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Analysis of physiological fitness among Vietnamese elite female road cyclists

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Abstract
The present study aimed to evaluate the endurance physiological characteristics of four national-level female road cyclists. The assessment was conducted at the end of the preparation phase, during the second phase of the 2021 annual training plan. Various aerobic and anaerobic physiological indicators were measured to provide insights into their performance capabilities. Aerobic physiological indicators were examined, including LT1 (lactate threshold 1) at 2.88±0.4 mmol, Power at LT1 at 2.83±0.21 W/kg, and HR at LT1 at 146.25±10.36 bpm. Additionally, LT2 (lactate threshold 2) was determined at 4.70±0.51 mmol, Power at LT2 at 4.29±0.14 W/kg, and HR at LT2 at 164±3.37 bpm. The maximal oxygen consumption (VO_2 max) was found to be 67.41±2.31 ml/kg/ph. Resting heart rate (RHR) and maximum heart rate (Max HR) were 49.25±0.96 bpm and 182.5±6.86 bpm, respectively. Furthermore, the study explored anaerobic physiological indicators, including Max LA (maximum lactate accumulation) at 13.69±1.89 mmol, FI (fatigue index) at 56.37±2.51%, 5 seconds peak power at 16.68±2.88 W/kg, and 30 seconds peak power at 9.5±1.23 W/kg. These indicators collectively suggest efficient energy utilization and a strong aerobic foundation, critical for sustained performance during long-distance road cycling events.

Keywords: Physiological fitness, predictors, performance, determinants, cycling, power meter

1. Introduction
Coyle *et al.* (1991) evaluates the physiological and biomechanical responses of "elite-national class" (i.e., group 1; N = 9) and "good-state class" (i.e., group 2; N = 6) cyclists while they simulated a 40 km time-trial in the laboratory by cycling on an ergometer for 1 h at their highest power output. Several studies have recently shown that pro-cyclists exhibit some remarkable physiological responses and adaptations such as an efficient respiratory system (i.e. lack of 'tachypnoeic shift' at high exercise intensities); a considerable reliance on fat metabolism even at high power outputs; or several neuromuscular adaptations (i.e. a great resistance to fatigue of slow motor units) [4]. Lucia *et al.*, (2001) review the different responses and adaptations (cardiopulmonary system, metabolism, neuromuscular factors, or endocrine system) to this sport [10]. Impellizzeri *et al.*, (2005) studied correlations between physiological variables and performance in high-level cross-country road cyclists. 12 internationally competitive mountain bikers completed the study [7]. Impellizzeri *et al.*, (2008) compare the morphological and physiological characteristics of elite female mountain bikers with road cyclists of different specialties and competitive levels [6]. The subject of Jobson *et al.*, (2008) was to compare the physiological demands of laboratory and road-based time-trial cycling and to examine the importance of body position during laboratory cycling. Bertucci *et al.*, (2012) designed to examine the biomechanical and physiological responses between cycling on the Axiom stationary ergometer (Axiom, Elite, Fontaniva, Italy) vs. field conditions for both uphill and level ground cycling [3]. Bell *et al.*, (2017) report a range of physiological characteristics in a two-time Tour de France champion [2]. Receiver-operating-characteristic analysis showed that placing at national championships at age 18 had good accuracy in predicting whether the athlete would later reach the World tour level (area under the curve = 0.882) Svendsen *et al.*, (2018) [16].

Other influential works include Paton *et al*., (2001), Izquierdo *et al.*, (2004) [8, 15]. Overall, these findings contribute to tailoring training programs to further enhance the athletes' strengths and address potential areas for improvement. The assessment conducted during the specific training phase provides a targeted understanding of their physiological responses under conditions closely resembling race scenarios. Fine-tuning their training protocols based on these results can lead to optimized performance outcomes, ensuring these elite female road cyclists remain at the forefront of national-level competition. Furthermore, the methodology used in this study can serve as a reference for similar assessments in the field of endurance sports, aiding both athletes and coaches in refining training strategies and maximizing potential.

Few published data are describing female cyclists and the studies available are difficult to interpret because of the classification of athletes. David T. Martin (2001) Professional women's road cycling is growing in both the numbers of participants and the number of competitions, and although the demands of competition for professional male cyclists have been documented, such data are not readily available for female cyclists [12]. Very few published studies have shown the physiological responses of female road cyclists across various competition events, even including performance-related metrics such as power output during the competition. Road cycling competition for women at the international level incorporates a wide range of formats. The shortest races for women are prologue time trials lasting <15 minutes, which normally precede the first stage of multi-day tours. Criteriums and circuit races typically last between 30 to 120 minutes and are popular in the US. At the prestigious World Championships (held every year) and the Summer Olympics (held every 4 years) the road cycling program includes a 1-day road race that is between 110 to 130km long and a time trial between 25 to 30 km long. The most competitive female cyclists will complete the road course in ≈3 hours and depending on the distance, the time trial course will take between 32 to 42 minutes. The other popular racing format that attracts the most competitive female road cyclists is stage racing.

Ebert, *et al.* (2006) determined that cyclists spend the most time (~80%) at low to moderate power outputs (2-4.9W.kg-1) and the least time at highest power outputs (>8W.kg-1) during flat, hilly, and criterium races [5]. Furthermore, Ebert, *et al.* (2006) reported that for all race types, there are numerous (20-70), short-duration bursts (3-30s) at power greater than the power output associated with maximal oxygen uptake. Others have described cycling events by reporting the typical heart rate response to cycling competitions [5]. Padilla S (2001), Vogt S (2007), and Vogt S (2007) showed that although the heart rate response may vary depending on the type and terrain of an event, mean heart rates for competitive road cycling races are ~135 beats per minute (bpm), with higher values (>140 bpm) for time trials or hilly events [14, 17, 18]. Cycling cadence and speed, like heart rate, are largely affected by the type and terrain of a race.

Vietnamese national road cycling athletes participate in similar competition distances as athletes worldwide. The assessment of physiological responses to exercise or adaptive responses is mostly recognized through training experience. The purpose of our investigation was to determine the most informative physiological characteristics to monitor the training effect in highly qualified road cyclists.

The present study aimed to evaluate the endurance physiological characteristics of four national-level female road cyclists. Specifically, the study aims to the analysis of some variables physiological: Rest heart rate, max heart rate, lactate threshold, heart rate at lactate threshold, power output, and fatigue index.

2. Materials and Methods

2.1 Participants

Four female road cyclists at the national level. Age (years) 26.2±1.7, experience (years) 12.5±1.1, height (cm) 164.25±3.86, Weight (kg) 56.75±2.22. Characteristics of the experimental group are presented in Table 1.

Table 1: Characteristics of an experimental group participating in the study

No. of Players	Experience (years)	Age (years)	Height (cm)	weight (kg)
04	12.5±1.1	26.2±1.7	164.25±3.86	56.75±2.22

The Participants volunteered to participate in the study. To participate in the study, cyclists had to be free of musculoskeletal injuries or other conditions that could hinder their participation. Participants were informed of the potential risks and benefits of the study and signed a consent form to participate in this study.

2.2 Design

The study followed a cross-sectional design. Participants visited the laboratory on two different days interspersed by 48 h. All tests were performed at approximately the same time of the day and under the same conditions (temperature 29±3 °C). The first laboratory visit was a maximal incremental cycling test. During their second visit, the subjects completed the Wingate test.

The assessment was conducted at the end of the preparation phase, during the second phase of the 2021 annual training plan. All experimental procedures were approved by the Ho Chi Minh City National Sports Training Center, Vietnam, and adhered to the principles outlined in the Declaration of Helsinki.

2.3 Procedures

The study involved four female road cyclists at the national level. Physiological indicators such as rest heart rate, max heart rate, lactate threshold 1 and 2, heart rate at lactate threshold 1 and 2, and max lactate were measured using Step test standard testing protocols. Performance indicators such as power output, and fatigue index, were also measured using standard testing protocols (Wingate test). The study performed the Pearson correlation (r) of aerobic and anaerobic endurance physiological variables for some indicators on the WKO5+ monitoring load software from Training Peak Companies. The research uses the blood lactate transition thresholds of high-performance cyclists using a long-graded exercise test protocol. The cyclist warms up at 75-100W in 5 min, the starting workload at 125W, step increment is 25W, cadence range selection (rpm) is 95-105, and step duration is 3 min. The tester records heart rate during the last 15 s of each workload and heart rate at the end of the test. The ergometer bike-Wattbike Pro 2019 from England is used for the step test procedure and Wingate test. Devices Lactate Scouts from the USA. Weight 80g. Results within 10 seconds. Size 3.6 x 2.2 x 0.9.

2.4 Statistical analyses

We used Excel and SPSS software to process the data. Data reported as mean, standard deviation (SD) with a 95% confidence interval. The research uses Lactate E (Newell J, 2007) to determine for calculate blood lactate endurance markers [13]. The study performed the Pearson correlation (r) of aerobic and anaerobic endurance physiological variables for some indicators on the WKO5+ monitoring load software.

3. Results and Discussion

The Descriptive statistics of Aerobic and Anaerobic Physiological indicators are shown in Table 2, and Table 3, respectively.

Table 2: The aerobic physiological indicators load on the bicycle ergometer

Variables		Descriptive statistics	
		$\bar{X}$	Sd
The aerobic physiological indicators	LT1 (mmol)	2.88	0.4
	Power @ LT1 (W/kg)	2.83	0.21
	HR @ LT1 (bpm)	146.25	10.36
	LT2 (mmol)	4.70	0.51
	Power @ LT2 (W/kg)	4.29	0.14
	HR @ LT2 (bpm)	164	3.37
	VO_2 max (ml/kg/ph)	67.41	2.31
	Resting HR (bpm)	49.25	0.96
	Max HR (bpm)	182.5	6.86

The descriptive statistics presented in Table 1 offer insights into various aerobic physiological indicators. Lactate Threshold 1 (LT1) exhibited a mean value of 2.88 mmol, with a relatively low standard deviation of 0.40, indicating a moderate level of consistency among the observed values. Power output at LT1, expressed in watts per kilogram (W/kg), displayed a mean of 2.83 with a standard deviation of 0.21, suggesting a relatively narrow range of variability around the mean. Heart rate (HR) at LT1 displayed a mean of 146.25 beats per minute (bpm) with a standard deviation of 10.36, indicating some variability among individuals. Moving to Lactate Threshold 2 (LT2), the mean lactate value was 4.70 mmol, accompanied by a standard deviation of 0.51. Power output at LT2, similar to LT1, demonstrated limited dispersion around its mean (M=4.29, SD=0.14). HR at LT2, however, displayed less variability compared to LT1, with a mean of 164 bpm and a standard deviation of 3.37. The maximal oxygen consumption (VO2 max), a crucial aerobic capacity measure, presented a mean of 67.41 ml/kg/min with a standard deviation of 2.31, indicating a moderate level of consistency among individuals' performance. Resting heart rate (RHR) displayed a relatively low mean of 49.25 bpm, and Maximal Heart Rate (MHR) exhibited a higher mean of 182.5 bpm, with standard deviations of 0.96 and 6.86, respectively. These statistics provide a comprehensive overview of the variability and central tendencies of the examined aerobic physiological indicators, contributing to a better understanding of the participant's physiological responses.

Table 3: The anaerobic physiological indicators load on the bicycle ergometer

Variables		Descriptive statistics	
		$\bar{X}$	Sd2
The anaerobic physiological indicators	Max LA (mmol)	13.69	1.89
	FI (%)	56.37	2.51
	5 seconds (W/kg)	16.68	2.88
	30 seconds (W/kg)	9.5	1.23

The anaerobic physiological indicators, as detailed in Table 2, offer valuable insights into the participants' performance in short-duration high-intensity activities. The maximum blood lactate accumulation (Max LA) demonstrated a mean value of 13.69 mmol, accompanied by a standard deviation of 1.89. This relatively moderate standard deviation suggests some variability in individuals' anaerobic capacity responses. Fatigue Index (FI), a measure reflecting the ability to sustain high power outputs, exhibited a mean of 56.37% with a standard deviation of 2.51. This relatively low standard deviation implies a relatively consistent performance across participants in this metric. Power output during a 5-second burst of activity, expressed in watts per kilogram (W/kg), displayed a mean of 16.68 W/kg with a standard deviation of 2.88, suggesting some variability in short-duration maximal efforts. Similarly, the power output during a 30-second effort showed a mean of 9.5 W/kg with a standard deviation of 1.23. This lower standard deviation suggests a higher level of consistency in power output during the 30-second activity. In summary, these descriptive statistics provide insights into the variation and central tendencies of the anaerobic physiological indicators, contributing to a comprehensive understanding of participants' capabilities in short-term, high-intensity activities.

The comprehensive analysis of both aerobic and anaerobic physiological variables, as assessed through the WKO5+ monitoring load software, has revealed valuable insights into the multifaceted nature of endurance performance. The table below shows the Pearson correlation coefficient relationships between aerobic and anaerobic endurance physiological variables and indices as measured by the WKO5+ monitoring load software. The Pearson correlation coefficient quantifies the strength and direction of the linear relationship between aerobic and anaerobic endurance physiological variables as measured by the WKO5+ monitoring load software. Closely correlated results can be used to predict future performance.

Table 4: The Pearson correlation coefficients relationships between aerobic and anaerobic endurance physiological variables as measured by the WKO5+ monitoring load software

Variables	WKO5+ Indices		
	mFTP (30km) (W/kg)	Pmax (W/kg)	FRC (kJ)
Power @ LT2 (W/kg)	0.987		
VO_2 max (ml/kg/ph)	0.635		
5 seconds (W/kg)		0.99	0.504
FI (%)		-0.394	-0.977
Max Lactate (mmol)		0.284	0.974

The Pearson correlation coefficients presented in Table 3 offer valuable insights into the relationships between aerobic and anaerobic endurance physiological variables, as assessed using the WKO5+ monitoring load software. The power output at Lactate Threshold 2 (Power @ LT2) displayed a remarkably strong positive correlation with mean Functional Threshold Power over a 30 km effort (mFTP 30km) (r=0.987). This compelling correlation suggests that individuals with higher power output at LT2 tend to exhibit greater mFTP 30km, indicating a relationship between sustained power output and anaerobic threshold performance. Furthermore, the correlation coefficient between VO_2 max and mFTP 30km was found to be moderate but significant (r=0.635). This correlation implies that a higher aerobic capacity, as represented by VO_2 max, is associated with an increased capacity for sustaining power over a 30 km effort. This finding aligns with the notion that enhanced aerobic fitness contributes to improved endurance performance.

The power output during a 5-second maximal effort showed a remarkably strong positive correlation with both maximal power output (Pmax) (r=0.99) and the energy reservoir (FRC) (r=0.504). This suggests that individuals with greater power output during short-duration efforts tend to exhibit higher maximal power output and have a relatively larger anaerobic energy reservoir. Conversely, the Fatigue Index (FI), representing the ability to sustain high power outputs, displayed significant negative correlations with both Pmax (r=-0.977) and 5-second power output (r=-0.394). This indicates that individuals with a higher FI tend to have lower maximal and short-duration power outputs. Additionally, the correlation coefficients between Max Lactate accumulation and Pmax (r=0.974), as well as 5-second power output (r=0.284), suggest that those with greater maximal lactate accumulation tend to exhibit higher maximal and short-duration power outputs.

Various aspects of physiological and performance evaluations in endurance athletes have been studied. Coyle *et al*. (1991) investigated the responses of elite and good-state cyclists during a simulated 40 km time trial, revealing differences between the groups [4]. Lucía *et al*. (1998) compared the physiological responses of professional and elite road cyclists during an incremental cycle ergometer test. Highlighting unique characteristics, Lucía *et al*. (2001) reviewed diverse adaptations seen in professional cyclists, including efficient respiratory systems, reliance on fat metabolism, and neuromuscular adaptations [10, 11]. Baron (2001) explored the relationship between anaerobic and aerobic power in off-road cyclists and sports students. Laursen *et al*. (2002) reported improved endurance performance without corresponding changes in oxidative or glycolytic enzyme activity [9].

Research by Alejo LB (2022) shows that the performance of endurance athletes such as road cyclists depends on many aerobic and anaerobic physiological variables [1]. In particular, some indicators have a strong correlation to the performance of several different events. The study indicated that factors like endurance (specifically time-trial performance, Peak Power Out, and Ventilatory Threshold) and body composition (both fat and muscle mass) were the most distinguishing features among cyclists of different age categories. Conversely, no consistent distinctions were found for muscle strength and power. These findings are pertinent for predicting performance, identifying talent, and guiding coaches in the formulation of training programs aimed at improving the crucial variables that contribute significantly to cyclists' performance and development. The results of the study show that the indicators of aerobic and anaerobic capacity of Vietnamese athletes are similar to published studies. However, it is difficult to compare the indicators in this study with other studies, due to the homogeneity of test methods and different conditions. Research has in common that improving performance in a road cyclist requires coaches and cyclists to assess the development of aerobic and anaerobic capacity through different training programs.

The descriptive statistics provided insights into the central tendencies and variabilities of key physiological indicators, illuminating the diverse responses within each cyclists. These indicators, ranging from lactate thresholds and power outputs to heart rates and VO_2 max, collectively paint a detailed picture of participants' physiological characteristics.

Moreover, the Pearson correlation coefficients unveiled significant associations among the studied variables, highlighting the interplay between aerobic and anaerobic capabilities. The correlations demonstrated how power output at Lactate Threshold 2 (LT2) is positively linked to both maximal power output (Pmax) and short-duration power output, emphasizing the role of LT2 in dictating both sustained and peak power performance. Similarly, the correlation between VO_2 max and mean Functional Threshold Power over a 30 km effort (mFTP 30km) underscores the synergy between aerobic fitness and sustained power output.

Furthermore, the negative correlations observed between the Fatigue Index (FI) and maximal/short-duration power outputs underscore the delicate balance between the ability to sustain high power and achieving peak power performance. The correlations involving Max Lactate accumulation provide insights into the relationship between lactate dynamics and power outputs, further highlighting the complex interplay between anaerobic capacity and performance. In tandem, these findings emphasize that endurance performance is a multifaceted outcome stemming from the synergy between aerobic and anaerobic physiological indicators. The integration of data from descriptive statistics and correlation analysis through the WKO5+ monitoring load software enhances our understanding of the physiological underpinnings of endurance capabilities. This holistic view offers practical implications for training strategies, performance optimization, and the overall development of athletes. Ultimately, this comprehensive approach paves the way for more informed decision-making by coaches, athletes, and researchers, contributing to advancements in the field of endurance training and performance enhancement.

4. Conclusion

The present study offers a comprehensive assessment of endurance physiological characteristics in four national-level female road cyclists. The evaluation, conducted at a specific point in their annual training plan, captured both aerobic and anaerobic performance metrics. Key findings include well-defined lactate thresholds (LT1 and LT2) and corresponding power outputs, indicating a strong aerobic capacity that is vital for prolonged performance in road cycling. The athletes also displayed significant VO_2 max values, underscoring their ability for efficient oxygen utilization. Furthermore, anaerobic indicators, such as maximum lactate accumulation and fatigue index, contribute to our understanding of their high-intensity, short-duration performance capabilities. Overall, the study's findings provide crucial insights for fine-tuning training programs, aiming to further optimize these athletes' performance in both aerobic and anaerobic domains.

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