards AG, Byrnes WC (2015) Field-measured drag area is a key correlate of level cycling time trial performance. PeerJ 3: e1144