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

Keywords: cycling position, inertial motion unit, aerodynamic drag, time-trial.

Purpose: Effective frontal area (AC_d, m^2) is the main parameter opposing motion on level ground in cycling (Debraux et al. 2011). To reduce AC_d, cyclists adopt a characteristic time trial (TT) position accounting for about 70 % of the total drag of the cyclist-bicycle system. When the cyclist is subdivided into 19 body segments, the highest AC_d values are found to be for the head, legs and arms, as these areas contribute the most to the frontal area of the cyclist (Defraeye et al. 2011). The drag area of the head in the TT position was higher than for the other positions because the head was the most protruding body segment in this position, consequently contributing significantly to increase AC_d. Additionally, it is very important to remain as stable as possible on the saddle to produce the highest power output (PO, W) during TTs to pretend increase the performance. The aim of this study was to analyse the effect of time-trial duration on head and lower back movements. We hypothesized that the more the duration of exercise is long the more the fatigue increases involving an increase of the head and lower back movements increasing AC_d.

Methods: 9 elite road cyclists performed all testing session with their personal TT bike on a 200 m covered velodrome (Bourges, France). The cyclists were fitted with 2 wireless systems, based on I-Nemo Inertial Motion Units (IMU, ST Microelectronics, Geneva, Switzerland) behind the head (figure 1) and lower back. The bicycle was also fitted with 1 IMU (under the saddle) and a rear wheel composed of a Powertap G3 hub (CycleOps, Madison, USA) for the measurement of speed (V, $m.s^{-1}$) and PO. Each IMU system was designed with a STM 32 microcontroller (MCU), miniaturized MEMS sensors: three-axis accelerometer, three-axis gyroscope and three-axis magnetometer. Data was sampled at 50 Hz. The AC_d was computed during three TTs of different durations according to the cyclists' categories. The data of the head and lower back were balanced with those of the bicycle. The effects of TT duration and time on head and lower back movements were tested using a two-way analysis of variance (ANOVA).

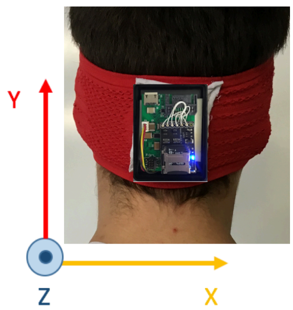

Figure 1. IMU orientation.

Results: A significant correlation was measured between AC_d and the angle changes around X-axis of the head IMU ($r = 0.51$, $p < 0.001$). Additionally, the angle variations of the head IMU were significantly influenced by 1) TT duration for the X ($p < 0.05$) and Y axes ($p < 0.001$) and 2) time for the X ($p < 0.001$) and Z axes ($p < 0.001$). Concerning the X-axis, angle variations were significantly higher ($p < 0.001$) in TT1 compared to TT2 (+55.7 %). Moreover,

these variations were significantly increased with the time in all TTs (figure 2). The largest increase in head movements was during TT1 (+ 143.1 %).
The lower back IMU was only affected by TT-duration around the three axes ($p < 0.05$).

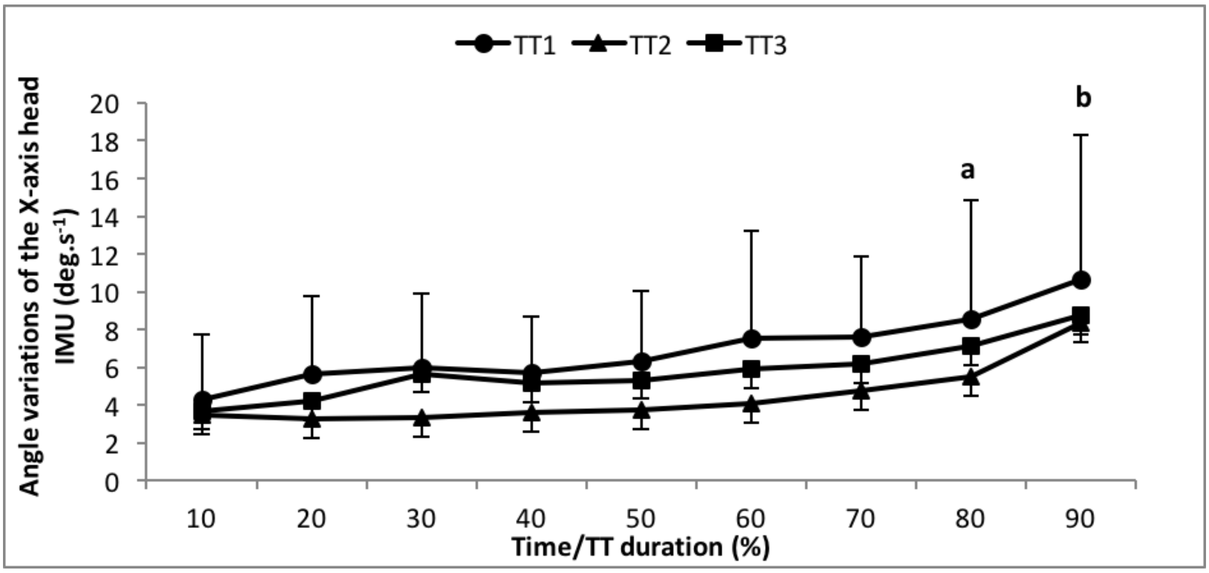

Figure 2. Influence of time on angle variations around the X-axis of the head IMU during the three time-based cycling time trials.
[a] Significant difference between the 20th and 30th tenth (p < 0.05)
[b] Significant difference between all tenth except for the 90th tenth (p < 0.05)

Conclusions: The main result of this study shows that the AC_d was significantly correlated with angle variations around X-axis of the head IMU which is in accordance with a previous study (Defraeye et al. 2011). Indeed, the authors reported that the head highly influenced drag value (19 % of the total AC_d) for the TT position. Additionally, the mean angles variations around X and Z axes of the head sensor increased over time for all the TT durations. The results suggest that the gradual accumulation of fatigue during TT induces an increase in head movements due to the impossibility to maintain an optimal position. This increase in head movements involved an increase in AC_d and therefore a decrease of the PO/AC_d ratio, a ratio linked to the performance in flat TT (Peterman et al. 2015). Inertial sensors appear to be very useful tool to detect small changes in TT position during real cycling locomotion on the field allowing to accurately measure the head movements. Future investigation should assess the degradation of the TT position in competitions.

References:

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