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EFFECTS OF TRAINING IN AN AERO POSITION ON METABOLIC ECONOMY

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ABSTRACT

Peveler W, Bishop P, Smith J, Richardson M. Effects Of Training In An Aero Position On Metabolic Economy. *JEPonline*. 2005;8(1):44-50. Previous studies have examined the metabolic cost of cycling in an aerodynamic position and found that there was a greater metabolic cost in this position when compared to an upright position. These studies only examined cyclists who train upright. This study compared cyclist who only train in an upright position and triathletes who only train in an aero position to determine if there was specificity to training position. Both groups completed two 30-min trials (one trial upright and the other aero) on two different days at the Watts at 70% of $\dot{V}O_2$ max and $\dot{V}O_2$ was recorded. It was found that the mean $\dot{V}O_2$ of the aero position (43.3 ± 5.5 mL/kg/min) was significantly higher than the upright position (41.2 ± 5.8 mL/kg/min) for cyclist and the means between aero (38.5 mL/kg/min ± 5.4) and upright positions (38.0 ± 5.3 mL/kg/min) were not significantly different for triathletes at $p < 0.05$. There does not appear to be the normal metabolic cost associated with riding in an aero position when examining triathletes who train only in that position. From this study it can be recommended that cyclists and triathletes should train in the position in which they race.

Key Words: Exercise, Cycling, Triathlon, Aerodynamics, Metabolism

INTRODUCTION

With advances in equipment and training, time trial records have dropped dramatically since the 1980's when aero bars were first introduced. Aerodynamics is very important to both time-trial cyclists and triathletes due to the fact that neither is allowed to draft behind another rider. A time trial cyclist competing in a 40 km race can save 90 s by using aero bars and riding in an aerodynamic position (1). This is a large amount of time when you consider that cyclists are often separated by less than one second at the finish line.

Time trials can be an important opportunity to gain a time advantage in stage races such as the Tour De France. Recently there has been a trend in professional cycling to train specifically for time trials. Anecdotal testimony of triathletes and coaches claim that there is specificity to training position. This raises the question as to whether or not there is specificity to a time trial cyclist's riding position. In the time trial or triathlon position, the rider is crouched low in aero bars, which is dramatically different than the traditional riding position.

When looking at the total aerodynamic drag of a rider, the bike only constitutes about 25-35% of the total drag (2). The body of the rider makes up the other 65-75%. So it makes sense that by decreasing the flat-plate area of the rider exposed to the wind, drag will be reduced. Using aero bars reduces the surface area of the cyclist dramatically. The effectiveness of using aero bars to cut wind resistance is well documented (1,3,4). When looking at cyclists riding outdoors, Sheel et al. (5) found that the aero position, when compared to riding upright with hands on the brake hoods, was more energy efficient. Both $\dot{V}O_2$ and $\dot{V}E$ were lower in the aero position than on the brake hoods. This makes sense considering an expected drag reduction equaling 100 Watts in the aero position, versus only a 9 Watt power loss when in an aero position (6).

This raises the question, what is the increased metabolic cost of riding in an aerodynamic position? Studies have looked at the metabolic cost of cycling in an aerodynamic position. Gnehm compared the upright and aero position, using 14 elite cyclists, and found that there was a greater metabolic cost in the aerodynamic position when compared to the more traditional racing position (6). Ashe et al. examined economy between aero and upright positions and found an increased metabolic cost to riding in an aero position, when testing untrained subjects (7). In 1994 Berry found that there was a trend towards a large time gap, while not significantly different, between riding in an aero position vs. upright (8). All cyclists lasted longer in the upright position than they did in the aero position. When looking at individual times, there was less of a time difference between those who trained occasionally with aero bars and those who do not. Berry then suggested, based on that observation, that individuals who race in the aero position should train in the aero position. In Berry's study the cyclists had to perform at 80% of $\dot{V}O_2\text{max}$ and 6 of the 22 subjects could not finish the 60 min test. At 80% of $\dot{V}O_2\text{max}$ it may have been hard for the cyclist to steady state long enough to compare data from one trial to another. In Gnehm's study the cyclists performed at 70% of $\dot{V}O_2\text{max}$ (6). Another study, that looked at four moderately trained triathletes, two high altitude climbers and four untrained individuals, found that there was no significant difference between the two positions (9); however this might be expected with less-trained participants and moderately trained triathletes.

Riding in an aero position changes the angle of the hips compared to an upright position. Heil et al. (10) reported an 11° change in hip angle affected cardiorespiratory responses. This is a similar change that occurs when dropping from an upright position to an aero position.

In all of these studies, with the exception that of Origenes and Ashe (7,9), the subjects were trained cyclists who habitually trained on bikes with traditional handlebars and not aero bars. There could be

specificity to training position and the change in angle could explain why riding with aerobars was less metabolically efficient in both Gnehm's (6) and Ashe's studies (7). Heil et al. (11) looked at changes in lower limb kinematics and hip angle. He found that cyclist performed better at angles that were most similar to the bikes on which they trained. This leads to the question of whether or not training in an aero position makes one metabolically efficient in that position.

The present study looked at a group of trained cyclists who never trained on aero bars, and a group of trained triathletes who train only on aero bars. It was hypothesized that there would be enough of a change in angle between the two positions, aero and upright, that there would be training adaptation to the position in which they train. That is, triathletes who train only with aerobars would be more efficient in that position and cyclists who train in a traditional position would be more efficient in that position.

METHODS

Subjects

Trained cyclists (n=10) and trained triathletes (n=10) were asked to participate in this study. The cyclists had been training and racing for at least one year and did not train with aero bars. Their experience ranged from category 4 to a cyclist who qualified for collegiate nationals. The triathletes had been training and racing for at least 1 year and trained only with aero bars. The triathletes' experience ranged from sprint to ironman distance races. All subjects were male in order to eliminate potential gender differences.

Prior to participation, all subjects filled out an informed consent form as well as a physical activity readiness questionnaire (PAR-Q) and health status questionnaire (HSQ) in accordance with the policies of the local Institutional Review Board for the Protection of Human Subjects. Subject age was limited to less than 45 years old and more than 18 years old. Participants were asked to come to all trials rested and well hydrated.

Procedures

Oxygen consumption was measured using automated indirect calorimetry (Vacumed VistaMini-CPX, Ventura CA), calibrated before each trial according to manufacturer's directions (Vacumed Instruction manual Y-17670, 2000) using gases of known concentration. Volume measurements were calibrated at the start of each test day with a 7 L calibration syringe. The laboratory accuracy measurement is approximately 3% based on reliability and comparison with other systems. A Monark 824 E cycle ergometer (Monark, Sweden) was used during this study. The ergometer was outfitted with a set of Syntace aerobars (Scott, US). Cyclists and triathletes were asked to bring in their own cycling shoes and pedals to be outfitted on the ergometer in order to customize the cycle as much as practical. A goniometer (LeMond Fitness Inc.) was used to set saddle height to a knee angle of 25-35° (12).

Subjects performed three separate trials with at least one day of rest in between. The first trial consisted of a graded protocol on a cycle ergometer to determine $\dot{V}O_2$ max. All subjects completed the protocol in the upright position. The protocol started with the subjects pedaling at greater than 85 rev/min and less than 110 rev/min depending on their personal pedaling cadence. The resistance was set at 1 kp for the first 2 min. Resistance increased by 0.5 kp/2 min until exhaustion. Every time the subjects dropped cadence below 85 rev/min they were encouraged to immediately increase their cadence until they could no longer keep their cadence at or above 85 rev/min. At this point the test was terminated.

$\dot{V}O_2$ was considered max when the subject's heart rate (HR) was equal to age-predicted maximum HR, their respiratory exchange ratio (RER) was greater than 1.15, and/or they reached a plateau, a leveling off or decline of $\dot{V}O_2$ with a continued increase in exercise intensity (13). Rating of perceived

exertion (RPE) was recorded every minute during the test using the Borg scale, which ranged from 6-20 (14).

On the second and third trial, subjects were asked to cycle for 30 min at the stage where they reached 70% of VO_2max . During one trial, the subjects were required to cycle in an aero position and in an upright position during the other. Pedaling cadence was kept as close as possible to 90 rev/min, depending on the normal training cadence used by each individual. Subjects were then required to keep the same cadence during both trials. VO_2 was measured, and RPE was taken every 2 min in order to compare the two trials. An industrial fan was directed on the subjects in order to help keep their body temperature down. The order of the trials was counterbalanced for both the cyclists and the triathletes. The two trials were compared for metabolic economy.

Statistical Analyses

Metabolic economy was determined by comparing means of the data recorded over the thirty minute trials between an upright and aero position for VO_2 , RPE, and HR. A dependant T-test was used to test the means and an apriori alpha of $P < 0.05$ was used to test significance.

RESULTS

Descriptive data of both cyclist and triathletes, who participated in this study, are listed in Table 1. The mean VO_2 in the aero position (43.3 ± 5.5 mL/kg/min) was significantly higher than the mean VO_2 in the upright position (41.2 ± 5.8 mL/kg/min). When comparing VO_2 in triathletes the means between aero and upright positions (38.5 ± 5.4 vs. 38.0 ± 5.3 mL/kg/min, respectively) were not significantly different.

Table 1. Descriptive Statistics.

Variable	CT		AT	
	Range	Mean \pm SD	Range	Mean \pm SD
Age (y)	20.0-41.0	27.4 \pm 7.0	20.0-44.0	33.2 \pm 7.0
Height (cm)	168.4-193.0	178.6 \pm 6.6	165.1-180.0	173.2 \pm 5.8
Weight (kg)	69.0-81.0	7.30 \pm 3.6	63.0-83.0	73.7 \pm 6.7
Body Fat (%)	5.1-19.9	8.9 \pm 4.3	5.1-12.4	10.6 \pm 2.4
VO_2max (mL/kg/min)	49.0-73.0	63.2 \pm 9.0	43.5-63.0	53.0 \pm 6.3

There was a significant difference ($p < 0.05$) in RPE between aero and upright positions in cyclists (12.2 ± 1.7 vs. 11.6 ± 1.5 , respectively) and triathletes (11.7 ± 1.9 vs. 12.4 ± 2.20 , respectively).

The mean HR in the upright position (beats/min) in cyclists was found to be significantly ($p < 0.05$) higher than that of the aero position (155.0 ± 10.3 vs. 153.3 ± 12.7 beats/min, respectively). There was no significant difference in the means of HR in the aero () and upright (144.4 ± 14.2 vs. 144.4 ± 14.1 beats/min, respectively) positions in triathletes. Individual mean heart rates between positions for both cyclists and triathletes are listed in Table 2.

DISCUSSION

The purpose of this study was to determine if the increased metabolic cost of riding in an aero position, typically used by cyclists, could be attenuated through training in an aero position. Previous research has been equivocal and, for the large part, only studied cyclists. This is the first time that a trained group of cyclists and a trained group of triathletes have been examined for this purpose.

Submaximal VO₂

Both groups rode at 70% of VO₂max in both the aero and the upright positions and the means were compared to determine in which position they were more efficient. It was found that cyclists, who only train in the upright position, were more economical in the upright position. This supports the findings of Gnehm et al. (6), who showed that there is an increased metabolic cost to riding in an aero position when examining trained cyclists. These findings also support Ashe et al. (7) who examined subjects who never ride in order to determine if there was a difference between the two positions with out any training affect that occurs due to cycling. They found that there is an increased metabolic cost to riding in an aero position in subjects who never cycle.

While there was an increased metabolic cost to riding in an aero position when examining cyclists, there was no significant difference in VO₂ when examining triathletes between aero and upright cycling. The means between the two positions were almost identical (upright 38.0 mL/kg/min and aero 38.5 mL/kg/min). This shows that there are benefits to training in the aero position by the attenuation of the increased metabolic cost normally found in cyclists when riding in an aero position. This builds on the observations of Berry et al. (8), where a small trend was reported for better economy in cyclists who occasionally trained in aero bars. Berry et al. looked at time to exhaustion in both positions and found that cyclist who never trained in aero bars had the largest difference between riding times in the upright and aero position. While not significant, time to exhaustion between the upright and aero positions was found to be less for those who did train occasionally with aero bars. This study would also support the findings of Heil et al. (11) that there is specificity to training position. Heil et al. found that cyclists preformed better at seat tube angles that were most similar to the bikes that they trained on. This study shows that aerobic power production was specific to the position in which these athletes trained when looking at metabolic cost and could explain the absence of increased metabolic cost to riding in the aero position for triathletes.

Heart Rate

Heart rate was also examined to verify economy between the aero and upright positions. In the triathletes there was no significant difference found in HR between the aero upright positions (both 144.4 beats/min). This would be expected due to the fact that the VO₂ between both positions were identical and HR and VO₂ share a linear relationship.

For cyclists, the mean HR in the upright position (155.0 beats/min) was higher than that of the aero position (153.3 beats/min). While this finding was statistically significant, 1.7 beats/min is not a large difference. However, given the linear relationship of HR and VO₂ this was not expected. When examining the individual data, 4 of the 10 cyclists showed a lower HR in the aero position compared to the upright position even though their VO₂ was higher in the aero position. When examining the individual data of the triathletes, 4 had higher heart rates in the upright position, with a mean difference of 7.9 beats/min. Six of the triathletes had a higher HR in the aero position, even though VO₂ was slightly higher in the upright position. Five of the 6 had a marginally higher mean HR, with a mean difference of 5.5 beats/min. One of the six had a significantly higher heart rate with a mean

Table 2. Heart rates for each subject between positions and groups (beats/min).

Subjec	CT	
	Upright	Aero
1	146.73	139.60
2	159.13	150.73
3	144.00	163.33
4	151.47	143.07
5	152.47	152.67
6	164.13	158.93
7	152.13	156.00
8	148.87	156.60
9	154.00	161.07
10	176.47	178.07
Subjec	AT	
	Upright	Aero
1	141.13	162.13
2	131.73	136.93
3	159.13	163.66
4	124.80	130.86
5	121.93	124.80
6	154.90	158.40
7	148.06	136.73
8	162.86	155.06
9	137.73	144.86
10	136.60	131.30

difference of 21 beats/min, even though VO_2 was basically the same between upright (mean of 36.7 mL/kg/min) and aero (mean of 36.1 mL/kg/min), with aero slightly lower. There does not seem to be a trend.

While VO_2 and HR share a linear relationship predicting VO_2 from HR can deviate up to 20% from actual recorded VO_2 (15). There may not be enough of a difference in VO_2 from trial 1 to trial 2 to show an effect through HR, even though there was a significant difference in VO_2 between trials. Heart rate can vary from day to day and hydration levels can greatly influence HR (15). This study was conducted in Tuscaloosa, Alabama over the summer and the average heat index was over 100° F. All participants were currently actively training and in their race season. Under these conditions it could be very hard to maintain adequate hydration levels, so this could have played a role in the variability of HR. Ambient temperature could not have played a role in HR variation, because testing was conducted indoors and at the same ambient temperature, with an industrial fan for cooling. A difference in stroke volume could have affected heart rate between the two positions. Exercising in a supine position produces a higher stroke volume compared to an upright position due to the reduced affect of gravity in that position (13). This increase in stroke volume would lower heart rate at any submaximal level due to an increased preloading. Franke et al. (16) found that stroke volume in an aero position was more similar to supine than upright at rest. However, they did find that there was no difference in stroke volume between aero and upright positions during exercise.

Rate of Perceived Exertion

RPE was used to help determine which position felt better to each individual. It was found that cyclists had a lower RPE in the upright position (11.6) when compared to the aero position (12.2) and the triathletes had a lower RPE in the aero position (11.7) compared to the upright position (12.4). This shows that each individual felt more comfortable in the position that they currently trained in.

CONCLUSIONS

When examining VO_2 and RPE it appears that aerobic power production is influenced by the position in which the subjects trained. Cyclists were found to be more metabolically efficient in the upright position than in the aero position. Triathletes were found to have the same VO_2 in both the aero position and the upright position. There did not seem to be the same increased metabolic cost in triathletes that there was in cyclists. Cyclists were found to be more comfortable in the upright and triathletes more comfortable in the aero position. It therefore would be recommended that triathletes do the majority of their training with aero bars due to the fact that is the position in which they race. Cyclists on the other hand should do the majority of their training upright and train occasionally in aero bars if they participate in time trials.

While cyclists race the majority of the time in the upright position they also race in the aero position during time trials. Increasing their metabolic efficiency in the aero position could greatly improve their time trial performance. Future research is needed to help determine how much time a cyclist should spend training in the aero position in order to help them with their time trials, while not negatively effecting their cycling. Also having an ergometer that can be adjusted to every rider would also be helpful in future research.

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