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POWER OUTPUT, MUSCLE ACTIVITY, AND FRONTAL AREA OF A CYCLIST IN DIFFERENT CYCLING POSITIONS

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Nine cyclists completed three trials of cycling 25W below lactate threshold (LT) with 1) hands on top of the brake hoods (BH); 2) hands below the dropped, curved, portion of the handlebars (DH); and 3) using clip-on triathlon aerobars (AB). Each trial lasted three minutes and was immediately followed by a 20sec maximal sprint during which power output and muscle EMG were measured. Frontal projection area (FPA) differed across all three positions. EMG did not differ between positions during submax or sprint cycling. Submax power output also did not differ, but during the sprint AB was lower than BH, while DH did not differ from the other conditions. Although power output was 8.1% less while cycling in the AB position than BH, its FPA was 17.4% less, indicating the AB position allows a savings in resistive power greater than that lost in power production.

KEYWORDS: bicycling, aerobars, EMG

INTRODUCTION:

Physiological changes in cycling position are not well understood and previous results have yielded results that are inconsistent. Research shows that changing positions may lead to a difference in muscle activity, metabolic costs, power output, and in RPE of athletes.

Ashe and colleagues (2003) found that when untrained subjects performed with maximal effort the upright position permitted greater VO2, ventilation. heart rate, and workload maxima than an aero position. Furthermore, at steady state exercise, cycling may be less costly in the upright position. Using elite cyclists Gnehm and coworkers (1997) found there was a greater metabolic cost in the aerodynamic position when compared to the other common cycling positions, upright and hands on drops. In contrast, trained but non-elite cyclists or triathletes do not show differences in physiological responses between upright and aero-bar positions (Origenes, et al., 1992; Swanton et al., 2006).

Swanton et al (2006) found no differences in power output between aero-bars, upright cycling on the brake-hoods or in the dropped handlebar position. However they noted that muscle activity of the deltoids was higher in the dropped handlebar position and found frontal projection area to be 19.2% less in the aero-bar position compared to hands on the drops and brake-hood positions. Although not specific to handlebar position Brown et al (1996) found muscle activity of the legs varied when hip position was altered. Savelberg and colleagues (2003) also found that muscle recruitment varied when the saddle was moved forward or aft while cycling.

Due to the inconsistency of results from previous studies regarding power output and muscular activity in different cycling positions additional research should be performed to determine the effect of using upright and aero positions while cycling. Therefore the purpose of the current paper was to examine the effect on peak power output, muscle activity as assessed by EMG, and frontal area projected to the air while using upright handlebar positions on the brake-hoods or dropped handlebars versus using aero-bars during cycling.

METHODS:

Nine recreational or sub-elite cyclists (Age = 24.8 ± 6.8 years; Height = 181.5 ± 6.4 cm; Weight = 76.9 ± 8.8 kg; VO_{2max} = 3.99 ± 0.80 L/min; Years riding competitively = 3.7 ± 1.9 years; Hours ridden per week = 7.7 ± 1.7) provided written voluntary consent to cycle at 25

W below lactate threshold and during a maximal 20 second sprint. The study was approved by the local institutional review board.
Testing took place on two days separated by 48 hours. Subjects were asked to refrain from training for 24 hours and eating for two hours prior to reporting for data collection and to "treat each testing session as a race". Subjects were first weighed on a balance beam scale to the nearest 100 g and stature was determined by stadiometer to the nearest 5 mm. Subjects used their own bicycle on a Magturbo stationary trainer (Minoura, Hayward, CA) with their preferred settings for saddle height and handlebar positions. The rear wheel was replaced by a Power-Tap Link™ (Saris Cycling , Madison, WI) instrumented wheel and cycling computer.
On the first day subjects began riding at a power output of 100W for three minutes. Workload was then increased 25W each three minutes until lactate threshold was achieved; lactate threshold (LT) was defined as an increase of > 1mmol/L of lactate over the previous workload. Following attainment of LT, workload was increased every minute until exhaustion. During the last 30 seconds of each three minute stage blood lactate was assessed via fingertip puncture with a Lactate-Pro analyzer (ARKRAY Inc., Kyoto, Japan). Oxygen uptake (VO_2) was assessed throughout the test using a Sensormedics VMax29C (Yorba Linda, CA). Peak VO_2 was the highest minute value attained during the ride. Maximal blood lactate was determined five minutes after cessation of cycling. Subjects were allowed to shift gears as desired, but were asked to maintain a cadence of approximately 90 rpm.
On the second day subjects cycled for five minutes at 100W. They then cycled at 25W below the power output attained at LT for three minutes and then performed an all-out sprint for 20 seconds. Five minutes recovery, consisting of a workload of $\leq$ 100 W, took place between work intervals. This order of cycling was performed four times in different positions. Subjects always began with the hands on top of the brake hoods. This was followed by each of three randomly ordered positions: 1) with the hands on top of the brake hoods (BH); 2) with the hands below the dropped, or curved, portion of the handlebars (DH); and 3) using clip-on triathlon bar extensions with the elbows resting on pads and hands extended to the end of the bar (AB). Subjects were allowed to shift gears as desired during the first BH condition, but were asked to maintain a consistent gearing during subsequent trials.
Power output and cadence were measured via the Power-Tap Link™ (Graber Products, Madison, WI) cycling computer. The cycling computer was interfaced with a magnetic bicycle hub laced into the rear wheel of the bicycle. This device fed data into the cycle computer, which were stored as ASCII text data files. The cycle computer and storage unit were mounted on the handle bars of the bicycle. Mounting and calibration of the cycling computer was done as recommended by Power-Tap Link™. The gearing ratio for all conditions was controlled by having the subjects ride in the same gear ratio for the final three trials.
Surface EMG data were recorded at 1000 Hz by electrodes placed on the right biceps femoris, rectus femoris, gluteus maximus, erector spinae, middle deltoid, and upper trapezius. Skin preparation included shaving any hair, removing dead skin from the surface with a roughing pad, and cleansing the surface with alcohol and testing for a resistance of < 5000 ohms. Three surface electrodes were used for each muscle with placement according to Cram, Kasman, and Holtz (1998). Wires for the surface electrodes were strung under the cycling shorts or shirt of the subject and connected to an amplifier. Data was streamed continuously through an analog to digital converter (Biopac Systems, Inc. Goleta, CA) to an IBM-compatible notebook computer and diskette. Electromyographic data were filtered with a 10Hz high pass filter, a 500Hz low pass filter (Winter, 1990) and saved with the use of computer software (AcqKnowledge 3.2, Biopac Systems, Inc. Goleta, CA). Saved EMG data were processed using Root Mean Square procedures using a time constant of 20 ms. EMG data was collected from 2:30 to 2:40 of the three minutes of submaximal cycling and for the last 10 seconds of maximal cycling.
Frontal projection area (FPA) was determined with the subjects wearing their own helmet and positioned in their self selected riding position for AB, BH, and DH with the pedal cranks perpendicular with the floor. The area of the FPA was calculated in m^2 according to the technique of Swanton et al. (2006).

Statistical analyses were performed using SPSS 13.0 for Windows. A One-way repeated measures Analysis of Variance was used to compare cycling conditions for the three cycling positions. The Independent variable was cycling position. Dependent variables were frontal projection area; submaximal values for power output and EMG for the six different muscles; as well as maximal values for power output and EMG for the six different muscles. An alpha level of 0.05 was selected with Greenhouse-Geyser correction if sphericity was violated. If significant differences were noted, a Bonferroni's post-hoc test was performed.

RESULTS:

Repeated Measures ANOVA across the positions found differences ($p < 0.05$) between all three frontal projection areas AB = 0.341 ± 0.015, DH = 0.395 ± 0.019, and BH = 0.413 ± 0.027 m^2. As shown in Table 1 there were no differences in EMG at maximal or submaximal power outputs for any of the muscles investigated ($p > 0.05$). Submaximal power output was not different ($p > 0.05$) across the positions AB = 202.6 ± 33.0, DH = 203.3 ± 32.5, and BH = 203.7 ±. 33.4 W. Peak power output was significantly ($p < 0.05$) lower for AB = 746.3 ± 187.1 compared to BH = 812.0 ± 145.1 W; while DH = 803.0 ± 165.8 W did not differ from either AB or BH ($p > 0.05$).

Table 1: Mean (± SD) RMS EMG (mV) for six muscles while cycling at submaximal and maximal power output in three handlebar positions (N = 9).

	Aerobars Submax EMG	Drops Submax EMG	Brakehoods Submax EMG	Aerobars Maximal EMG	Drops Maximal EMG	Brakehoods Maximal EMG
Trapezius	8.01 (6.96)	10.03 (8.41)	8.46 (4.46)	32.42 (23.86)	33.36 (18.60)	40.69 (26.37)
Deltoid	8.03 (7.00)	10.02 (8.39)	8.32 (4.48)	32.29 (23.71)	33.22 (18.73)	59.96 (45.76)
Erector Spinae	22.41 (22.62)	11.22 (5.61)	15.93 (12.15)	32.30 (23.63)	22.77 (15.38)	37.34 (34.37)
Gluteals	19.11 (21.36)	37.40 (48.08)	20.14 (25.62)	36.85 (15.76)	44.72 (21.17)	46.40 (31.57)
Quadriceps	66.47 (71.62)	21.54 (21.51)	21.30 (18.35)	74.76 (60.84)	49.81 (22.17)	51.27 (18.03)
Hamstrings	5.17 (4.52)	10.77 (14.70)	8.22 (10.06)	12.70 (9.21)	12.98 (7.49)	14.11 (12.80)

DISCUSSION:

The major findings of the current study were that power output when using the aerobar position (AB) was 8.1% less than that of the hands on brake hoods (BH), while frontal projection area (FPA) was 17.4% lower in AB compared to BH. The decrease in FPA, though not as large, is similar to findings of Swanton et al. (2006). In the current study absolute values for FPA were slightly higher than those of Swanton et al. (2006), however, their subjects were assessed without helmets, while the current subjects wore their helmets. Swanton et al. (2006) found no difference in power output between the three positions (AB, BH, and DH) when cycling at 70% of predicted heart rate reserve. The lack of difference in power output was similar to that found when subjects of the current study cycled 25 W below LT. These findings should not be unexpected, as subjects were asked to cycle at equivalent intensities across the different positions. When the current subjects were asked to sprint all out, the 8.1% lower peak power output during AB suggests that performance might be compromised in this position. However, because FPA was also 17.4% lower than BH, the lower power would seem to be more than offset as indicated by previous work (Ashe et al. 2003; Gnehm et al. 1997). Indeed, as power to overcome drag is related to frontal surface area, if the other major variables contributing to drag (air density, velocity of air passing the rider, coefficient of drag, and rolling resistance of the bicycle) are held constant then the changing the FPA from 0.413 to 0.341 m^2 would decrease power required to cycle at 30 $km \cdot hr^{-1}$ from 141 to 116 W (Dettinger, 2007). This value of 17.7% is quite similar to the change in FPA from BH to AB and would appear to be more than offset by the concomitant 8.1% drop in power during maximal sprint cycling. The lack of difference in muscle activity (indicated by EMG) across the positions is in contrast to previous findings (Savelberg et al. 2003; Swanton et al. 2006). It should be noted that Deltoid EMG during the sprint approached significance ($p = 0.068$) with the BH condition (59.96 ± 45.76 mV) having values higher than AB and DH (32.29 ± 23.71 and 33.22 ± 18.73 mV respectively). The lack of difference was likely due to the large variability of measurements across a relatively small sample.

CONCLUSION:

Findings of the current study indicate that as a cyclist moves from a more upright position (BH and DH) to a more aerodynamic position (AB) frontal projection area and power output during maximal effort are both decreased. However as the sprint power output does not decrease in the same magnitude as FPA, the cyclist likely benefits from a savings in drag resistance greater than that lost in sprint power production; especially at high speeds attained during sprinting.

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