

## **Aerobic And Anaerobic Changes In Collegiate Male Runners Across A Cross-Country Season**

CORY W. BAUMANN †<sup>1,2</sup> and THOMAS J. WETTER ‡<sup>1</sup>

<sup>1</sup>Human Performance Laboratory, Department of Health Promotion and Human Development, University of Wisconsin-Stevens Point, Stevens Point, Wisconsin, USA

<sup>2</sup>Applied Physiology Laboratory, Department of Kinesiology, Georgia State University, Atlanta, Georgia, USA

<sup>1</sup>Human Performance Laboratory, Department of Health Promotion and Human Development, University of Wisconsin-Stevens Point, Stevens Point, Wisconsin, USA

†denotes graduate student author, ‡denotes professional author

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### ABSTRACT

*Int J Exerc Sci* 3(4) : 225-232, 2010. The purpose of this study was to assess the physiological characteristics of trained NCAA Division III male runners across a competitive season of cross-country. Eight male distance runners (age 20.6±1.4 y) were administered a battery of aerobic and anaerobic laboratory tests at the beginning and end of an 8-10 week racing season. Aerobic testing included maximal oxygen uptake ( $VO_{2max}$ ), running economy (RE), ventilatory threshold (VT) and the onset of blood lactate accumulation (OBLA). Anaerobic testing consisted of the vertical jump (VJ) and the Wingate test. Final testing revealed anaerobic Wingate peak power significantly declined (11.8±1.1 to 10.7±1.0 W·kg<sup>-1</sup>) ( $P = 0.006$ ), while no significant changes were seen in VJ or any aerobic parameters ( $P > 0.05$ ). These results indicate that a competitive cross-country season of training and racing diminished anaerobic peak power and failed to elicit quantifiable aerobic adaptations in previously trained collegiate distance runners.

KEY WORDS: Seasonal Changes, Endurance Training, Motivation, Psychological Factors

### INTRODUCTION

Success in distance running involves a combination of physiologic determinants including: maximal oxygen uptake ( $VO_{2max}$ ), running economy (RE), ventilatory threshold (VT) and the onset of blood lactate accumulation (OBLA). While improvements in these variables are usually seen when an untrained individual begins to train, less clear is the effect of training in individuals who have already

attained high levels of aerobic fitness. In studies evaluating the physiological changes across a single season in trained runners, findings have been mixed (10,20,28). The greatest aerobic adaptations, however, are generally seen in younger less experienced runners, with minimal changes in more experienced runners. Despite the lack of data regarding improvements in  $VO_{2max}$ , RE, VT and the OBLA among trained individuals; knowledgeable coaches presumably structure workouts to improve

one or more of the above and thus enhance race performance. Common training workouts include easy running for longer than race distance, tempo or “threshold” runs and above race pace interval training. The scientific research is ambiguous about the influence of these training methods on increasing  $VO_{2max}$ , RE, VT or the OBLA in highly trained athletes (17).

In addition to the factors traditionally associated with endurance performance, anaerobic power and/or capacity might play a crucial role especially in team racing events where a finishing kick may be used to pass a runner on an opposing team. Prior research has shown that the finishing order of a race could be determined by which athlete had the greatest anaerobic system to assist in a finishing sprint (4,12). Little research is available about changes in anaerobic power during a season of competitive training. One study using isolated single muscle fibers taken from male collegiate cross-country runners found that the peak power of myosin heavy chain type I fibers declined after a season of competitive training and tapering (10); however, it is not clear if such an effect would correspond to any changes in whole muscle power output.

Therefore, the purpose of this study was to assess the physiological characteristics of National Collegiate Athletic Association (NCAA) Division III male runners across a competitive cross-country season.

## METHODS

### *Subjects and Training Program*

Eight male NCAA Division III cross-country runners ( $20.6 \pm 1.4$  y), were recruited one week prior to the beginning of their

cross-country season. The subjects had  $8.5 \pm 1.4$  y (range 6-11 y) of competitive running experience and all had completed a preseason 5-km time trial within the range of 15:09 min:s to 15:39 min:s. Descriptive characteristics of the subjects are shown in Table 1. For the month prior to the start of the season, the runners had individually trained at high volume ( $112.6 \pm 18.3$  km week<sup>-1</sup>); a typical week consisted of one 15-25 minute tempo run at 80-85%  $VO_{2max}$  and 5-6 long runs at a moderate intensity. During the season, intensity increased and volume significantly decreased to  $84.3 \pm 16.6$  km week<sup>-1</sup> ( $P = 0.003$ ). The in-season regimen included 1-2 weekly training sessions at tempo or “threshold” pace and/or  $VO_{2max}$  pace. Prescribed velocities were based on the subjects' 5-km time trial; all training sessions were planned and adjusted by the team's head coach. Competitive 8-km races were generally run every other weekend. Training sessions varied from week to week and were altered to taper for qualifying races. All subjects completed a medical history questionnaire, an informed consent and were free of any medical limitations. Approval was granted by the University of Wisconsin-Stevens Point Institutional Review Board for the Protection of Human Subjects.

### *Procedure*

Tests were conducted twice (8-10 weeks apart); at the start and end of the season. Before each testing period the subjects completed a questionnaire regarding training distance, a rating of difficulty during their last race and rating of perceived fitness (0-10 scale, with 10 being the most difficult and the highest fitness level). Tests were completed within a 3-day period, with the 2<sup>nd</sup> day used as a rest period. Height, weight, RE, and  $VO_{2max}$

were measured on Day 1; body composition and anaerobic characteristics on Day 3. Running tests were conducted on a motor-driven treadmill (TMX425C Full Vision Inc., Newton KS). Subjects wore a Hans Rudolph Vmask and expired and inspired concentrations of oxygen and carbon dioxide were continuously collected using a calibrated SensorMedics Vmax 29 analyzer. Subjects wore Polar monitors to measure heart rate (HR) and rated their perceived exertion (RPE) using the Borg 6-20 scale (3). Body composition was measured using a 3-site (chest, abdomen, thigh) skinfold technique and done in accordance with ACSM guidelines (1).

Table 1. Descriptive characteristics at the start and end of the cross-country season (n = 8).

Variable	Start of Season	End of Season
Height (cm)	181.0±5.9	
Mass (kg)	69.9±6.0	70.2±6.4
Body Fat (%)	6.4±2.3	6.4±2.3
Distance Ran/Week (km)	112.6±18.3	84.3±16.6*

Values are mean±SD

\*Significant difference ( $P < 0.05$ )

### Aerobic Measures

Running economy (RE) was conducted at two standardized running velocities on a level grade (0%). After a warm up, subjects ran for 5 minutes each at 16.1 km·h<sup>-1</sup> and 19.3 km·h<sup>-1</sup>. Oxygen uptake (VO<sub>2</sub>) and HR during the final 3 minutes of each trial were recorded and averaged. Subjects reported RPE at the end of the 3<sup>rd</sup> and 5<sup>th</sup> minutes. After recovery from the RE test (> 60min), VO<sub>2max</sub>, VT, and OBLA were determined using an incremental protocol with stages of 2 min. Speed gradually increased to 19.3

Table 2. Aerobic values at the start and end of the cross-country season (n = 8).

Variable	Start of Season	End of Season
<b>Maximal Test</b>		
VO <sub>2max</sub> (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	71.9±4.6	71.9±3.2
HR (beats·min <sup>-1</sup> )	194±4	196±4
Blood Lactate (mmol·L <sup>-1</sup> )	10.0±2.9	9.4±1.8
Duration (min: s)	12:20±0:41	12:26±0:46
VT (%VO <sub>2max</sub> )	76.7±6.5	78.0±5.6
OBLA (%VO <sub>2max</sub> )	94.3±3.3	93.9±2.6
<b>Running Economy at 16.1 km·h<sup>-1</sup></b>		
VO <sub>2</sub> (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	52.5±2.4	54.2±3.0
VO <sub>2</sub> (%VO <sub>2max</sub> )	73.3±6.0	75.4±3.9
HR (beats·min <sup>-1</sup> )	159±6	161±7
RPE (Borg scale)	10±1	10±1
<b>Running Economy at 19.3 km·h<sup>-1</sup></b>		
VO <sub>2</sub> (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	64.5±3.4	65.0±2.8
VO <sub>2</sub> (%VO <sub>2max</sub> )	90.2±8.2	90.6±3.4
HR (beats·min <sup>-1</sup> )	179±5	182±5
RPE (Borg scale)	14±1	14±1

Values are mean±SD.

km·h<sup>-1</sup> followed by increases in grade (up to 7%). At the end of each stage HR, RPE and blood lactate levels were recorded. VO<sub>2max</sub> was recorded as the highest 30-s value. Ventilatory threshold (VT) was determined using the following criteria: 1) an increase in V<sub>E</sub>/VO<sub>2</sub> without an increase in V<sub>E</sub>/VCO<sub>2</sub> and 2) an increase in F<sub>EO2</sub> without a decrease in F<sub>E</sub>CO<sub>2</sub> (26). Blood lactate levels were obtained using a Lactate Plus Analyzer (NOVA Biomedical, Waltham MA), via finger prick during the test with subjects continuing to run. The OBLA was defined as a blood lactate level of 4 mmol·L<sup>-1</sup> (23).

### Anaerobic Measures

Vertical jump was measured using a Vertec Tester (Power Systems 22550, Knoxville TN). Subjects first recorded a maximal reach score with their dominate arm, then standing in a flat footed position with feet shoulder width apart, subjects jumped at a maximal intensity using their dominate arm. Vertical jump (VJ) scores were calculated by subtracting the jump from the reach and the best of two jump trials was used. A 30-s Wingate protocol was used to assess peak power (PP), average power (AP), minimum power (MP) and power drop (PD) outputs using a Monark cycle ergometer (Ergonomic 894 E Peak Bike). Subjects warmed up for 2 minutes at a low intensity effort and performed one short sprint before the start of the test. The brake weight corresponded to 0.09 kg per kg of body mass and remained constant for both testing periods regardless of any weight changes within the subjects.

### Data Analysis

Data were analyzed using a paired *t* test to compare the pre vs. post-season measurements. Data are reported as a mean

and standard deviation (SD) unless stated otherwise. A  $P$  value of  $< 0.05$  was used to establish significance.

## RESULTS

Over the course of the 8-10 week competitive season, there were no significant changes in body mass or percent body fat. Subjects rated the last race as significantly more difficult than the first race of the season ( $8.3 \pm 0.7$  to  $9.4 \pm 1.2$  rating of perceived difficulty) ( $P = 0.04$ ). There were no significant changes in  $VO_{2max}$ , RE, VT or the OBLA. Values are reported in Table 2.

Table 3. Anaerobic values at the start and end of the cross-country season ( $n = 8$ ).

Variable	Start of Season	End of Season
Vertical Jump (cm)	$50.1 \pm 7.0$	$49.2 \pm 7.8$
Wingate Bike Test ( $W \cdot kg^{-1}$ )		
Peak Power	$11.8 \pm 1.1$	$10.7 \pm 1.0^*$
Average Power	$8.6 \pm 0.9$	$8.4 \pm 0.6$
Minimum Power	$5.3 \pm 1.1$	$5.7 \pm 0.8$
Power Drop	$6.5 \pm 1.2$	$5.0 \pm 1.2^*$

Values are mean  $\pm$  SD.

\*Significant difference ( $P < 0.05$ )

Anaerobic values are reported in Table 3. At the end of the season PP was significantly lower ( $P = 0.006$ ) and was apparent in all subjects (Figure 1). The decrease in PP averaged  $8.9 \pm 5.9\%$ . Because MP did not change, the PD was significantly less ( $P = 0.02$ ) at the end of the season. No significant changes were seen in AP or VJ.

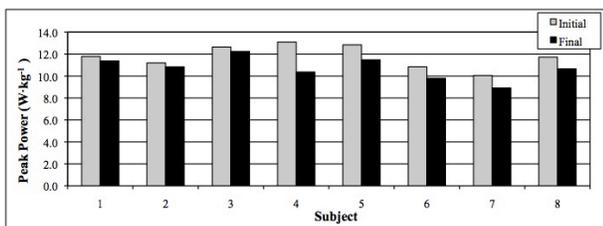


Figure 1. Individual Wingate peak power at initial and final testing periods ( $P = 0.006$ ).

## DISCUSSION

The purpose of this study was to determine the changes occurring after a season of cross-country racing among trained runners previously engaged in high mileage training. Peak anaerobic power dropped 9% from the initial testing period, while no significant changes occurred in  $VO_{2max}$ , RE, VT, OBLA, body fat percentage or the VJ.

A primary goal of our research was to investigate changes that occur in high level athletes undergoing their typical training program. The subjects in the study were the 8 fastest finishers in a preseason 5-km time trial and all had competed the previous season (spring) in track with half achieving national provisional qualifying standards in distance events. Following the track season the subjects trained 3 months at high volume before the initial testing period. During the cross-country season, training shifted to lower volume, but higher intensity. At the end of the season the team achieved a 4<sup>th</sup> place finish at cross-country national Division III championships. Studies of a similar design have been conducted on female collegiate runners (28) and male adolescent runners (20). However, to our knowledge no studies have examined both aerobic and anaerobic changes in a group of highly competitive runners during a competitive season of training and racing.

The mean  $VO_{2max}$  of our subjects was  $71.9 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  (range of  $67\text{-}80 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ); these values are common among highly trained endurance runners. Bulbulian, Wilcox and Darabos (4) reported that 12 NCAA Division I cross-country runners had a mean  $VO_{2max}$  of  $72.1 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  (range of  $66\text{-}76 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ), likewise Scott et al. (22) recorded a mean  $VO_{2max}$  of

70.9 ml · kg<sup>-1</sup>·min<sup>-1</sup> in NCAA Division I track distance runners. No improvement in VO<sub>2max</sub> was seen at the end of the season. This absence of improvement in highly trained individuals has been previously documented (2,24). In a similar study design, Harber and colleagues (10) reported no significant change in VO<sub>2max</sub> (70.5±0.7 to 71.7±1.2 ml · kg<sup>-1</sup>·min<sup>-1</sup>) of 5 NCAA Division I runners after a competitive season of cross-country. Conversely, Plank, Hipp and Mahon (20) reported that VO<sub>2max</sub> increased significantly in adolescent runners after a season of cross-country. Some authors suggest that runners approaching their trainable limits need to train at high percentages of VO<sub>2max</sub> to enhance VO<sub>2max</sub> (16). The training intensity of the current subjects did increase over the course of the season and did include sessions at VO<sub>2max</sub>. In highly trained individuals, Ekblom (8) suggests that a plateau in VO<sub>2max</sub> can occur after several years of training. Whether the current subjects reached their trainable limit for VO<sub>2max</sub> enhancement cannot be determined from our study.

Running economy (RE) is a well established component of successful distance running (21). At 16.1 km · h<sup>-1</sup>, our runners were slightly less economical (3-6%) compared to previous research of sub-elite to elite endurance runners (5,6). Few studies have tested RE at 19.3 km · h<sup>-1</sup> as this is above the steady state level of most runners. We chose this speed to mimic the average velocity of our subjects in their 8-km race. Using the prediction equations of Daniels's and Daniels's (7) our runners consumed ~6% more oxygen at this speed when compared with elite runners, yet were more economical when compared with equations developed for the general public (1). No change was seen in RE at the end of the

season. While some have reported changes in RE in moderately trained recreational runners (9) and highly trained endurance runners (2) after the addition of supplementary training, Wilcox and Bulbulian (28) found that RE did not change in 7 collegiate females over the course of their cross-country season. Jones and Carter (14) suggest that 8-10 weeks of training may be too short for measurable improvements in RE, especially in already trained individuals.

Successful training programs cause a rightward shift of VT and the OBLA to higher power outputs or running speeds, this adaptation allows for a higher sustained absolute and relative exercise intensity (14). Previous research in distance runners has found values for VT or OBLA that were similar (27), higher (4), or lower (24) when compared with our subjects. Reported values may differ as a result of the treadmill testing protocols used (25). No significant changes to VT and the OBLA occurred from the beginning to the end of the season in our runners. This contrasts with a trend ( $P = 0.057$ ) for lower submaximal blood lactate levels following a cross-country season that was seen in trained male adolescent runners (20), but is consistent with other findings of no changes despite the incorporation of training at the velocity associated with OBLA (2,24). Research into the most effective intensity that causes enhanced VT and the OBLA is unknown (17). Because the subjects added weekly workouts at high intensities during the course of the season the lack of improvement could be attributed to an insufficient time between the testing periods or the attainment of an improvement plateau; both reasons were

previously stated for the absence of change in  $VO_{2max}$  and RE.

Although the aerobic parameters discussed previously are important determinants of endurance performance; one's ability to produce ATP anaerobically may also be vital, as during a pass or final sprint of a race and may be an effective discriminator of performance when comparing an aerobically homogeneous group of endurance runners (4,12). We assessed anaerobic power using a VJ and Wingate test. Vertical jump values of the subjects were nearly 20% higher than what Houmard and colleagues (12) reported in 10 well-trained, but older (mean age 32) distance runners ( $VO_{2max} = 62 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ),  $\sim 50 \text{ cm}$  compared to  $\sim 40 \text{ cm}$ . Wingate PP averaged  $11.2 \pm 1.2 \text{ W} \cdot \text{kg}^{-1}$ , a value comparable to the  $11.7 \pm 2.3 \text{ W} \cdot \text{kg}^{-1}$  recorded by 6 national level 5-km and 10-km track specialists (13), where as Scott et al. (22) reported higher values in 4 NCAA Division I track distance runners ( $13.2 \pm 0.66 \text{ W} \cdot \text{kg}^{-1}$ ). After the cross-country season PP dropped significantly and VJ appeared to decline by 1.8%, but was not significant. Kraemer and colleagues (15) reported a non-significant decrease in PP after 8 fit individuals performed 12 weeks of high intensity endurance training. We did not assess the mechanism(s) responsible for the decline in anaerobic power. Others however (10), using an isolated muscle fiber technique reported that peak power of slow-twitch myofibers were 39% lower after a competitive cross-country season in collegiate runners. It was concluded that the added interval training and racing of the competitive season diminished absolute and normalized power particularly in slow-twitch myofibers and had no effect on fast-twitch myofibers. The extent to which the

decreased power in isolated fibers influenced the whole muscle power output was not determined (10). The current study's findings would be in line with a decline in the whole muscle power output. Harber et al. (10) speculated that a drop in power would not be a limiting factor in performance and that sustained submaximal power outputs are essential in distance running. For the runners in the current study, average power (AP) did not change across the season despite the decrease in PP. Clearly; more research is needed to examine changes in anaerobic parameters and those effects on the performance of endurance athletes.

In addition to the physiological variables measured; psychological or motivational factors may also influence performance (19). Tolerating fatigue at the end of a race often requires great mental concentration; this effort may be used to activate muscle fibers that are not easily recruited to compensate for fatigued muscle fibers. Hopkins and Hewson (11) suggest that most of the differences in performance variability probably arise from differences in competitive experience and attitude toward competing. In the current study 2 subjects reported a feeling of lower fitness after the competitive season, while the remaining 6 felt they maintained their initial fitness or obtained a higher fitness ( $7.8 \pm 0.9$  to  $8.5 \pm 1.1$  rating of perceived fitness) ( $P = 0.14$ ). Furthermore, the subjects' perceived the last race of the season to be more difficult than the first; this finding could be interpreted to mean the subjects ran harder during the end of the season. Therefore, increasing runners' motivation or psychological attitudes towards training and racing may be vital to

success when physiological characteristics have reached obtainable limits.

The “real-life” design of our research study has some important limitations. The sample size is relatively small, thereby reducing statistical power. The team coach issued workouts and therefore the “training stress” likely differed between the subjects since training volume, intensity, and competition in races was individualized. Some subjects also added strength training during the season. There is research to show that strength training could improve RE by allowing the muscles to utilize more elastic energy and reduce the amount of energy wasted in braking force (18,21). Not all subjects did the final testing period during the same week due to the fact that only 6 of the subjects were allowed to compete in the final race of the season. The final testing for the 6 individuals was done 2 to 4 days following the national cross-country race and it is possible that some subjects may have been fatigued or not fully recovered.

In summary, following a competitive cross-country season, Wingate PP was reduced, and  $VO_{2max}$ , RE, VT and the OBLA were unchanged. It is possible the test measurements were not sensitive enough to detect small changes or that 8-10 weeks was an insufficient amount of time to elicit quantifiable results. It could be speculated that though aerobic measures were unchanged, the competitive season resulted in changes to the runners’ attitudes towards racing, motivation and/or other physiological factors that may be vital to distance running success.

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Corresponding Author: Cory W. Baumann, Department of Kinesiology, Georgia State University, Atlanta, GA 30302, Cell: (608) 780-1154, Fax: (404) 413-8053, cbaumann1@student.gsu.edu.

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