BIOMECHANICAL & PHYSIOLOGICAL CHARACTERISATION OF FOUR CYCLING POSITIONS

Alan Swanton[1], Amir Shafat[2], Ross Anderson[2&3]

[1]National Coaching & Training Centre, Limerick, Ireland
[2]PE & Sport Sciences Dept., University of Limerick, Ireland
[3]Biomechanics Research Unit, College of Science, University of Limerick, Ireland

This study examined the effect of a change in body position on a selection of biomechanical and physiological variables affecting triathlon performance. Ten local triathletes, participated in this investigation. This study also introduces a novel, inexpensive method of calculating frontal projection area (FPA). FPA decreased a total of 31.6% as the athletes moved from the hoods position to the superman position. No changes in physiological performance variables were reported across the cycling positions. The superman position was found to elicit detrimental effects on peak sprint power output and body comfort. This data lends to the conclusion that the superman position does not offer a greater advantage to the triathlete.

KEY WORDS: aerodynamics, frontal projection area, triathlon

INTRODUCTION: Cycling performance is a fine balance between biomechanical advantage and physiological efficiency. Since drafting is not permitted in triathlon, knowledge of how these variables interact and affect triathlon performance are of the utmost importance. The aerodynamic advantage from a reduced frontal projection area (FPA) when the cyclist assumes a forward crouched upper body position is well established (Capelli *et al*, 1993). At speeds exceeding 30 km/hour, aerodynamic resistance represents $>$ 90% of the total resistance that the cyclist encounters (Faria *et al*., 2005). A model reported by Jeukendrup & Martin (2001) found that a change to an aerodynamic body position is the second most important determinant of performance after training, accounting for 5.5 min improvement in a 64.0 min 40 km time trial in trained cyclists. Anecdotal evidence suggests that these biomechanically efficient changes in body position may cause physiological changes. Cycling in a crouched position may limit chest expansion, reduce chest volume, increase respiration rates and may result in reduced efficiency. This is supported by an investigation of 14 elite cyclists (Gnehm *et al*., 1997) who found a significantly greater metabolic cost in the aero position compared with the more traditional upright position. Triathletes must maintain a sufficient energy reserve following the cycle to perform the run. Therefore, it seems logical to find the most aerodynamically efficient riding position without compensating power output or comfort of the triathlete during performance. This study also introduces a novel, inexpensive and widely available method of calculating FPA, which provides an alternative to those who cannot access a wind tunnel. Furthermore, this project aimed to quantify the FPA of a group of triathletes and to investigate if a change in body position results in changes in physiological performance variables.

METHODS: Ten (7 male & 3 female) young healthy triathletes from a local club (body mass 78.5 ± 16.9kg: height 1.76 ± 0.09m) participated in the investigation having given informed consent (approved by the University Research Ethics Committee). The study analysed four cycling positions commonly used in road racing, triathlon and pursuit cycling. Minimal instruction was given to the participants as they moved into each of their preferred positions. In the first position the volunteer sat upright with their arms straight and hands placed on the hoods position (HP). For the second position the subject's hands moved down onto the loops (LP) with slight elbow flexion. The third position, the triathlon racing position using the tri-bars (TP) has previously been described as, "*elbows on triathlon aero bars, arms inside the projected frontal body area, torso flat, head tucked low between the shoulders*" (Bassett et al., 1999). The final position, the superman position (SP), has been described by the same authors as, "*arms extended forward in diving posture with the head tucked between* *the arms – the elbows and hands are far forward of the steering axis*". Pilot studies indicated that SP was excessively exhaustive in nature; therefore HP, LP and TP were performed in a randomised order while the SP was always the fourth position analysed to minimise experimental interference. Tests were performed on the participants own racing bike mounted on a Kingcycle air-braked ergometer (Kingcycle Ltd., High Wycombe, Bucks, U.K.) according to manufacturers instructions.

Volunteers warmed up for 10 min using their customary routine. Each participant completed the following test schedule. The volunteers assumed their first randomised position and cycled for 10 min at an exercise intensity equivalent to 70% heart rate reserve (calculated from the Karvonen formula). Each position was maintained for 10 minutes and within that time body comfort was measured every minute on a Likert scale. Rate of perceived exertion (RPE) was recorded every 2 minutes. During minutes seven to nine an expired gas sample was collected using a Douglas bag set-up and analysed for expired gas oxygen and carbon dioxide concentration using AMIS 2001 (Innovision 2001, Denmark). Shoulder muscle activation, as measured by Electromyography (EMG), of the left and right medial deltoids was continuously recorded. Finally respiration rate was recorded using a respiration belt (Powerlab 4/25 & pneumotrace, AD Instruments, UK). Maximal power output was recorded from the Kingcycle during a 30 second sprint at the end of each 10 min bout. Volunteers were allowed to recover from the sprint until their HR returned to 120bpm. The same procedure was then repeated for the next randomised position. , knee, hip and shoulder angles were obtained for all four positions in the sagital plane. It should be noted that only FPA, EMG, comfort and peak power were measured in the SP.

To calculate FPA the volunteers were asked to position themselves in each position with the pedal cranks perpendicular with the floor. A digital image (5 mega pixel) was captured of the participant and a calibration object (CO) from the frontal plane. The images were analysed in an image-processing package (Adobe Photoshop 7.0 - Adobe, San Jose, USA). Firstly, the *rectangular marquee tool* was used to extract the portion of the image containing the upper body of the cyclist (Figure 1A). The portion of the image containing the CO was also extracted. The *magnetic lasso tool* was then used to extract the cyclist (or the CO) from the background of the image; this selection was then pasted as a new image with a white background (see Figure 1B). Following this, the image was converted to an image of two colours by reducing the contrast to minus 100% (*image – adjustments – brightness/contrast – contrast*). The resulting image (see Figure 1C) contained a representation of the FPA for that position. To calculate the actual FPA the image was represented as a histogram (containing the number of pixels of each colour). The CO image was processed in the same way. The area of the FPA could then be calculated in pixels and converted to m^2.

Figure 1 – Image A (left), Image B (middle), and Image C (right)

The data were analysed separately using full factorial repeated measures general linear model ANOVAs. Mauchly's test of sphericity was used to determine the homogeneity of variance within the data, and where this test was significant a Greenhouse-Geisser correction was used. Pairwise comparisons were resultantly made on the data; a Bonferroni correction was applied for multiple comparisons.

RESULTS: Hip and shoulder joint angles indicated that each position was significantly different (all P<0.05) for all other positions when considered from a kinematic perspective. Knee angles were statistically similar in all positions supporting the decision to analyse upper body FPA only. FPA was found to be significantly reduced (P<0.00) in the TP (0.328 ± 0.058 m^2) and SP (0.309 ± 0.062 m^2) compared to HP (0.406 ± 0.036 m^2) and LP (0.406 ± 0.036 m^2). TP and SP were similar; LP and HP were also similar. Ventilation (V_E), breathing frequency, tidal volume (TV), VO_2 and RPE were similar in all positions (Table 1).

Table 1 – Physiological measures in three cycling positions

	Hoods (HP)	**Loops (LP)**	**Tri – bars (TP)**
V_E (L/min.)	54.47 ± 9.24	52.15 ± 10.24	51.98 ± 9.31
Frequency (breath/min.)	28.0 ± 2.0	27.0 ± 2.0	28.0 ± 2.0
TV (L/breath)	1.9 ± 0.3	2.1 ± 0.3	1.9 ± 0.4
VO_2 (ml/kg/min)	12.0 ± 2.1	11.7 ± 1.8	12.0 ± 2.8
RPE	48.8 ± 6.0	47.3 ± 6.0	50.0 ± 6.0

Data are mean±S.D. n=10 for all positions

Power outputs across the 3 most upright positions were not significantly different with the HP (517 ± 184 W), LP (502 ± 185 W), TP (522 ± 183 W) but was significantly lower in SP (385 ± 143 W, P ≤ 0.001). Body comfort followed an identical pattern with no change across the HP (71.6 ± 12.3), LP (70.1 ± 11.2) and TP (75.5 ± 9.2) but was significantly and dramatically lower for the SP (32.4 ± 16.4). EMG results were analysed using a confidence interval analysis. The results showed that the deltoids were activated to a similar extent in HP (58.83 ± 10.67 uVs), TP (56.70 ± 17.64 uVs) and SP (60.36 ± 20.72 uVs) but were found to be elevated in LP (60.48 ± 7.96 uVs) although this only approached statistical significance

DISCUSSION: FPA decreased a total of 24.0% as the subject moved from the HP to the TP. These results are slightly lower than those reported by Faria et al. (2005) who reported a 30-35% reduction in drag when moving for the upright to the aero position. Wind tunnel data suggests that the superman position, on an aero bike, lowers the overall wind resistance about 5% compared with the standard aero position (Bassett et al., 1999). The present study found a slightly greater decrease (7.7%) as the subject moved from the TP to the SP. Bassett *et al*. (1999) reported the FPA (bike not included) of a 69kg volunteer in the TP to be 0.292m^2. The value reported in the present study for the TP (0.328 ± 0.058 m^2) is slightly higher but considering the greater mean body mass (78.5 ± 16.9kg) encountered in the present study, this increased body mass may account for the slightly larger recorded values of the present investigation.

The physiological response to the aero position is not well understood. Berry *et al*. (1994) suggested that ventilation changes only became apparent after prolonged exhaustive exercise. This finding supports data obtained in the present study showing no significant change in the physiological parameters. Gnehm *et al*., (1997) found a greater metabolic cost in the extreme aero-position in 14 elite cyclists. However, the present subject group were trained in the aero position whereas elite cyclists may be less accustomed to the aero-position, which may have elicited the greater metabolic cost. This confirms the conclusion by Berry et al. (1994) who recommended that cyclists who raced with aerobars (tri-bars) should also train with aerobars.

Peak power and comfort were significantly (P ≤ 0.001) and dramatically reduced in the SP. This dramatic reduction was represented by a 26% decrease in mean peak power and a 58% decrease in comfort as the athlete moved from the TP to the SP. However, we must be cautious with the conclusions from such a finding since volunteers may have been fatigued by prior testing, elevating the metabolic cost of the effort and reducing power output. However, the small improvement in FPA suggests that SP may only be appropriate following extensive training and acclimatisation. For example, Chris Boardman used the SP position throughout his 1996 one-hour world record (56.375 km). Maintenance of the more aerodynamic SP would not be a viable option for a triathlete who has to run a minimum of 10 km once dismounted from the bike.

CONCLUSION: This abstract reports a novel and economic approach for the analysis for PFA. However, further validation is required against data obtained in a wind tunnel.

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