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Conference abstract

How low can you go - exploring the balance between aerodynamic advantages and derived disadvantages from lowering of the upper-body

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Abstract: Lowering of the upper body to optimize cycling time trial (TT) performance is a balance between aerodynamic benefits from reducing the rider's frontal area and the reported detrimental physiological effects of decreasing the hip-torso angle. To explore this issue in trained athletes and across positions relevant for elite TT, racing positions for international (top-10 world championships [WC] TT finishers), and national elite (10 male) cyclists were analyzed. Lab studies on the national group were completed to evaluate effects on exercise economy, muscle oxygenation and perceived exertion for their habitual position, respectively, the range of racing positions observed for both groups of elite TT riders. Torso-horizontal angel for top-10 WC finishers ranged from 4-12˚ and in the national elite ranged from 8-18˚. For the lowest observed and lab-investigated position (4˚ torso-angle), perceived exertion was aggravated compared to the more upright 12˚ and 20˚ positions and higher than scores for rider's habitual position. However, there was no difference in overall energy expenditure, gross- and delta efficiency or measures of muscle oxygenation across the investigated range of positions. Observations from this study indicate that elite time trial cyclists may adopt a very low position without compromising exercise economy or muscle oxygen delivery. However, the elevated exertion expressed for the lowest position indicate that other (individual/not accounted for) factors may affect and compromise the ability to adapt to very low racing positions.

Keywords: *exercise economy; torso angle; aerodynamics; time trial*

1. Introduction

Aerodynamic resistance as determined by the product of the riders (and bikes) frontal area (A) and the coefficient of drag (Cd) is indeed a factor of major importance for outdoor cycling performance (Debraux et al., 2009, 2011; Heil, 2001). Particularly, for time trial (TT) performance it is attractive to lower the upper body to reduce the CdA and hence reduce the power output required to sustain a given pace or increase speed for a given power output. The aerodynamic benefits from lowering of the upper body to reduce the rider's frontal area may however, be outweighed by the detrimental effects of decreasing the hip-torso angle on exercise economy and power output (Faulkner & Jobling, 2021; Fintelman et al., 2014, 2015; Grappe et al., 1998). The reported impairments in exercise efficiency when reducing the hip-torso angle from 24˚ to 0˚ degrees is in stark contrast to observations from elite time trials, where riders appear to adopt a torso position much lower than optimal. However, it remains unknown if elite TT riders can adopt at very low racing position without compromising exercise economy and the ability to produce power. Therefore, the aim of this study is to investigate the variation of the torso angle among elite TT-cyclists and secondly, to investigate the effect of a gradually reduction of the torso angle on physiological performance parameters among national elite TT-cyclists.

2. Materials and Methods

To the above aim we analyzed racing positions for international (top-10 world championships [WC] TT finishers), and national elite (N = 10 male (age: 23 ±3 years, height 190 ± 7 cm, body mass; 76.5 ± 7 kg)) TT-cyclists. Subsequently laboratory tests on the national group were completed to evaluate effects on exercise economy, muscle oxygenation and perceived exertion for their normal TT position, 4˚, 12˚ and 20˚ torso-horizontal angles (covering the range of racing positions observed). The participants provided their written informed consent and the study was performed in accordance with the declaration of Helsinki.

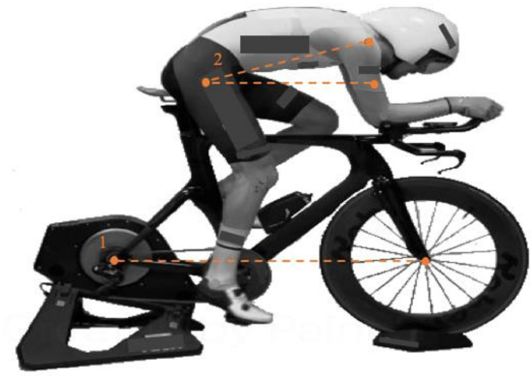

Figure 1. Representative rider in his habitual [normal] TT position and illustration of the determination of torso angle (° between line 2 [line between the trochanter major and processus acromion] the horizontal plane [between the two-wheel]).

The analysis of the riders’ habitual racing positions was performed in an image analysis software (ImageJ, National Institutes of Health, USA) (see Figure 1) from a photo of the riders in a sagittal plan.

The laboratory test started with 15 min warm-up followed by three submaximal exercise bouts - completed for each torso position in randomized order (15 min between positions tested) at fixed cadence (constant during and across trials) similar to their reported TT cadence and with 100 watts between the submaximal workloads (adjusted to the riders’ power output from national TT to secure that steady state could be achieved and maintained across all three bouts).

Total energy expenditure, gross- and delta efficiency (i.e. the slope of the regression line between the delta increase in external power output divide by the delta increase in total energy expenditure) was calculated for each position from steady state oxygen uptake and respiratory exchange ratio (indirect calorimetry; (Garby & Astrup, 1987; Péronnet & Massicotte, 1991)). Muscle oxygen saturation of vastus lateralis **(**SmO_2) was evaluated with a near-infrared spectrophotometry sleeve (Graspor, Graspor Aps, Viby J, Denmark) and the participants provided rating of perceived exertion (Borg, 1970) immediately after the last workload of each torso angle tested.

Statistical analysis was performed by using GraphPad Prism version 9.3.1 (La Jolla, CA, USA). The Shapiro-Wilk test was performed to test for normality and distributions. One-way repeat measures ANOVA of variances were used to determine the effect of the torso angle on variables. If a significant interaction effect was observed, a Bonferroni post hoc analyses was conducted. Data are presented as mean (standard deviation (SD)) and the accepted significant level was set to $P \leq 0.05$ unless otherwise are stated. The dataset was cleaned for outliers and data points was excluded if the exceeds ± 2 SD of the mean. To determine the required simple size (N), a sample size calculation was performed with a power (β) = 80% and $\alpha = 0.05$ on data from pilot-trials.

3. Results

Torso-horizontal angel for top-10 WC finishers ranged from 4-12˚ with an 8.2˚ mean, while the national elite TT racing positions were in the range from 8-18˚ with an 12.6˚ mean. For the lowest observed and lab-investigated position (4˚ torso-angle), RPE was aggravated compared to the more upright 12˚ and 20˚ positions and higher than scores for riders' normal TT positions (see Figure 2).

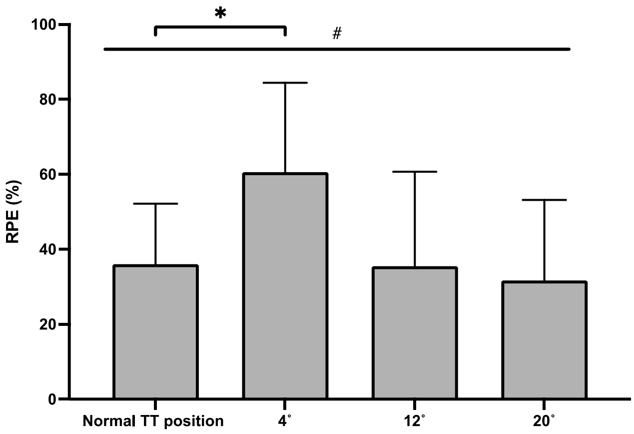

Figure 2. Rating of perceived exertion (RPE: % of maximal effort) at highest evaluated workload. Data are mean (bars + SD) for 10 elite cyclists in their normal TT (habitual race) position and the fixed positions with 4, 12 and 20˚ torso angle. # main effect of torso angle ($P < 0.05$). *significant higher than the normal TT position; $P < 0.001$.

However, there was no difference in overall total energy expenditure, gross efficiency, delta efficiency or measures of SmO_2 at the highest sub-maximal insentient with steady state oxygen uptake across the investigated range of positions (see Table 1).

Table 1	Normal TT position	4˚	12˚	20˚
Total energy expenditure (J/s)	1410 (194)	1393 (218)	1399 (196)	1372 (172)
Gross efficiency (%)	21.3 (2.9)	21.9 (2.8)	22.1 (2.7)	21.8 (2.3)
Delta efficiency (%)	28.4 (3.7)	29.1 (4.9)	29.4 (4.6)	27.4 (1.8)
SmO_2 (%)	39.8 (8.0)	39.8 (7.9)	38.8 (6.8)	40.2 (10.9)

Table 1. Total energy expenditure (J/s), gross efficiency (%), delta efficiency (%) and muscle oxygenation saturation (SmO_2) at highest evaluated workload. Data presents mean (and SD) for n = 10 in the normal TT (habitual race) position and the fixed positions with 4, 12 and 20˚ torso angle

4. Conclusion

The present observations indicate that elite time trial cyclists may adopt a very low (and aerodynamic attractive) position without compromising exercise economy or muscle oxygen delivery. However, the elevated exertion expressed for the lowest position indicated that other (individual/not accounted for) factors may affect and potentially compromise the ability to adapt to a very low racing position.

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