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Changes in physiological fitness of Vietnamese talent female road cyclists after a 12-week preparatory phase

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Abstract

This study aim to evaluate the changes in physiological and performance indicators after a 12-week preparatory phase of four female national-level road cyclists using a power measuring device. The cyclists were monitored load over the preparatory training phase using power meter. Changes in physiological and performance indicators were analyzed. The study found a significant changes in resting heart rate and max heart rate. However, the heart rate at different lactate threshold was insignificant changes. Max lactate (mmol), fatigue index (%), power 5 seconds (W/kg), and power 30 seconds (W/kg) showed statistically significant changes with 0.59,-2.3, 0.32, and 0.42, respectively. The result indicated that the tested cyclists had lower resting heart rates and higher max heart rates compared to global average. However, they had lower power output for longer durations, lower VO$_2$ max, and lower power at different lactate thresholds. The results of this study may contribute to the existing body of knowledge and inform future interventions aimed at optimizing training programs and enhancing performance in various athletic disciplines.

Keywords: Physiological fitness, performance, road cyclist, power meter

1. Introduction

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 [6]. 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 of length and a time trial between 25 to 30km long. The most competitive female cyclists will complete the road course in about 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 (about 80%) at low to moderate power outputs (2-4.9 W.Kg^{-1}) and the least time at highest power outputs (>8W.kg^{-1}) during flat, hilly, and criterium races [3]. Furthermore, Ebert, *et al.* (2006) reported that for all race types, there are numerous (20–70), short-duration bursts (3–30 s) at power greater than the power output associated with maximal oxygen uptake [3]. Others have described cycling events by reporting the typical heart rate response to cycling competitions. Padilla S (2001), 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 [10, 15, 16].

Cycling cadence and speed, like heart rate, are largely affected by the type and terrain of a race. According to Vogt, S (2007) generally slowest speeds and cadences are reported during hilly events while the fastest speeds and cadences are reported during flat races and time trials [15]. Lucia A (2001) Road cycling is an extremely demanding endurance sport characterized by its cyclic nature, large training volumes, and high intensities [5]. Mujika I (2001). The activity is comprised of several different disciplines with clear physiological differences according to the typology of the cyclist and the particularities of the event (length, elevation gain, mass, or individual start, etc.) [8]. Peinado, A.B (2018) Therefore, different types of riders specialized in specific events and efforts have appeared time trialists, sprinters, and grand tour riders are some examples [7, 11, 13].

Hunter Allen (2019) has proved that the integration of power measuring devices in the training of competitive cyclists offers numerous advantages [4]. These devices provide objective and accurate measurements, enable individualized training zones, facilitate effective pacing strategies, and help identify areas for performance improvement. By harnessing the power of data, athletes, and coaches can optimize training, track progress, and make informed decisions to enhance the performance of competitive cyclists.

Vietnamese national road cycling athletes participate in similar competition distances as athletes worldwide. Monitoring physiological responses to exercise or adaptive responses is mostly recognized through the training experience. Vo Quoc Thang (2021) demonstrated that the application of devices for managing exercise intensity in the training of Vietnamese road cycling athletes still has many limitations. Some athletes use heart rate monitoring devices during their training as a tool to recognize training intensity; however, managing the volume of exercise over an extended period to understand adaptive responses as well as to prevent training overload is not common. This research is to evaluate the changes in physiological and performance indicators of female cyclists by using a power meter for load monitoring. Specifically, the study aims to determine whether the use of a power meter has an impact rest heart rate, max heart rate, lactate threshold, heart rate at lactate threshold, power output, and fatigue index of female road cyclists at the national level.

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 Player	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 longitudinal observational 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 Procedure

The study involved four female road cyclists at the national level who were monitored over preparatory phase using a power meter. 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 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. To evaluate the changes before and after the training process, we used analysis of variance (ANOVA) and t-test for mean values and standard deviations. The research uses Lactate E (Newell J, 2007) to determine for calculating blood lactate endurance markers [9].

3. Results and Discussion

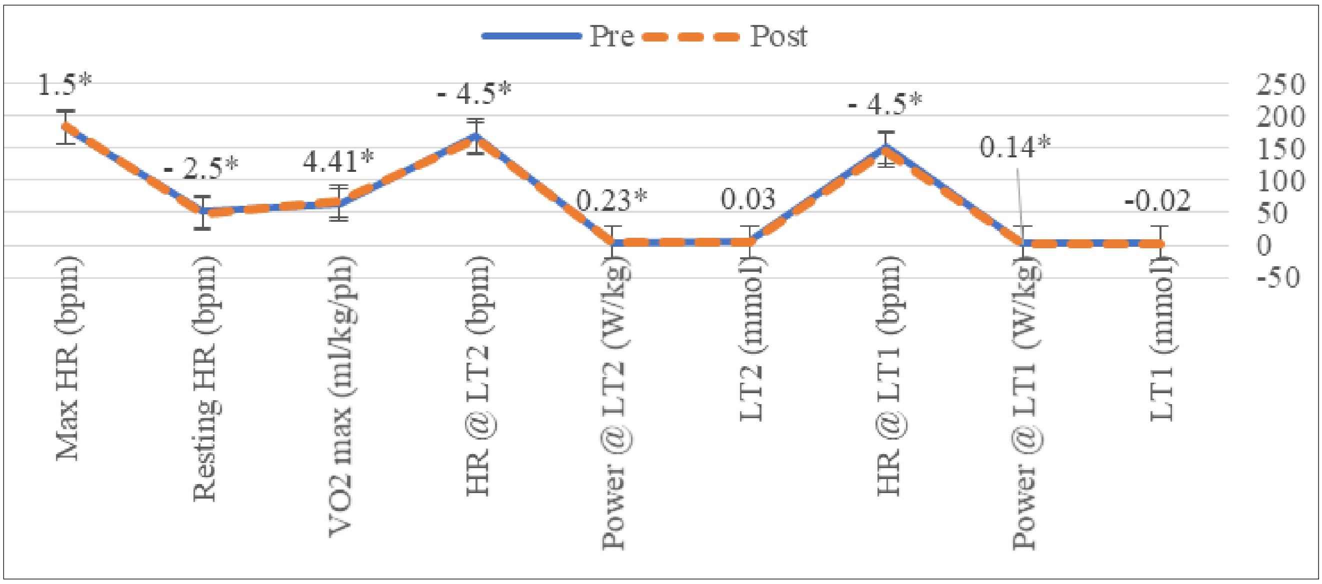
The changes in Aerobic and Anaerobic Physiological indicators after preparatory phase cycle of using a power meter for load monitoring are shown in Table 2, and Table 3, respectively.

A comparative analysis was conducted to evaluate the changes in various aerobic physiological indicators between the pre-intervention (Pre) and post-intervention (Post) stages. Descriptive statistics, including mean ($\overline{X}$) and standard deviation (Sd), were calculated for each variable. The differences (d) between pre and post-values were also examined, along with their associated significance levels (Sig.).

Table 2: The change of aerobic physiological indicators after preparatory phase cycle

Variables		**Pre**		**Post**		**d**	**Sig.**
		$\bar{X}$	**Sd1**	$\bar{X}$	**Sd2**		
The aerobic physiological indicators	LT1 (mmol)	2.9	0.42	2.88	0.4	-0.02	0.83
	Power @ LT1 (W/kg)	2.69	0.21	2.83	0.21	0.14	0.00*
	HR @ LT1 (bpm)	150.75	6.34	146.25	10.36	-4.50	0.00*
	LT2 (mmol)	4.73	0.65	4.70	0.51	-0.03	0.76
	Power @ LT2 (W/kg)	4.06	0.13	4.29	0.14	0.23	0.00*
	HR @ LT2 (bpm)	168.5	2.65	164	3.37	-4.5	0.00*
	VO$_2$ max (ml/kg/ph)	63	2.16	67.41	2.31	4.41	0.00*
	Resting HR (bpm)	51.75	0.96	49.25	0.96	-2.5	0.01*
	Max HR (bpm)	181	6.68	182.5	6.86	1.5	0.01*

*Significant difference (p<0.05). Note: LT1: Lactate 1; LT2: Lactate 2; HR: Heart rate.



*Significant difference (p<0.05)

Fig 1: The change of aerobic physiological indicators after a preparatory cycle phase

The table presents the following results for each variable: *LT1 (mmol):* The mean LT1 value decreased slightly from 2.9 (Pre) to 2.88 (Post), showing a negligible decrease (d=-0.02, P=0.83). *Power @ LT1 (W/kg):* The mean power at LT1 increased from 2.69 (Pre) to 2.83 (Post), indicating a significant improvement (d=0.14, p<0.05). *HR @ LT1 (bpm):* There was a notable decrease in heart rate at LT1, with a change from 150.75 (Pre) to 146.25 (Post) (d=-4.50, p<0.05). *LT2 (mmol):* The mean LT2 value exhibited a marginal reduction from 4.73 (Pre) to 4.70 (Post) (d=-0.03, P=0.76). *Power @ LT2 (W/kg):* Power at LT2 displayed a significant increase, rising from 4.06 (Pre) to 4.29 (Post) (d=0.23, p<0.05). *HR @ LT2 (bpm):* Heart rate at LT2 experienced a substantial drop, with values shifting from 168.5 (Pre) to 164 (Post) (d=-4.5, p<0.05). *VO$_2$ max (ml/kg/ph):* There was a noteworthy enhancement in VO2 max, as it increased from 63 (Pre) to 67.41 (Post) (d=4.41, p<0.05). *Resting HR (bpm):* Resting heart rate displayed a significant decrease from 51.75 (Pre) to 49.25 (Post) (d=-2.5, p<0.05). *Max HR (bpm):* Maximum heart rate showed a minor increase from 181 (Pre) to 182.5 (Post) (d=1.5, p<0.05).

Statistical significance (p<0.05) was observed for several variables, indicating meaningful changes in physiological indicators following the intervention.

Table 3: The change of anaerobic physiological indicators after a preparatory phase cycle

Variables		**Pre**		**Post**		**D**	**Sig.**
		$\bar{X}$	**Sd1**	$\bar{X}$	**Sd2**		
The anaerobic physiological indicators	Max LA (mmol)	13.1	1.81	13.69	1.89	0.59	0.00*
	FI (%)	58.63	3.3	56.37	2.51	-2.3	0.03*
	5 seconds (W/kg)	16.36	2.83	16.68	2.88	0.32	0.00*
	30 seconds (W/kg)	9.08	1.18	9.5	1.23	0.42	0.00*

*Significant difference (p<0.05). Note: FI: Fatigue Index (%)

A comparison was conducted between pre-intervention (Pre) and post-intervention (Post) values for various anaerobic physiological indicators. Descriptive statistics, including mean ($\bar{X}$) and standard deviation (Sd), were calculated for each variable. The differences (d) and significance levels (Sig.) were also examined.

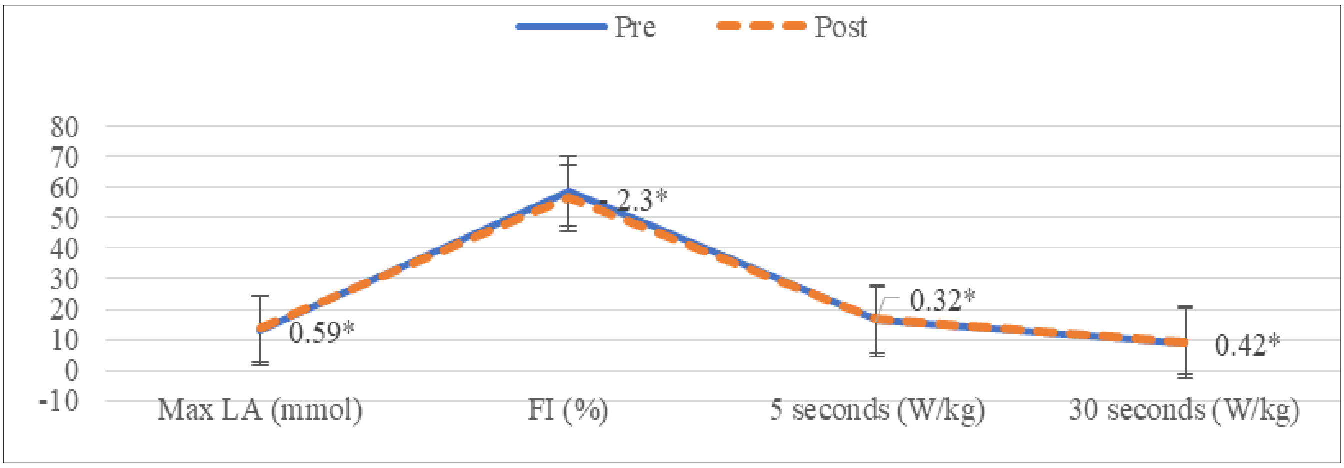


Fig 2: Comparison of pre-and post intervention anaerobic physiological indicator

The table displays the following results for each variable

Max LA (mmol): There was a slight increase in the mean Max LA value from 13.1 (Pre) to 13.69 (Post), yielding a positive difference ($d=0.59$, $p<0.05$). *FI (%):* The mean FI percentage exhibited a notable decrease, shifting from 58.63 (Pre) to 56.37 (Post) ($d=-2.3$, $P=0.03$*). *5 seconds (W/kg)*: The mean power output for 5 seconds demonstrated an increase from 16.36 (Pre) to 16.68 (Post), with a positive difference ($d=0.32$, $p<0.05$). *30 seconds (W/kg):* Power output for 30 seconds displayed an increase from 9.08 (Pre) to 9.5 (Post), resulting in a positive difference ($d=0.42$, $p<0.05$).

Schumacher *et al*. (2001) examined the effects of power-based training on performance in trained cyclists [12]. The researchers found that athletes who incorporated power meters into their training programs showed significant improvements in time trial performance compared to those who trained without power measurement. This study demonstrated the effectiveness of power-based training in optimizing performance outcomes. Hunter Allen *et al*. (2019), investigated the relationship between power output and time trial performance in trained cyclists [4]. The results showed a strong correlation between power output and time trial performance, indicating that monitoring and training with power can be a valuable tool for predicting and improving race performance. Weston M *et al*. (2014) examined the impact of power-based training on physiological adaptations and performance in competitive cyclists [17]. The researchers observed that athletes who utilized power meters in their training achieved greater improvements in functional threshold power, VO_2 max, and time trial performance compared to a control group.

Much research has been done on endurance training programs, especially for cyclists. Tomlin, DL (2001) suggested that aerobic metabolism plays an important role in sports performance, sometimes directly contributing to competitive performance, making a large contribution to cyclists' performance, cyclists' recovery [14]. Appropriate aerobic endurance training programs not only help athletes develop endurance capacity alone but also help maintain capacity during the exercises themselves at certain intervals and the fastest recovery for the athlete, prepare the following exercises.

Research by Buchheit M and Laursen PB (2013), shows that aerobic endurance development programs are often developed at subthreshold and high-intensity intervals, resulting in significant volume expansion, maximum oxygen absorption VO_2 max (ml/kg/min) and lactate threshold [1]. However, heart rate monitors work well in situations where the riding intensity is kept relatively stable, such as longer, lower-intensity endurance or base training rides. The key benefits of power are the instantaneous feedback it provides and the lack of external influences that would otherwise undermine the data. The precision and real-time feedback of a power meter also allow coaches and cyclists to target specific training adaptations easier than with a heart rate monitor.

This study provided further evidence for the efficacy of power-based training in enhancing cycling performance. These studies, among others, consistently demonstrate the positive impact of power measuring devices on training effectiveness and performance outcomes in cycling. The evidence from these research works supports the integration of power meters into training programs to enhance performance monitoring, individualize training intensities, and improve race strategies for competitive cyclists.

Much research proved that using a power meter for training will help decrease fat percentage and increase muscle percentage suggesting that cyclists were able to optimize their body composition and improve their power-to-weight ratio using a power meter. The decrease in resting heart rate and increase in max heart rate suggest that cyclists were able to improve their cardiovascular fitness and increase their work capacity. However, the lack of significant changes in lactate threshold, heart rate at lactate threshold, and power output suggests that the use of a power meter may not have a significant impact on these performance indicators. It is possible that the cyclists were already operating at their maximal lactate threshold and that further improvements in power output could only be achieved through other training interventions. The results of this study indicate that the use of a power meter can have a significant impact on the physiological and performance indicators of female road cyclists at the national level.

Regarding the aerobic physiological indicators, the use of a power meter demonstrated significant improvements across multiple key parameters. The increase in power output at both LT1 and LT2 indicates enhanced endurance capacity, potentially attributed to improved oxygen utilization and energy production mechanisms. The substantial elevation in VO_2 max, a crucial marker of aerobic fitness, underscores the use of a power meter's positive impact on participants' cardiovascular efficiency and capacity to sustain high-intensity exercise. The reductions in heart rate responses at LT1 and LT2 further affirm the use of a power meter's influence on cardiovascular adaptation, as lower heart rates at comparable exercise intensities suggest enhanced cardiovascular efficiency and reduced strain on the cardiovascular system.

Shifting the focus to anaerobic physiological indicators, the use of a power meter exhibited meaningful changes that signify improvements in short-duration, high-intensity performance. The observed increase in power output during 5-second and 30-second efforts implies augmented anaerobic power and capacity. This enhancement is of significance in activities demanding rapid bursts of energy, such as sprinting and explosive movements. The decrease in fatigue index (FI) percentage indicates an enhanced ability to sustain high-intensity efforts over time, suggesting improved muscular endurance and fatigue resistance.

Collectively, these findings substantiate the efficacy of the use of a power meter in enhancing both aerobic and anaerobic physiological attributes. The improvements noted across various parameters collectively contribute to a more comprehensive understanding of the use of a power meter's impact on the participants' overall physical performance. The use of a power meter's ability to enhance endurance, cardiovascular efficiency, and anaerobic performance capabilities underscores its potential utility in optimizing training regimens for athletes seeking to improve their athletic prowess and competitive edge.

Comparing the indicators of this study to those of the world, it is important to note that the results of this study may not be generalizable to all female road cyclists. Additionally, the indicators of this study do not exceed or underperform in comparison to the world's average.

Anaerobic physiological indicators and VO_2 max variable of this research compared with the research of Coyle, E. (1995), Lucia A, *et al*. (2001), and Hunter Allen *et al*. (2019) are shown in Table 3 [2, 4, 5].

Table 4: Anaerobic physiological indicators and VO_2 max variable of this research compared with world-class cyclists

Level	5 second *(W/kg)	30 second *(W/kg)	VO_2 max **(ml/kg/ph)
World-class	17.9 ≥	11.2 ≥	75.5
Exceptional	< 16.5 ≥	< 10.4 ≥	
Excellent	< 15.3 ≥	< 9.8 ≥	
Very good	< 13.9 ≥	< 9.1 ≥	
Good	< 12.6 ≥	< 8 ≥	
Moderate	< 11.3 ≥	< 7.3 ≥	
Fair	< 10 ≥	< 6.9 ≥	
Recreational	≤ 8.6	≤ 6.1	
Thanh Tu, Pham (2021)	16.68	9.5	67.4

Note: *Data from Coggan, *et al*. (2006), ** Data from Coyle, E. (1995), Lucia A, *et al*. (2001) [2, 5]

Comparing these results with global indicators revealed that the national-level cyclists had higher max heart rates than the global average. However, they had lower power output for longer durations, lower VO_2 max, and lower power at lactate thresholds 1 and 2.

While the observational study design provides valuable insights into the changes in selected physiological and performance indicators following a 6-month training program, it is important to acknowledge its limitations. Observational studies cannot establish causality or determine the direct impact of the intervention being studied. Instead, they rely on observing and evaluating existing conditions without manipulating variables. In the context of assessing the effectiveness of power measuring devices in training applications, observational studies can provide preliminary evidence regarding the association between power output and physical fitness indicators. However, to establish a stronger understanding of the efficacy of power measuring devices, further research using experimental designs, such as randomized controlled trials, is warranted.

4. Conclusions

In conclusion, these findings suggest that improve the physiological and performance indicators of female cyclists. The results of this study may contribute to the existing body of knowledge and inform future interventions aimed at optimizing training programs and enhancing performance in various athletic disciplines.

The study found significant changes in resting heart rate and max heart rate ($p<0.05$), max lactate (mmol), fatigue index (%), power 5 seconds (W/kg), and power 30 seconds (W/kg) with d of 0.59,-2.3, 0.32, and 0.42, respectively ($p<0.05$). However, its impact on performance indicators such as lactate thresholds 1 and 2 may not be significant. Further research is needed to determine the optimal use of power meters in cycling training and performance.

In light of the comprehensive analysis conducted on the collected data, it is evident that the implemented use of a power meter has yielded noteworthy alterations in both aerobic and anaerobic physiological indicators among the participants. The comparison of pre-intervention (Pre) and post-intervention (Post) values has provided valuable insights into the effects of the intervention on various physiological parameters, shedding light on the efficacy of the use of a power meter in enhancing athletic performance.

In essence, the findings highlight the use of a power meter's capacity to induce favorable adaptations in physiological markers pivotal for athletic success. As the pursuit of enhanced performance remains a constant endeavor, this study offers valuable insights into the mechanisms by which such use of a power meter can propel athletes toward their performance goals, potentially reshaping training methodologies and competitive strategies.

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