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The Relationship Between FTP And VO2max Ability and Strength and Flexibility in Cyclists

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Abstract

The study aimed to investigate the relationship between VO2max and FTP in female road cyclists with strength (right/left-hand grip, back, leg), flexibility, and anthropometric variables. Descriptive statistics are presented as median and interquartile range. The median values of the participants were as follows: height 158.5 cm, body weight 54.9 kg, body fat percentage 19.6%, and body muscle mass 41.5 kg. The participants' leg strength was measured at 70 kg, while their back strength was found to be 50 kg. Their right-hand grip strength was 29.1 kg, and their left-hand grip strength was 29.6 kg. The participant's flexibility was measured at 32 cm. Their VO2max was found to be 58.2 ml/kg/min, with a VO2max pulse of 189 beats/min and a VO2max workload of 262 watts. During the FTP test, the participant's mean pulse rate was 181 beats/min, mean cadence was 83 rpm, mean workload was 184 watts, normalized power was 185 watts, and relative power was 3.1 watts/kg. The study found a moderate positive correlation between VO2max and back strength and a strong negative correlation with flexibility. Additionally, a strong positive relationship was observed between VO2max workload value and body muscle mass, as well as right- and left-hand grip strength. No relationship was found between VO2max HR, AnT VO2, AnT HR, and AnT workload. Furthermore, the study found a moderate positive correlation between FTP value and body muscle mass and a very strong positive correlation with calendar age. The study also found significant correlations between mean FTP cadence and body muscle mass, as well as between mean FTP workload and body muscle mass. Additionally, a very strong positive correlation was observed between mean FTP workload and calendar age. Finally, a strong negative correlation was found between FTP relative strength and flexibility. The study concluded that as the strength of the back muscles in the group increased, so did their VO2max and FTP values, along with an increase in body muscle mass. The results suggest that back strength and body muscle mass are important variables for the participants in the study.

Keywords: *Cycling, FTP, VO_2max, Strength, Flexibility*

INTRODUCTION

Road cycling is a complex sport that is influenced by several factors, including physiological, psychological, biomechanical, and technical-tactical aspects (Beattie et al., 2017; Beedie & Foad, 2009; Lucía et al., 2001). Athletes specialize in different areas, such as sprinting, time trials, and climbing, depending on their physiological structure (Beattie et al., 2017). Research has shown that female professional cyclists competing at the international level are typically between the ages of 21 and 28 years of age, with a height range of 162-174 cm, a body weight of 55.4-58.8 kg, and a body fat percentage of 7-12% (Martin et al., 2001). While anaerobic characteristics are important for short and intense cycling races (Faria et al., 2005a; Garcia et al., 2000; Olds, 2001), competitive performance is primarily related to aerobic fitness variables (Coyle et al., 1991; Mujika & Padilla, 2001a; Olds et al., 1995). The effects of variables on athlete performance are best predicted by monitoring training and competition. This can be done both in the field and in the laboratory environments, with the use of technology on the rise. Maximum oxygen uptake (VO_2max), functional threshold power (FTP), and anaerobic threshold tests are crucial measurements for maintaining and improving performance in cyclists. The VO_2max test is typically conducted in laboratories (Rønnestad, 2022; Sitko et al., 2020; Vinetti et al., 2023).

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According to Lucia et al. (2002a), the maximum oxygen uptake capacity is one of the most significant determinants of performance in cyclists. Research suggests that VO_2max testing alone cannot determine performance in elite road cyclists and trained amateur cyclists (Lucia et al., 2002; Mujika & Padilla, 2001b).

Heart rate is a leading performance indicator in cyclists as it determines the intensity of the load and provides information about the current performance status (Topraklı & Kılınç, 2017). Studies have shown a linear relationship between heart rate and maximal oxygen consumption (Foster et al., 1999; Gilman, 1996; Cebi et al., 2021), which is defined as the highest amount of oxygen utilization that the body can use during exercise. Changes in an athlete's performance status can be detected by an increase in VO_2max (Bassett & Howley, 2000). Although VO_2max is considered a prerequisite, many factors can influence the results. Faria et al. (2005b) found that professional cyclists had an average VO_2max value of 74 ml/kg/min. Other tests, such as functional threshold power (FTP), are also used to predict performance (Sørensen et al., 2019).

The FTP test is defined as the power a cyclist can sustain in a quasi-steady state for one hour (Allen et al., 2010). It conceptualises performance equivalence and the highest sustainable oxidative metabolic rate (Jones et al., 2019). Martin et al. (2001) found that female cyclists competing at a professional level produced 5.5 W/kg of power per kilogram of body weight.

The increase in muscle mass in endurance athletes is not associated with training (Taipale, 2013). However, according to Ronnestad et al. (2010) and Losnegard et al. (2011), the increase in muscle mass in athletes is associated with endurance exercises. As a result, the inclusion of strength training in athletes' training programs is becoming more common. Several authors have reported an increase in Type IIa fibre ratios and a decrease in Type IIx fibre ratios following the addition of resistance training to training programs. These changes have been observed to result in improvements in various performance markers, such as the number of cadences after fatigue and increases in peak power output (Hibbs et al., 2008; Levin et al., 2009).

The study is significant in addressing the lack of literature on female cyclists and guiding athletes and coaches in their preparation for competition. This study aimed to examine the relationship between VO_2max and FTP values and other parameters, such as strength, flexibility, and anthropometric variables in female cycling athletes.

The hypotheses of the study are as follows: (i) an increase in athletes' back strength will result in an increase in VO_2max values, and (ii) an increase in athletes' body muscle mass will result in an increase in FTP values.

MATERIALS AND METHODS

Research Model

The study involved nine female road cyclists with a mean age of 25.4 years. It followed an experimental model and measured variables such as VO_2max, FTP, strength (right-left hand grip, back, leg), flexibility, and anthropometric variables.

Measurements

The measurements were taken at the Application and Research Centre of the Sports Science Faculty of Alanya Alaaddin Keykubat University.

Anthropometric Measurements

Participants' height was measured using the German SECA stadiometer, with an accuracy of 0.1 cm in the anatomical standing position and barefoot. Body weight and body fat percentage were measured using the Tanita BC-601 model device, with a sensitivity of 0.1 kg, while the participants were barefoot and wearing minimal clothing. Body mass index was calculated as body weight (kg) divided by the square of height (m2) (Gordon et al., 1988).

Strength Test Measurements

Hand grip strength was measured using a Takei A5401 electronic dynamometer, which has a measuring range of 5.0-100 kg with an accuracy of 0.1 kg. Participants were instructed to stand upright with their arms fully

extended and look straight ahead. The dynamometer was adjusted to fit their hands, and three repetitions were performed, starting with the dominant hand. The highest score was recorded. During the measurement, participants were instructed not to shake the dynamometer and to keep it at a safe distance from their bodies (Kim et al., 2018).

The study employed a Baseline brand dynamometer to measure leg and back strength. Participants were instructed to step onto the bench, bend their knees, and then, with their arms stretched and back straight, pull the dynamometer bar vertically upwards. Three repetitions were performed, and the highest score was recorded. To improve back strength, participants were instructed to step on the bench and pull the dynamometer bar upwards with their body upright, using their shoulders to generate force. Three repetitions were performed, and the highest score was recorded (Aktaş, 2015).

Flexibility Measurements

A flexibility test was conducted on the Baseline modified sit-stand bench. The bench was adjusted to the arm length of the athlete, and they were instructed to reach forward without bending their knees. The highest distance reached in centimetres was recorded after two repetitions (Aktaş, 2015).

FTP Test Measurements

The FTP test was performed using the Tacx Neo 2T Smart Trainer. Before starting the test, the participants were instructed to warm up for 10 minutes at 100 watts until they felt tired. Following the warm-up, they performed 2 sets of 20 seconds of maximum effort with 3 minutes of rest between each set. A 5-minute rest period was given after the loads. Then, the athletes were asked to report the maximum power output they could sustain for 20 minutes (Jeffries et al., 2019).

VO_2max Test Measurements

The VO_2max test was performed using a Cosmed Fitmate PRO cycle ergometer. The athletes wore an oxygen analyser mask, and heart rate data was recorded using a Polar pulse band. The test continued until the athlete was exhausted, with a workload increase of 25 watts per minute (Hill et al., 2018; Klika et al., 2007).

Data Analysis

Statistical analyses were performed using Excel (Analysis Tool Pack) and SPSS 22.0 software. To test the normality of the variables, the kurtosis and skewness test were applied with a threshold of ±2. Although the test result was within the threshold, the Shapiro-Wilk test was conducted due to the small sample size (less than 50 participants). The test revealed that the data did not follow a normal distribution (George & Mallery, 2016). Descriptive statistics were analysed using median and interquartile values for variables that did not follow a normal distribution. The Spearman correlation test was used to analyse relationships. The significance level was set at $p<0.05$.

FINDINGS

Table 1 presents the results of the anthropometric measurements, strength tests, and flexibility measurements. Table 2 shows the VO_2max values of the athletes, while Table 3 shows the FTP test values. Table 4 presents the relationships between the athletes' VO_2max values and their strength, flexibility, and anthropometric measurements. Table 5 shows the relationships between the FTP test values and the athletes' strength, flexibility, and anthropometric measurements.

Table 1. Anthropometric measurements, strength tests, and flexibility assessments of the participating athletes

n=9		Percentage	
	Median	25%	75%
Calendar age (years)	25.4	18.7	31.1
Height (cm)	158.5	157.3	167.3
Body weight (kg)	54.9	52.0	59.0
BFP (%)	19.6	17.8	22.4
BMM (kg)	41.5	38.7	45.2
Leg strength (kg)	70	62.5	82.5
Back strength (kg)	50	45	77.5
Right HGS (kg)	29.1	27.2	33.9
Left HGS (kg)	29.6	25.6	33.9
Flexibility (cm)	32.0	19.8	42.5

BFP=Body Fat Percentage, BMM=Body Muscle Mass, HGS=Hand Grip Strength

The study measured the strength and flexibility of female road cyclists. Median leg strength was 70 kg, back strength was 50 kg, left-hand grip strength was 29.6 kg, and right-hand grip strength was 29.1 kg. The median flexibility was 32 cm.

Table 2. VO_2max values of the participating athletes

n=9		Percentages	
	Median	25%	75%
VO_2max (ml/kg/min)	58.2	51.0	59.9
VO_2max HR (beats/min)	189.0	181.0	195.0
VO_2max workload (watt)	262.0	237.0	293.5
AnT VO_2 (ml/kg/min)	28.0	22.3	33.0
AnT HR (beats/min)	143.0	126.0	159.0
AnT workload (watt)	87.0	74.0	106.0

AnT=Anaerobic Threshold

Upon analysis of the athletes' VO_2max test results, it was found that the median value of VO_2max was 58.2 ml/kg/min, the median value of VO_2max pulse rate was 189 beats/min, and the median value of VO_2max workload was 262 watts.

Table 3. FTP test values of the participating athletes

n=9	Median	Percentage	
		25%	75%
FTP max HR (beats/min)	189.0	178.0	202.0
FTP mean pulse (beats/min)	181.0	171.5	191.0
FTP mean cadence (rpm)	83.0	80.0	95.5
FTP mean workload (watt)	184.0	173.0	199.0
FTP normalized (watt)	185.0	164.5	194.0
FTP relative (watt/kg)	3.1	2.9	3.5

Upon examination of the results, it was found that the maximum pulse rate had a median value of 189 beats/min, while the mean pulse rate had a median value of 181 beats/min. The median value of the mean cadence was 83 rpm, and the median value of the mean workload was 184 watts. Additionally, the median value of normalized power was 185 watts, and the median value of relative power was 3.1 watts/kg.

Table 4. The relationships between VO_2max test results and anthropometric measurements, strength tests, and flexibility measurements of the participating athletes

n=9		Calendar age	Height	BFP	BMM	Leg Strength	Back Strength	Right HGS	Left HGS	Flexibility
VO_2max (ml/kg/min)	**rho**	0.62	0.00	-0.43	0.02	0.00	0.68	0.45	0.22	-0.75
	p	0.08	1.00	0.24	0.97	1.00	0.05*	0.22	0.58	0.02*
	rho	-0.20	0.14	0.24	-0.01	0.23	-0.15	0.32	-0.06	0.07

VO_2max HR (beats/min)	**p**	0.60	0.71	0.54	0.98	0.55	0.69	0.40	0.88	0.86
VO_2max workload (watt)	**rho**	0.94	0.54	-0.62	0.81	0.23	0.34	0.75	0.72	-0.49
	p	0.00	0.13	0.07	0.01*	0.55	0.37	0.02*	0.03*	0.18
AnT VO_2 (ml/kg/min)	**rho**	0.07	-0.18	-0.27	-0.28	0.02	0.29	0.13	-0.07	-0.48
	p	0.87	0.64	0.49	0.46	0.97	0.45	0.73	0.87	0.19
AnT HR (beats/min)	**rho**	-0.43	0.05	0.43	-0.18	0.22	-0.25	0.13	-0.17	0.15
	p	0.24	0.90	0.24	0.64	0.57	0.51	0.73	0.67	0.70
AnT workload (watt)	**rho**	0.03	0.03	-0.18	-0.06	0.30	0.19	0.33	0.1	-0.31
	p	0.95	0.94	0.65	0.88	0.43	0.63	0.38	0.81	0.42

BFP=Body fat percentage, BMM=Body muscle mass, HGS= Hand grip strength

The study found a moderate positive correlation between VO_2max and back strength, as well as a strong negative correlation with flexibility in female athletes. Additionally, a strong positive relationship was observed between VO_2max workload value and body muscle mass, as well as right-left hand grip strength. However, no relationship was found between VO_2max HR, AnT VO_2, AnT HR, and AnT workload.

Table 5. The relationships between FTP test results and anthropometric measurements, strength tests, and flexibility measurements of the participating athletes

n=9		**Calendar age**	**Height**	**BFP**	**BMM**	**Leg Strength**	**Back Strength**	**Right HGS**	**Left HGS**	**Flexibility**
FTP (watt)	**rho**	0.93	0.48	-0.58	0.68	-0.04	0.24	0.60	0.48	-0.40
	P	0.00*	0.19	0.10	0.05*	0.92	0.54	0.09	0.19	0.29
FTP mean pulse (beats/min)	**rho**	-0.36	-0.06	0.26	-0.23	0.05	-0.20	0.11	-0.27	-0.06
	p	0.34	0.87	0.50	0.56	0.90	0.61	0.78	0.48	0.88
FTP mean cadence (rpm)	**rho**	0.55	0.55	-0.37	0.73	0.13	0.04	0.24	0.61	-0.13
	p	0.13	0.12	0.33	0.03*	0.74	0.91	0.54	0.08	0.73
FTP mean workload (watts)	**rho**	0.93	0.48	-0.58	0.68	-0.04	0.24	0.60	0.48	-0.40
	p	0.00*	0.19	0.10	0.05*	0.92	0.54	0.09	0.19	0.29
FTP normalized (watt)	**rho**	0.38	0.05	0.03	0.57	0.40	0.10	0.62	0.52	-0.57
	p	0.31	0.94	0.93	0.11	0.29	0.80	0.08	0.15	0.11
FTP Relative (watt)	**rho**	0.53	0.17	-0.47	0.07	0.04	0.56	0.47	0.22	-0.72
	P	0.14	0.67	0.21	0.87	0.92	0.12	0.21	0.58	0.03*

BFP=Body fat percentage, BMM=Body muscle mass, HGS= Hand grip strength

The study found that in female athletes, there was a moderate positive correlation between FTP value and body muscle mass, as well as a very strong positive correlation with calendar age. Additionally, a strong positive relationship was observed between FTP average cadence and body muscle mass, while a moderate positive relationship was found between FTP mean workload and body muscle mass and a very strong positive relationship with calendar age. A strong negative correlation was observed between FTP relative strength and flexibility. However, no correlation was found between FTP mean pulse rate and any other variable.

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

This study examined the relationships between FTP and VO_2max abilities in female cyclists and their strength, flexibility, and anthropometric variables. The analysis revealed shortcomings in the relationship between FTP and VO_2max ability with the mentioned variables.

This section presents studies on calendar age, height, body weight, and VO_2max values. Wyatt and Dhimar (2016) conducted a study on 11 elite women with a mean age of 22.5±5.1 years, a height of 167.2±6.2 cm, and a body weight of 63.8±9.7 kg. Sendra-Perez et al. (2022) conducted a study on 14 female cyclists with a mean age of 27±8 years, a height of 1.66±0.1 cm, and a body weight of 60.6±7.2 kg. Impellizzeri et al. (2008) categorized female cyclists into normal (n=10), time trials (n=5), and climbers (n=12). The study found that normal cyclists had a mean age of 24.7 ± 2.9 years, a height of 165.3 ± 6.2 cm, a body weight of 58.0 ± 4.6 kg, and a VO_2max of 57.0 ± 3.6 ml/kg/min. Time trial cyclists, on the other hand, had a mean age of 22.8 ± 4.6 years, a height of 171 ± 5.9 cm, a body weight of 61.6 ± 3.1 kg, and a VO_2max of 63.1 ± 3.2 ml/kg/min. The study found that the mean age of the climbing cyclists was 28.3 ± 5.0 years, with a height of 166.6 ± 3.6 cm, a body weight of 51.8 ± 3.4 kg, and VO_2max of 64.8 ± 2.6 ml/kg/min. Ebert et al. (2005) reported that the mean age of 15 female cyclists was 24.1 years, with a height of 168.7 ± 5.7 cm and a body weight of 57.9 ± 3.6 kg. Burke (1980) found that the height of seven elite female cyclists was 167.7 ± 10.7 cm, body weight was 61 ± 8.5 kg, and VO_2max was 57.4 ± 6.6 ml/kg/min. Pfeiffer et al. (1993) found that the mean age of 16 female cyclists was 28±3 years, with a body weight of 61±4 kg and VO_2max of 64.2±4.0 ml/kg/min. In their study Wilber et al., (1997) found that the mean age was 26±5 years, height was 171±5 cm, body weight was 60.4±3.6 kg and VO_2max was 63.8±4.2 ml/kg/min. According to a study by Akbaş et al. (2023) on female cyclists, the median VO_2max was 46.9 ml/kg/min, the median VO_2max workload was 237.0 watts, and the median VO_2max pulse was 194. The median ANT VO_2 was 25.1 ml/kg/min, the median ANT workload was 87 watts, and the median ANT pulse was 144 beats/min. The median age of the female athletes in this study was 25.4 years, with a median height of 158.5 cm, a median body weight of 54.9 kg, and a median VO_2max of 58.2 ml/kg/min.

This section presents studies that explore the relationships between FTP and VO_2max abilities with various variables. Denham et al. (2020) conducted a study with 11 female cyclists and found a moderately strong positive correlation between FTP and VO_2max. They also revealed that age and body weight could predict FTP and VO_2max. Brandth (2022) conducted a study with five female athletes and found a correlation between FTP and VO2max.

Akbaş et al. (2023) found a strong positive correlation between FTP values and age, height, body weight, and VO_2max (ml/kg/min) in a study of 14 male cyclists. In contrast, Sorensen et al. (2019b) found no significant relationship between VO_2max (ml/kg/min) and FTP in a study of 11 male cyclists. The mean FTP was 272.8±29.6 watts, and the mean VO_2max (ml/kg/min) was 46.3±4.5. Our study found a positive correlation between VO_2max and back strength and a negative correlation with flexibility. Additionally, a positive relationship was observed between VO_2max workload and body muscle mass, as well as right-left hand grip strength. The FTP value was positively correlated with body muscle mass and calendar age. Additionally, there was a positive relationship between FTP average workload body muscle mass, and calendar age. However, a negative relationship was found between FTP relative strength and flexibility.

Therefore, as the back strength value of the participants increases, VO_2max values and FTP values also increase with increasing body muscle mass. Strength values are a crucial variable for the study participants. To make generalisations about FTP ability and VO_2max values, it is recommended to conduct studies with large groups that have a parametric distribution.

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