

Journal of Undergraduate Kinesiology Research

Official Research Journal of the Department of Kinesiology
University of Wisconsin – Eau Claire

Volume 3, Number 2 May 2007

Editor-in-Chief, Lance C. Dalleck, Ph.D.

Review Board: Jeffery J. Janot Ph.D. and Don Bredle, Ph.D.



PHYSIOLOGICAL PROFILES OF DIVISION III FEMALE DISTANCE RUNNERS AND PREDICTING FUTURE PERFORMANCE

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ABSTRACT

Barnes, SN, Borlee, CS, Hornbeck, KJ, Kaminske, BL, Klein, JJ. Physiological Profiles of Division III Female Distance Runners and Predicting Future Performance. *Journal of Undergraduate Kinesiology Research* 2007; 2 (2):40-47. **Purpose:** This study will aim to explain VO_2 max, ventilatory threshold, and running economy and their relationship to 3000 meter race performance. **Methods:** Eight collegiate Division III female distance runners ($n=8$) that had a recorded 3000 meter race within the previous four months were recruited via word of mouth and email. Age (19.4 ± 1.5 yrs), height (168.9 ± 6.1 cm), weight (60.2 ± 5.3 kg), and percent body fat ($21.83\pm 3.26\%$) were also documented. A single treadmill test was conducted to record the needed data such as VO_2 max (53.1 ± 2.6 ml/kg/min) and ventilatory threshold ($.7\pm 0.1$). Three 4-minute stages were conducted to test for running economy. **Results:** A multiple regression revealed there was a significant linear relationship between ventilatory threshold and 3000 meter performance, $F_{(1,6)} = 6.4$, $R^2 = .5$, $\sigma = 26.8$, $p < .05$, $3k = VT(319.4) + 445.1$ (where $3k =$ 3000 meter performance; $VT =$ subject's ventilatory threshold). There was another significant relationship between the speed at which VO_2 max was reached and 3000 meter performance, $F_{(1,6)} = 14.5$, $R^2 = .7$, $\sigma = 20.9$, $p < .05$, $3k = \text{Speed}(-57.7) + 1302.3$, (where $3k =$ 3000 meter performance; $\text{Speed} =$ subject's speed at which she reached VO_2 max). **Conclusion:** Our findings can be applied specifically to coaches and athletes looking to improve 3000 meter performance. By interpreting the athletes' results, coaches will be more informed on the athletes' strengths and weaknesses. Training can then be adjusted to meet the athletes' needs to improve performance.

Key Words: track, cross country, training, aerobic, VO_2 max, running economy, ventilatory threshold, speed at VO_2 max

INTRODUCTION

Running performance is multi-faceted and includes VO_2 max, running economy and ventilatory threshold. VO_2 max is the maximum amount of oxygen the body can utilize during a specified period of usually intense exercise. The purpose of conducting a maximal oxygen consumption test is to measure aerobic fitness (2). From a general approach, oxygen uptake (VO_2 max) appears to be a vital indicator of the athlete's ability to generate locomotive efforts of middle to long duration (8).

Running economy is proportional to the oxygen cost for a given velocity and estimated from measuring steady state oxygen consumption during sub-maximal running. In metabolic terms, runners with good running economy use less oxygen at the same velocity than runners with poor running economy (13).

Lactate threshold, which is reported as a percent of VO_{2max} , is the point during increasingly intense exercise at which blood lactate begins to accumulate above resting levels and is thought to represent the start of anaerobic metabolism (1). Many sport scientists use lactate threshold to assess the physiological capacity of athletes and to establish training intensity (11). In this study, ventilatory threshold was used as a substitute for lactate threshold. The ventilatory threshold is an important index of the capacity for prolonged exercise. Originally, the ventilatory threshold was termed anaerobic threshold which was used as an indirect or noninvasive estimate of the lactate threshold (1).

Physiological profiles of runners include VO_{2max} , running economy, and ventilatory threshold. Elite female runners have been measured to reach a peak VO_2 of 51.96 ml/kg/min \pm 6.51 during a 3000 meter race (5). Certain types of training programs have been shown to improve the VO_{2max} and lactate threshold measurements of athletes, thus improving their 3000 meter race performance times (6). Similarly, a linear increase in VO_{2max} has shown to be one of the best predictors of progressive distance running improvements in both men and women (4). However, improvements of VO_{2max} and blood lactate profiles require training specific to the desired running velocity at competition, thus ensuring that the correct metabolic energy system is being utilized (3). A study done by Hausswirth showed that VO_{2max} alone cannot be a determinant of performance. For example, it has been observed that individuals with similar VO_{2max} measurements demonstrated a wide range of performances. Likewise, those with dissimilar VO_{2max} measurements demonstrated similar performance abilities (8). This has drawn our attention to other possible determinants of performance. Runners with good running economy use less energy and therefore use less oxygen than runners with poor running economy at the same velocity. Running economy tests done on treadmills can give a good indication of how economical a runner is and how running economy changes over time (12). According to Saunders, the importance of running economy to successful distance running is well established (12). It has also been found that body type variations may also lead to a change in running economy. Lucia et al reported that lower leg girth and length impacted running economy of Eritrean distance runners. Individuals with smaller lower leg girths and longer lengths of the lower leg yielded better running economy (10).

The purpose of this study was to measure the physiological profiles, including VO_{2max} , ventilatory threshold, and running economy of female Division III track athletes and compare their profiles to their 3000 meter race times.

METHODS

Subjects

The subjects who participated in this study were eight trained female collegiate Division III distance runners. The recruiting process for subjects was done via email and direct request through fellow teammates and coaches. Female runners who were currently trained and who had raced a 3000 meter run within the last four months were selected. Each individual was given and asked to complete an informed consent form before participation began. Descriptive characteristics of all participants are displayed in *Table 2*. This study was approved by the University Institutional Review Board for Human Subjects Research.

Instrumentation

A Detecto Weighing Scale (Model No. 3PY2003A) and a Seca Stadiometer (Pat. No. 4694581) were used to measure each subject's weight and height. A Lange Skinfold Caliper from Beta Technology Incorporated in Cambridge, MD (Pat. No. 3,008,239) was used to measure percent body fat. The temperature and humidity were determined using a thermometer from Control Co. in Friendswood,

TX and a Swift Scientist Barometer from Swift Instruments Incorporated in France was used to determine barometric pressure. The Med Graphics Cardiopulmonary Diagnostic Systems Cart Cardio 2 (Model No. 790602-001R) and Gas Module (Model No. 762014-202R) from Medical Graphics Corporation in St. Paul, MN was used along with a Woodway USA Treadmill (Model No.: DESMO-S) from Waukesha, WI to measure each runners VO_2 max and ventilatory threshold measurements. Also, the Med Graphics Cardio respiratory Diagnostic Systems 3-liter Calibration Syringe (P/N 704001-003) from St. Paul, MN was used to calibrate the cart. A Polar Heart Rate Monitor a1 from Polar Electro Incorporated in Woodbury, NY was used for accurately measuring heart rate.

Procedures

All subjects were asked to follow pre-test guidelines prior to being tested. The following instructions were given to all participants in regards to pre-test guidelines: normal hydration, no vigorous physical activity during the prior 24 hour period, no consumption of alcohol for the prior 24 hours, adequate rest, no recent use of stimulants (i.e. caffeine), and wear proper exercise clothing (running shoes, exercise clothing, no under wire bras, etcetera).

All instruments for the following procedures are described in full in the *Instrumentation* section. Each subject's height and weight were measured. Skinfold measurements were then taken at the following sites: triceps, suprailium, and thigh. Each site was measured three times to ensure accuracy and consistency. The values were then used in a formula to predict body fat percentages. The formula was derived from research done by Jackson and Pollock (7).

The subjects put a heart rate monitor on prior to starting the exercise test. Before beginning the test, valves on both gas tanks were opened to begin calibration. Calibration included entering correct barometric pressure, room temperature, and room humidity. We turned on the vacuum pump, purged with the pneumotach (3-liter syringe), and then started the gas analyzers using known and consistent gas concentrations. For this study, we used manual control on a treadmill so that the researchers would have complete control over the speed of the treadmill and follow a predetermined protocol. The first two minutes of the protocol were used as a warm-up for each client. The minutes 0-2 were done at a brisk walking pace of 3.5 miles per hour. The next three stages of the protocol were used to test running economy and were four minutes in length (minutes 2-6, 6-10, and 10-14). Minutes 2-6 were at 6.0 mph with 0% grade. Minutes 6-10 were at 7.0 mph with 0% grade and minutes 10-14 were at 8.0 mph with 0% grade. The protocol continued past these stages and moved in to the VO_2 max section of the test. Starting at minute 14:30 the speed was increased by 0.2 mph every 30 seconds while maintaining a 0% grade throughout the test (i.e. minute 14:30 @ 8.2 mph, minute 15:00 @ 8.4 mph, etc, see *Table 1*). At the end of each stage (four minute stages for running economy, one minute stages for VO_2 max), we recorded heart rate and rating of perceived exhaustion (RPE) on a 1-10 scale. The subjects ran to volitional fatigue. In reviewing the data, we gave specific attention to finding the speeds at which each athlete reached ventilatory threshold and VO_2 max.

The validity of this was determined by certain data including a respiratory exchange ratio (RER) of at least 1.1, a heart rate max within 11 bpm of the subject's age-predicted max heart rate, and a VO_2 plateau. We also recorded the speed at the point of ventilatory threshold and VO_2 max. Following the test, we reviewed the given data for the test which included treadmill data collection, anaerobic threshold, time down, and summary. Within the results of running economy, we were looking for the steady state VO_2 at the end of the first three stages. The VO_2 max test yielded data involving lactate threshold and maximal oxygen consumption. The ventilatory threshold was determined automatically by the Med Graphics cart and was calculated to be at the point at which expiratory CO_2 increased at a faster, steadier rate.

Table 1 – Treadmill protocol used to assess running economy, VT, and VO₂max

Stage	Time (min)	Speed (mph)	Grade (%)
Warm-up	0-2	3.5	0
	2-6	6	0
	6-10	7	0
	10-14	8	0
Running Economy	14:30-15	8.2	0
	15-15:30	8.4	0
	15:30-16	8.6	0
VO ₂ max			
<i>Speed increased until volitional fatigue</i>			

Statistical Analysis

Reported data on descriptive characteristics for all subjects was calculated and based on mean and standard deviation. A multiple regression was done to merge all variables that were predictive of 3000 meter race times. Each individual athlete's personal best in a 3000 meter run from the previous four months was used as the dependant variable in the regression model. Statistical Analyses were performed using Statistical Package for the Social Sciences (SPSS; Chicago, IL) 14.0. Data was checked for assumptions and normal distribution. Level of significance was set at $p < 0.05$.

RESULTS

Multiple linear regression analysis was used to formulate a model for predicting Division III female distance runner's best 3000 meter performances from each individual's VO₂max, ventilatory threshold, and running economy. Basic descriptive statistics are shown in *Table 2*, and for performance variables shown in *Table 3*. There was a significant linear relationship between ventilatory threshold and 3000 meter performance, $F_{(1,6)} = 6.4$, $R^2 = .5$, $p < .05$. About 52% of the variability in 3000 meter performances can be accounted for by ventilatory threshold. The standard error of the estimate for predicting 3000 meter performance from ventilatory threshold is about 27 seconds. The following equation can be used to predict 3000 meter performance from ventilatory threshold: $3k = VT(319.4) + 445.1$ (where $3k =$ 3000 meter performance; $VT =$ subject's ventilatory threshold). There was also a significant linear relationship between the speed at which VO₂max was recorded and 3000 meter performance, $F_{(1,6)} = 14.5$, $R^2 = 0.7$, $p < .05$. About 71% of the variability in 3000 meter performances can be accounted for by the speed at VO₂max. The standard error of the estimate for predicting 3000 meter performances from speed at VO₂max is about 21 seconds. The following equation can be used to predict 3000 meter performance from the speed at VO₂max: $3k = \text{Speed}(-57.7) + 1302.3$, (where $3k =$ 3000 meter performance; $\text{Speed} =$ subject's speed at which she reached VO₂max). All other relationships between each predictor variable and the criterion variable were not significant. When all three predictor variables (VO₂max, ventilatory threshold, running economy) combined there was about 64% of the variability in 3000 meter performances accounted for.

Table 2 – Subject characteristics (mean ± standard deviation)



Age (years)	19.4 ±1.5
Height (cm)	168.9 ±6.1
Weight (kg)	60.2 ±5.3
Percent Body Fat (%)	21.8 ±3.3

Table 3 – Descriptives of physiological and performance attributes of subjects (mean ± standard deviation)



VO ₂ max (ml/kg/min)	53.1 ±2.6
Speed @ VO ₂ max (mph)	11.0 ±0.5
Ventilatory Threshold (%)	0.7 ±0.1
Speed @ Ventilatory Threshold (mph)	7.3 ±0.7
Running Economy (ml/kg/min · mph ⁻¹)	4.9 ±1.2
3000 meter race time (sec)	670.4 ±35.7

DISCUSSION

The aim of this study was to explore the physiological profiles of collegiate Division III female distance runners. We analyzed their profiles in order to find which variables were the strongest predictors of performance. From the results of our research, data collection, and careful analysis, certain assumptions can be made in regards to the relationship of these variables.

Previous research has found that maximum oxygen uptake (VO_{2max}) is the greatest predictor of race time (8). Our study slightly contradicted these findings as we found the speed at VO_{2max} to be the best indicator of race performance, as it was accountable for 70.8% of variability in performance times. This variable is actually a combination of VO_{2max} and running economy. Runners that can reach their VO_{2max} at higher speeds are able to run using sub-maximal efforts at speeds at which other runners are using their maximal oxygen consumption. Thus, this usually indicates economically efficient runners will reach their VO_{2max} at a higher speed. This can be a huge asset as the speed of the race increases. Our subjects mean speed at VO_{2max} was 11.0 ± 0.5 mph. This doesn't seem like a lot but when the range of 10.5 mph versus 11.5 mph is compared there is a significant difference in race pace. The individuals who reached their VO_{2max} at 11.5 mph can be physiologically able to run at a 1-mile pace of 5-minutes and 12-seconds versus the individuals who maxed out at 10.5 mph and are able to run a pace of roughly 5-minutes and 42-seconds. Based on the speed at which they reached their VO_{2max} , the runners have very different ability levels.

This study used ventilatory threshold as a substitute for lactate threshold. Lactate threshold is often used to assess the physiological capacity and to establish training intensity of athletes as it is the point at which blood lactate begins to accumulate above resting levels (12). As stated before, this increase in blood lactate marks the start of anaerobic metabolism (1). Ventilatory threshold proved to be the next best predictor of race performance. A previous study completed by Nicholson and Sleivert also found lactate threshold to be a useful tool to monitor aerobic or training status (11). In our study, statistical analysis showed that ventilatory threshold was accountable for 51.7% of race time variability. These values show that when VO_{2max} values between individuals are similar, ventilatory threshold can be an excellent predictor of running performance. As athletes reach their ventilatory threshold, the onset of fatigue occurs with more severity. Thus, runners who have a higher ventilatory threshold will fatigue later versus other runners that have lower ventilatory thresholds. This can yield more intense and longer duration bouts. The mean speed at which the subjects reached their ventilatory threshold was 7.3 ± 0.7 . Again, this doesn't seem significant, but there is a significant change in race pace. The runners who reached their ventilatory threshold later were running at a 1-mile pace of 7-minutes and 30-seconds. The subjects that reached their ventilatory threshold earlier were only running at a 1-mile pace of roughly 9-minutes. This demonstrates how having a ventilatory threshold at a higher speed can allow a runner to run at a higher intensity without crossing the threshold.

VO_{2max} , or the maximum amount of oxygen the body can utilize during a specific period of usually intense exercise, alone only accounted for 11.6% variability in our study. In elite runners, VO_{2max} values have been measured to be around 65 ± 6 ml/kg/min in comparison to our subjects mean value of 53.1 ± 2.6 ml/kg/min (9). This indicates that VO_{2max} is a good predictor of performance when the values are different among subjects. Because our subjects had VO_{2max} values that were very similar, VO_{2max} was not a great variable to predict the relationship between it and performance. Running efficiency, or running economy, was only responsible for 15.2% of the variability of race performance. Together, as speed at VO_{2max} , the two variables of VO_{2max} and running economy were a great indicator of performance (as stated earlier).

VO_{2max} has commonly been thought to be the most important variable to predict race performance and on which to base training programs. Our research indicates that other variables, such as the speed at VO_{2max} and ventilatory threshold, play a more important role in performance ability. According to our study, training programs and goals should be more focused on these two variables.

CONCLUSION

Our research shows a high relationship between speed at VO_2max and running performance of collegiate Division III female 3000 meter runners. It accounted for 70.8% of race time variability in our subjects. This shows the importance of VO_2max and running economy, as the speed at VO_2max encompasses both. The VO_2max values of our subjects were very similar ($\text{SD} \pm 2.6 \text{ ml/kg/min}$), therefore leading to a low indication of performance. VO_2max is still an important variable in regards to race performance as demonstrated by the higher VO_2max values of elite runners. Theoretically, a study that compared the physiological profiles of elite runners versus less competitive runners would probably indicate VO_2max as a strong predictor of performance because of the large difference between the two groups.

Ventilatory threshold was also found to be a strong predictor of race performance among our subjects as it was responsible for 51.7% of variability in race time. This indicates that ventilatory threshold can be a strong predictor of success, especially when VO_2max values are similar among subjects.

This information can be valuable to athletes and professionals in the field of distance running. This can be especially useful for coaches with athletes with similar aerobic capacities. Training speeds can be increased to help athletes adapt to higher intensities, therefore, allowing them to reach their VO_2max at higher speeds. Race performances could be improved significantly because they will be able to sustain a higher pace or intensity for a longer duration.

Training should also be focused on ventilatory threshold improvement. As stated earlier, once an athlete reaches the ventilatory threshold, fatigue increases at a faster rate. Similar to the speed at which VO_2max is reached, a later ventilatory threshold will yield the ability to sustain a higher pace or intensity for a longer duration.

The generalizability of our study is gender (f), age (19.4 ± 1.5 yrs), level of training (3000 meter), and level of competitiveness (collegiate Division III). Limitations include sample size ($n=8$), time constraints, and the impossible guarantee that the subjects followed all pretest guidelines.

Future research should concentrate on training programs and the effects they have on physiological profiles of athletes. A longer duration study could yield greater improvements in performance due to the change in one variable more than another, among many other theoretical findings. This information would be very useful to coaches as an aid in creating programs to increase their athletes' abilities.

ACKNOWLEDGEMENTS

We would like to thank all those who made this study possible, especially Dr. Lance Dalleck for his guidance throughout the study and Dr. Donald Bredle for his help in the UW – Eau Claire Exercise Physiology Laboratory. Thank you also to our subjects for their time, efforts, and willingness to participate.

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