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Correlation of Isocapnic Buffering Phase with Aerobic and Anaerobic Power in Athletes*

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Abstract

The aim of the study was to detect the relationship of isocapnic buffering phase values with the values of both aerobic and anaerobic power. A total of 14 athletes, five females and nine males, with ages between 18 and 25 volunteered to participate in the present study. At the beginning, the values of height, body mass, and body fat ratio of the volunteers were collected as required. Then, a maximal exercise test was applied to the volunteers and during the test, the values of maximal oxygen consumption capacity (VO_{2max}), amount of oxygen consumed (VO_2), amount of carbon dioxide produced (VCO_2), ventilatory threshold, respiratory compensation point, and maximal heart rate were determined. Isocapnic buffering and hypocapnic hyperventilation phases were determined from the ventilatory threshold and respiratory compensation point values. One week after the maximal exercise test, the Wingate anaerobic test was applied to the volunteers and anaerobic power values were calculated. A significant relationship was found between the values of isocapnic buffering and hypocapnic hyperventilation, and the values of maximal heart rate (beats/min), ventilatory threshold VO_2 (ml/kg/min), ventilatory threshold heart rate (beats/min), ventilatory threshold speed (km/hour), respiratory compensation point heart rate (beats/min), and respiratory compensation point speed (km/hour) in both male and female volunteers. The findings collected hereby indicate that as the VO_{2max} levels of athletes increase, both their cardiopulmonary data and anaerobic power values and also their ability to resist the intensity of exercises applied after entering anaerobic threshold, increase.
Keywords: Anaerobic power, Aerobic capacity, Isocapnic buffering phase

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INTRODUCTION

Both aerobic capacity and anaerobic power are key features that determine the athletic performance (Armstrong and Welsman, 2020). Furthermore, although the level of anaerobic threshold is another factor affecting the performance of an athlete, the ability to resist the exercise intensities applied after entering anaerobic threshold is very much important in athletes for continuing their performances (Ghosh, 2004). Anaerobic threshold can be found by means of the blood lactate measurements during exercises and it can also be predicted during the maximal exercise testing by the methods of non-invasive gas exchange called as ventilatory threshold (Beaver et al., 1986). Carbon dioxide is produced, in addition to carbon dioxide produced by aerobic metabolism after a certain point of exercise practices, also as a result of buffering hydrogen ions (H^+) dissociated from accumulated lactic acid with bicarbonate. Ventilation phase begins to accelerate in response to this non-metabolic carbon dioxide exposed by buffering H^+ (Chicharrro et al., 2000). Ventilatory threshold corresponds to the point where the linearity between both minute ventilation (VE) and carbon dioxide production (VCO_2) and oxygen uptake (VO_2) is spoiled. If H+ rises above the buffering capacity of circulating bicarbonate, it causes the pH level of blood to shift towards the acid side, and the acidosis revealed stimulates the carotid bodies, causing hyperventilation (Chicharrro et al., 2000). The slope of curve indicating correlation between VE and VCO_2 becomes steeper with hyperventilation. This additional ventilation reaction is called the Respiratory Compensation Point (RCP) (Meyer et al., 2004). The area between ventilatory threshold, determined during maximal exercise test, and respiratory compensation point is referred to as the isocapnic buffering phase. Isocapnic buffering phase reflects the compensation for exercise-induced metabolic acidosis (Whipp et al., 1989). The area between the respiratory compensation point and the end of exercise is known, on the other hand, as the hypocapnic hyperventilation phase (Chicharrro et al., 2000).

Evaluation of isocapnic buffer phase during maximal exercise test has significance since it provides non-invasively estimated data about buffering capacity of athletes. It has been reported that the length of isocapnic buffering phase in athletes competing in unlike sports may vary depending on intensity and coverage aspects of training (Hasanli et al., 2015; Hirakoba and Yunoki, 2002). It has been declared, therefore, that the length of isocapnic buffering phase may be related to buffering capacity, lactate kinetics, and sensitivity of carotid substances to exercise-induced metabolic acidosis (Bentley et al., 2005).

Some scholars have reported that the athletes with higher aerobic capacities also have higher isocapnic buffering phases (Hirakoba and Yunoki, 2002; Oshima et al., 1997). There are studies, meanwhile, claiming also that the isocapnic buffering phase has no concern with endurance performance (Eryılmaz et al., 2018; Lenti et al., 2011). It has recently been indicated that the isocapnic buffering phase can be utilized to assess both aerobic and anaerobic capacities of athletes (Hasanli et al., 2015). It has been reported that the increases in blood lactate values during the isocapnic buffering phase are higher in athletes practicing anaerobic training than in athletes practicing aerobic endurance training (Hasanli et al., 2015; Hirakoba and Yunoki, 2002).

There is restricted literature available on this topic. However, there are contradictions in the results of studies reviewing the correlations of isocapnic buffering phase with both aerobic and anaerobic power. This study was accomplished, therefore, on the grounds revealing the correlation of isocapnic buffering phase with aerobic or anaerobic power.

METHOD

Research Model

This research is an experimental research model with a single group and the relationship between single measurement results was examined.

Study Group

The volunteer athletes, comprised of 5 females and 9 males, who have actively engaged in sports for at least five years and aged between 18 and 25, participated in this study.

Ethical Approval

Approval for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of the Sivas Cumhuriyet University dated 25.05.2022 with decision number 2022-05/06 prior to the start of the study.

Experimental Design

Measurements of the volunteers participated in the study were carried out, as required, in the Performance Measurement Laboratory, Faculty of Sports Sciences, Sivas Cumhuriyet University. Initially, the values of height, body weight, and body fat ratio, of which the measurement procedures were explained below, were collected from the volunteers. Then, the maximal exercise test was applied to the volunteers, and during the test, the capacity of maximal oxygen consumption (VO_{2max}), amount of oxygen consumed (VO_2), amount of carbon dioxide produced (VCO_2), maximal heart rate, ventilatory threshold, respiratory compensation point, isocapnic buffering, and hypocapnic hyperventilation values were determined accordingly. A week after the aforesaid measurements, the Wingate anaerobic test was applied to the volunteers and as a result of the test, the levels of maximum power, minimum power, average power, and power drop were detected as required.

Data Collection Tools

Height and Body Weight Measurements: The heights of volunteers involved in the study were measured, while they were barefoot, using a tape measure with an accuracy level of 0.1 cm. The body- weights, on the other hand, were measured while they were again barefoot and in only shorts using a brand Tanita BIA device with an accuracy level of 0.1 kg.

Body Fat Ratio Measurement: The body fat ratio measurement was implemented utilizing a brand TANITA Body Composition Analyser. The volunteers were asked not to eat anything for at least 4 hours prior to the measurement; not to drink anything including alcohol and caffeinated drinks; not to use saunas or baths for at least 2 hours prior to the measurement, and not to engage in any physical activity during the day.

Maximal Exercise Test

The test was started with a running speed of 7 km/h on a terrain having an inclination level of 5% and afterwards the speed was increased by 1 km/h per minute, allowing the volunteers to continue exercising until they were completely exhausted. Reaching the maximal heart rates during the test (maximum heart rate – age = maximum performance), having a respiratory exchange rate (RER), which was expressed as the instantaneous ratio of consumed carbon dioxide (VCO_2) and breathed in oxygen (VO_2), to be risen above 1.10, and having an oxygen uptake level remaining at a plateau despite the gradually increased exercise intensities, were all accepted as the criteria for attaining VO_{2max}. The highest 15-second oxygen uptake value, where at least two of the relevant criteria happened simultaneously, was confirmed as the VO_{2max} (ml/kg/min). Time to Exhaustion was determined as the total duration of test (Eryılmaz and Polat, 2021).

Ventilatory Threshold, Respiratory Compensation Point, Maximal Heart Rate

Ventilatory threshold values of the volunteers were determined non-invasively by means of the V-Slope method (Hirakoba and Yunoki, 2002). Depending on this method, the position of VO_2 curve was evaluated with regard to VCO_2. While VCO_2 and VO_2 increase proportionally to each other at the beginning of exercises, the slope of VCO_2 to VO_2 curve is roughly equal to 1. After a certain point of exercises, however, the correlation between VCO_2 and VO_2 indicates a much steeper inclination because of the non-metabolic CO_2 released as a result of buffering the accumulated lactic acid, in addition to CO_2 produced by aerobic metabolism, with bicarbonate. After plotting the VO_2 curve (x-axis) corresponding to VCO_2 (y-axis), the linear regression analysis was accomplished to sketch two regression lines with slopes equal to or above 1 (or closer). The values of VO_2 (ml/kg/min), heart rate, and running speed (km/hour) corresponding to ventilatory threshold point were determined, accepting the intersection of aforegiven two regression lines as ventilatory threshold hereby. The point where VE/VCO_2 value started to increase while $PETCO_2$ value started to decrease was found in order to determine the respiratory compensation point values, and this point was recorded as the value of respiratory compensation point. Values of VO_2 (ml/kg/min), heart rate, and running speed (km/h) corresponding the to respiratory compensation point were determined accordingly. The highest pulse level attained by the volunteers during the test was recorded as the maximum heart rate.

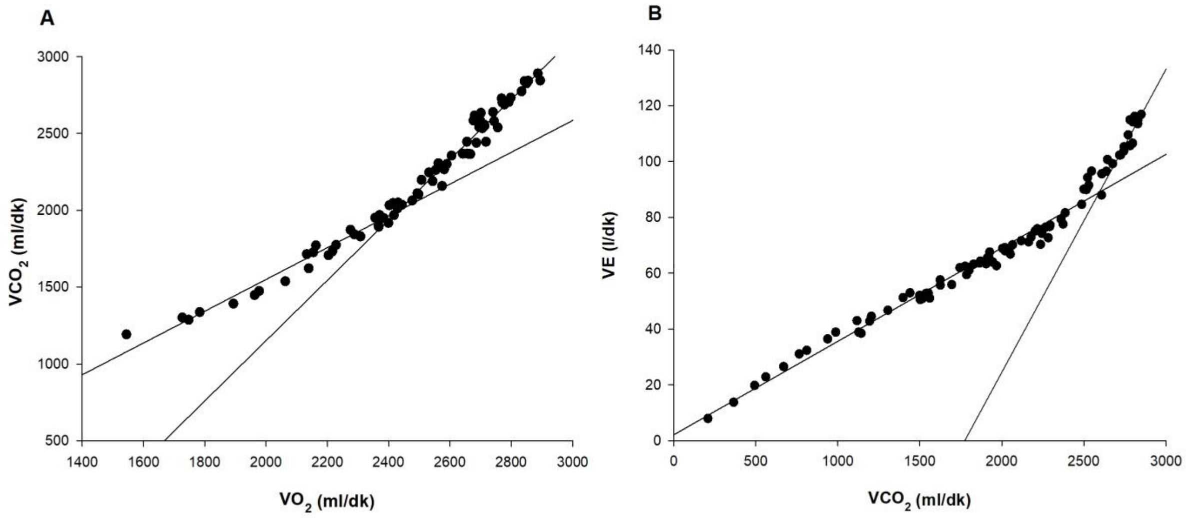

Figure 1. Examples indicating an athlete's ventilatory threshold (A) and respiratory compensation point (B).

Determination of Isocapnic Buffering and Hypocapnic Hyperventilation Phases

The isocapnic buffering phase was computed as the difference between the respiratory compensation point and ventilatory threshold, and it was represented by the values of both absolute VO_2 (ml/kg/min) and running speed (km/h) (Beaver et al., 1986). The hypocapnic hyperventilation phase was computed as the difference between the end of exercise and respiratory compensation point, and it was represented by the values of both absolute VO_2 (ml/kg/min) and running speed (km/h) (Beaver et al., 1986).

Wingate Anaerobic Power Test

The Wingate anaerobic power test was implemented using a bicycle ergometer, brand Monark Ergomedic 894 E. After the volunteers warmed up adequately, a resistance level about 7.5% of an athlete's body weight was adjusted. The volunteers cycled pedals at maximum rates against a predetermined resistance for 30 seconds. Following the test, the values of maximum power, minimum power, average power, and power drop were estimated.

Data Analysis

Initially, the descriptive statistical calculations of the data collected in the present study were performed. Then, the Shapiro-Wilk test, the graphs of skewness, kurtosis, histogram, Q-Q, and P-P were utilised to find whether the data were distributed normally. Since the relevant data did not indicate a normal distribution, the Spearman correlation analysis was applied to determine the correlation of aerobic and anaerobic power data with the isocapnic buffering data. The significance level was accepted as $p < 0.05$.

FINDINGS

In this section of the study, the findings obtained as a result of the analysis are presented.

Table 1. Descriptive informations about the volunteers

	Female (n=5)			Male (n=9)		
	$\bar{X}$ ± SD	Min.	Max.	$\bar{X}$ ± SD	Min.	Max.
Age (Years)	19,40 ± 2,40	17	22	18,1 ± 1,83	16	22
Height (cm)	167,80 ± 6,26	161	173	174,33 ± 3,57	171	180
Body Weight (kg)	63,00 ± 4,84	57	68	78,44 ± 7,36	64	87

The descriptive information about the volunteers are submitted in Table 1. According to the data given, the average age of the female volunteers was determined as 19.40 ± 2.40 (years), height 167.80 ± 6.26 (cm), and body weight 63.00 ± 4.84 (kg). Average age of the male volunteers, on the other hand, was estimated as 18.1 ± 1.83 (years), height 174.33 ± 3.57 (cm), and body weight 78.44 ± 7.36 (kg).

Table 2. Ventilatory threshold, respiratory compensation point, and maximal oxygen consumption values of volunteers

Variables	Female		Male	
	Median	(25% - 75%)	Median	(25% - 75%)
VO_{2max} (ml/kg/min)	42,70	39,75 - 47,50	51,80	48,60 - 54,00
Maximal Heart Rate (Beats/min)	204,00	185,00 - 205,00	202,00	198,50 - 206,50
Maximal Speed (km/hours)	12,00	11,00 -13,00	14,00	13,00 - 14,50
Time to Exhaustion (sec)	343,00	276,50 - 392,00	434,00	364,00 - 479,50
Ventilatory Threshold VO_2 (ml/kg/min)	34,80	32,50 - 42,30	48,80	36,50 - 51,25
Ventilatory Threshold Heart Rate (beats/min)	162	155 - 183	181	173 -183
Ventilatory Threshold Speed (km/h)	8,00	8,00 - 11,00	13,00	9,00 - 13,00
Respiratory Compensation Point VO_2 (ml/kg/min)	40,40	38,30 - 45,50	50,40	45,20 - 53,35
Respiratory Compensation Point Heart Rate (beats/min)	183	176 - 192	194	186 - 195
Respiratory Compensation Point Speed (km/h)	10,00	9,50 - 12,00	14,00	11,00 - 14,50

The values of anaerobic threshold, ventilatory threshold point, and maximal oxygen consumption of the volunteers took part in the study are available in Table 2. When the relevant values were reviewed, the VO_{2max} (ml/kg/min) values of the female volunteers were found as 42.70 (39.75 - 47.50), the maximal heart rate (beats/min) values 204.00 (185.00 - 205.00), the maximal speed (km/hour) values 12.00 (11.00-13.00), and the time to exhaustion (sec) values 343.00 (276.50 - 392.00). Therefore, the ventilatory threshold VO_2 (ml/kg/min) values were calculated as 34.80 (32.50 - 42.30), the ventilatory threshold heart rate (beats/min) values 162 (155 - 183), and the ventilatory threshold speed (km/h) values 8.00 (8.00 - 11.00). Accordingly, the respiratory compensation point VO_2 (ml/kg/min) values were determined as 40.40 (38.30 - 45.50), the respiratory compensation point heart rate (beats/min) values 183 (176 - 192), and the respiratory compensation point speed (km/h) values 10.00 (9.50 - 12.00).

For the male volunteers, on the other hand, the VO_{2max} (ml/kg/min) values were calculated as 51.80 (48.60 - 54.00), the maximal heart rate (beats/min) values 202.00 (198.50 - 206.50), the maximal speed (km/h) values 14.00 (13.00 - 14.50), and the time to exhaustion (sec) values 434.00 (364.00 - 479.50). Meanwhile, the ventilatory threshold VO_2 (ml/kg/min) values were computed as 48.80 (36.50 - 51.25), the ventilatory threshold heart rate (beats/min) values 181 (173 - 183), and the ventilatory threshold speed (km/h) values 13.00 (9.00 - 13.00). Therefore, the respiratory compensation point VO_2 (ml/kg/min) values were 50.40 (45.20 - 53.35), the respiratory compensation point heart rate (beats/min) values 194 (186 - 195), and the respiratory compensation point speed (km/h) values 14.00 (11.00-14.50).

Table 3. Isocapnic buffering and hypocapnic hyperventilation values of volunteers

Variables	Female		Male	
	Median	(25% - 75%)	Median	(25% - 75%)
Isocapnic Buffering Phase VO_2 (ml/kg/min)	3,20	2,30 - 7,90	2,30	1,75 - 6,15
Isocapnic Buffering Speed (km/h)	1,00	1,00 - 2,00	1,00	1,00 - 2,00
Hypocapnic HyperventilationVO_2 (ml/kg/min)	2,00	1,30 - 2,30	1,10	0,5 - 2,40
Hypocapnic Hyperventilation Speed (km/h)	1,00	1,00 - 2,00	1,00	1,00 - 2,00

The isocapnic buffering and hypocapnic hyperventilation values of the volunteers participated in the present study are available in Table 3. When the values collected were reviewed, the isocapnic buffering phase VO_2 (ml/kg/min) values of the female volunteers were found as 3.20 (2.30 - 7.90), the isocapnic buffering speed (km/hour) values 1.00 (1.00 - 2, 00), the hypocapnic hyperventilation VO_2 (ml/kg/min) values 2.00 (1.30 - 2.30), and the hypocapnic hyperventilation speed (km/hour) values 1.00 (1.00 - 2.00) accordingly. On the other hand, the isocapnic buffering phase VO_2 (ml/kg/min) values of the males were calculated as 2.30 (1.75 - 6.15), the isocapnic buffer speed (km/hour) values 1.00 (1.00 - 2.00), the hypocapnic hyperventilation VO_2 (ml/kg/min) values 1.10 (0,5 - 2.40), and finally the hypocapnic hyperventilation speed (km/hour) values 1.00 (1.00 - 2.00).

Table 4. Wingate test values of volunteers

Variables	Female		Male	
	Median	(%25 - %75)	Median	(%25 - %75)
Maximal Power (W/kg)	11,12	11,12 - 12,27	15,33	13,48 - 16,33
Average Power (W/kg)	7,20	7,20 - 7,69	9,75	9,17 - 10,09
Minimum Power (W/kg)	4,35	4,35 - 5,37	5,90	5,80 - 6,28
Power Drop (%)	60,82	56.21- 60,82	61,55	56,98 - 64,27

The Wingate test results of the volunteers participated in this study are available in Table 4. When the values acquired were examined, the maximum power (W/kg) values of the females were calculated as 11.12 (11.12 - 12.27), average power (W/kg) values 7.20 (7.20 - 7.69), minimum power (W/kg) 4.35 (4.35 - 5.37), and power drop (%) 60.82 (56.21 - 60.82). On the other hand, the maximal power (W/kg) values of the males were found as 15.33 (13.48 - 16.33), average power (W/kg) 9.75 (9.17 - 10.09), minimum power (W/kg) 5.90 (5.80 - 6.28), and power drop (%) 61.55 (56.98 - 64.27).

Table 5. Correlation of values of isocapnic buffering and hypocapnic hyperventilation with performance variables in female volunteers

Variables		Isocapnic Buffering VO_2 (ml/kg/min)	Isocapnic Buffering Speed (sec)	Hypocapnic Hyperventilation VO_2 (ml/kg/min)	Hypocapnic Hyperventilation Speed (sec)
VO_{2max} (ml/kg/min)	r	,111	-,304	,111	-,304
Maximal Heart Rate (beats/min)		**-1,000****	**-,913***	**-1,000****	**-,913***
Maximal Speed (km/h)		,859	,619	,859	,619
Time to Exhaustion (sec)		0,111	-,304	,111	-,304
Ventilatory threshold VO_2 (ml/kg/min)		-,667	**-,913***	-,667	**-,913***
Ventilatory threshold Heart Rate (beats/min)		-,667	**-,913***	-,667	**-,913***
Ventilatory threshold Speed (km/h)		-,667	**-,913***	-,667	**-,913***
Respiratory Compensation Point VO_2 (ml/kg/min)		,111	-,304	,111	-,304
Respiratory Compensation Point Heart Rate (beats/min)		-,667	**-,913***	-,667	**-,913***
Respiratory Compensation Point Speed (km/h)		-,667	**-,913***	-,667	**-,913***

*** p<0.05 ** p<0.01**

The relationship of the isocapnic buffering and hypocapnic hyperventilation values with the performance variables in the female volunteers participated in the present study are available in Table 5. The review accomplished on the values revealed a negative correlation between the values of maximal heartbeat (beats/min) and the values of isocapnic buffering VO_2 (ml/kg/min), isocapnic buffer speed (sec), hypocapnic hyperventilation VO_2 (ml/kg/min), and hypocapnic hyperventilation speed (sec). A negative correlation was, meanwhile, observed between the values of ventilatory threshold VO_2 (ml/kg/min) and the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation speed (sec). A negative relationship was detected between the values of ventilatory threshold heart rate (beats/min) and the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation speed (sec), as well as again a negative correlation between the values of ventilatory threshold speed (km/h) and the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation speed (sec). Furthermore, a negative relationship was observed between the respiratory compensation point heart rate (beats/min) values and the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation speed (sec), as well as again a negative relationship between the respiratory compensation point speed (km/h) values and the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation speed (sec).

Table 6. Correlation of the values of isocapnic buffering and hypocapnic hyperventilation with performance variables in male volunteers.

Variables		**Isocapnic Buffering VO_2 (ml/kg/min)**	**Isocapnic Buffering Speed (sec)**	**Hypocapnic Hyperventilation VO_2 (ml/kg/min)**	**Hypocapnic Hyperventilation Speed (sec)**
VO_{2max} (ml/kg/min)		-,385	,175	-,609	**-,832****
Maximal Heart Rate (beats/min)		**-,812****	**-,877****	**-,858****	-,647
Maximal Speed (km/h)		-,450	,178	-,652	**-,843****
Time to Exhaustion (sec)		-,402	,175	**-,670***	**-,832****
Ventilatory Threshold VO_2 (ml/kg/min)	**r**	-,573	-,351	**-,884****	**-,832****
Ventilatory Threshold Heart Rate (beats/min)		**-,846****	-,526	-,627	**-,832****
Ventilatory Threshold Speed (km/h)		-,667	**-,913***	-,667	**-,913***
Respiratory Compensation Point VO_2 (ml/kg/min)		-,385	,175	-,609	**-,832****
Respiratory Compensation Point Heart Rate (beats/min)		**-,795***	-,175	-,369	**-,832****
Respiratory Compensation Point Speed (km/h)		**-,787***	-,207	**-,734***	**-,982****

*** p<0.05 ** p<0.01**

The correlation of the isocapnic buffering and hypocapnic hyperventilation values with the performance variables in the male volunteers participated in this study is available in Table 6. The review carried out in the relevant values revealed a negative correlation between the values of VO_{2max} (ml/kg/min) and Hypocapnic Hyperventilation speed (sec) and likewise again a negative correlation between the Maximal Heart Rate (beats/min) values and the values of isocapnic buffering VO_2 (ml/kg/min), isocapnic buffering speed (sec), and hypocapnic hyperventilation VO_2 (ml/kg/min) for the males. Furthermore, there was a negative relationship between the values of Maximal Speed (km/h) and Hypocapnic Hyperventilation Speed (sec), and again a negative relationship between the values of Time to Exhaustion (sec) and the values of both Hypocapnic Hyperventilation VO_2 (ml/kg/min) and Hypocapnic Hyperventilation Speed (sec). The study revealed a negative correlation between the Ventilatory threshold VO_2 (ml/kg/min) values and the values of both hypocapnic hyperventilation VO_2 (ml/kg/min) and hypocapnic hyperventilation speed (sec), as well as again a negative correlation between the Ventilatory threshold Heart Rate (beats/min) values and the values of both Isocapnic Buffering VO_2 and Hypocapnic Hyperventilation Speed (sec). There was, meanwhile, a negative correlation between the Ventilatory threshold Speed (km/h) values and the values of both Isocapnic Buffering Speed (sec) and Hypocapnic Hyperventilation Speed (sec), as well as a negative correlation between the values of Respiratory Compensation Point VO_2 (ml/kg/min) and Hypocapnic Hyperventilation Speed (sec). The present study revealed a negative correlation between the Respiratory Compensation Point Heart Rate (beats/min) values and the values of both Isocapnic Buffering VO_2 (ml/kg/min) and Hypocapnic Hyperventilation Speed (sec), as well as again a negative correlation between the Respiratory Compensation Point Speed (km/h) values and the values of Isocapnic Buffering VO_2 (ml/kg/min), Hypocapnic Hyperventilation VO_2 (ml/kg/min), and Hypocapnic Hyperventilation Speed (sec).

Table 7. Correlation of the values of isocapnic buffering, hypocapnic hyperventilation, and VO_2max with Wingate test results in female volunteers

Variables		**Isocapnic Buffering VO_2 (ml/kg/min)**	**Isocapnic Buffering Speed (km/h)**	**Hypocapnic Hyperventilation VO_2 (ml/kg/min)**	**Hypocapnic Hyperventilation Speed (sec)**	**VO_2maks (ml/kg/min)**
Maximal Power (W/kg)		-,304	-,667	-,330	-,570	**,913***
Average Power (W/kg)	**r**	-,280	-,612	-,270	-,645	**,921***
Minimum Power (W/kg)		-,260	-,510	-,250	-,590	**,890***
Power Drop (%)		,260	,550	,240	,680	**-,930***

*** p<0.05**

The correlation of the values of isocapnic buffering, hypocapnic hyperventilation, and VO_{2max} with the results of Wingate test in the female volunteers is shown in Table 7. When the relevant values were reviewed, whereas the study revealed a positive relationship between the VO_{2max} (ml/kg/min) value and the values of maximal power (W/kg), average power (W/kg), and minimum power (W/kg), a negative relationship was detected between VO_{2max} (ml/kg/min) and power drop (%).

Table 8. Relationship of the values of isocapnic buffering, hypocapnic hyperventilation, and VO_2max with Wingate test results in male volunteers

Variables		**Isocapnic Buffering (ml/kg/min)**	**Isocapnic Buffering Speed (km/h)**	**Hypocapnic Hyperventilation VO_2 (ml/kg/min)**	**Hypocapnic Hyperventilation Speed (km/h)**	**VO_{2max} (ml/kg/min)**
Maximal Power (W/kg)		-,350	-,351	,189	,092	-,504
Average Power (W/kg)	**r**	-,043	,000	,318	,092	-,197
Minimum Power (W/kg)		-,299	,175	-,180	-,647	**,778***
Power Drop (%)		,026	-,351	,361	,555	**-,897****

*** p<0.05 ** p<0.01**

The correlation of the values of isocapnic buffering, hypocapnic hyperventilation, and VO_{2max} with the results of Wingate test in the male volunteers is available in Table 8. When the values were examined, the study revealed, in the male volunteers, a positive relationship between the VO_{2max} (ml/kg/min) value and minimum power (W/kg), and a negative relationship between the values of VO_{2max} (ml/kg/min) and power drop (%).

DISCUSSION AND CONCLUSION

It is crucial to measure the maximum oxygen consumption and anaerobic threshold in order to detect the optimal training intensity for an athlete and assess his/her reaction to training (Allen et al., 1985). Meanwhile, all factors that determine the rate and amount of total oxygen consumed must be taken into account in order to evaluate the aerobic performance of an athlete. Maximum oxygen consumption, anaerobic threshold, also called ventilatory threshold, and respiratory compensation values, all of which are the most important criteria for finding the aerobic endurance, enable athletes to practice for longer periods of time under homeostatic conditions (Hirakoba and Yunoki, 2002).

The knowledge of the values of maximum oxygen consumption, anaerobic threshold, respiratory compensation point, and isocapnic buffering phase of athletes plays a crucial part in order to make contributions as required for familiarizing with the needs of and the differences in athletes. It becomes, hence, important to understand whether the isocapnic buffering values are correlated with the values of the oxygen consumption and anaerobic performance. Although the studies reviewing the correlation between the values of isocapnic buffering phase and maximum oxygen consumption are available in the literature, the studies reviewing their correlation with anaerobic performance remain fairly limited.

Lenti et al., (2011) have claimed that the duration of the isocapnic buffer phase decreases as a person gets older and also it is higher in trained individuals with high endurance, regardless of age. Having a higher isocapnic buffering phase suggests that it indicates an athlete's ability to resist after entering the anaerobic threshold and it positively affects an athlete's capacity to continue exercise practices. Having higher isocapnic buffering values bring to mind, on the other hand, that the stimuli for anaerobic training promote the H+ buffering capacity and such an improvement may contribute to the ability to sustain the loading efforts above the anaerobic threshold for relatively longer periods. Röcker et al., (1994) have reported that the exclusive 400 m runners had possessed higher isocapnic buffering phases compared to the athletes of aerobic endurance training. They have reported, furthermore, that there was no statistically significant difference ($p>0.05$) in terms of the maximal running speed and VO_{2max} values between the 400m runners and aerobic training athletes who took part in their research.

A negative correlation was observed between the values of Hypocapnic Hyperventilation Rate (sec) and VO_{2max} (ml/kg/min) in the male volunteers participated in the present study. Furthermore, a negative correlation was found between the ventilatory threshold VO_2 (ml/kg/min) values and the values of both hypocapnic hyperventilation VO_2 (ml/kg/min) and hypocapnic hyperventilation rate (sec). However, the study revealed again a negative correlation between the values of Respiratory Compensation Point VO_2 (ml/kg/min) and Hypocapnic Hyperventilation Rate (sec). Again a negative correlation was determined between the values of Hypocapnic Hyperventilation VO_2 (ml/kg/min) and Hypocapnic Hyperventilation Rate (sec). A negative correlation was observed, once more, between the Time to Exhaustion (sec) values and the values of Hypocapnic Hyperventilation VO_2 (ml/kg/min) and Hypocapnic Hyperventilation Rate (sec).

The data collected hereby suggest that as the VO_{2max} levels increase, athletes can perform at higher speeds and reach fatigue level later, and also, as the VO_{2max} levels go up, athletes get to the levels of ventilatory threshold and respiratory compensation point later. Measuring aerobic capacity using the cardiopulmonary exercise testing during exercises can be considered as a reflection of the performance of organ systems, which can be a measure of the amount of oxygen consumed (Wasserman et al., 2010). The VO_{2max} value, determined through the exercise protocols to be increased gradually, is the major criterion affecting the aerobic endurance performance (Eryılmaz and Polat, 2021). During the cardiopulmonary exercise testing, the level of lactic acid begins to increase after reaching the anaerobic threshold (Oshima et al., 1998). The circulating bicarbonate ions compensate for the lactic acidosis (Wasserman, 1984). The lactic acid production begins, following a certain point, to be compensated by circulating bicarbonate and thereby by hyperventilation. This point is called the ventilatory threshold, known also as the anaerobic threshold (Whipp et al., 1989). The ventilatory threshold is the point where the balance between the amount of air exhaled and the amount of oxygen consumed changes depending on increased effort. An increase in anaerobic glycolysis as a result of insufficiency of aerobic energy sources during exercises causes an increase in lactate level and then the state of lactic acidosis develops. To buffer the lactic acidosis resulted, CO_2 excretion increases and the balance of CO_2/O_2 is deteriorated. Accordingly, intense utilization of the anaerobic energy systems begins at ventilatory threshold, and this value rises depending upon increased training intensity. It has been determined that the athletes with higher ventilatory thresholds would also have increased aerobic properties (Wasserman et al., 2010) Having rises also in the isocapnic and hypocapnic valueswhen the VO_{2max} value goes up, suggests, on the other hand, that such a state improves the buffering capacity of H^+ and this improvement may contribute to sustain the exercises for a relatively longer time above ventilatory threshold. Hasanli et al., (2015) have reported, in their study, a negative correlation between the relative increase in lactate and aerobic capacity during isocapnic buffering. It has been declared, on the other hand, that the isocapnic buffer periods were longer and the exercise tolerances above the threshold were higher.

Therefore, though utilizing the anaerobic energy systems after entering the ventilatory threshold is related to the aerobic systems, the athletes with well enough anaerobic capacities are expected to be able to continue exercise practices above the ventilatory threshold for a longer period of time. Specific metabolic adaptations improved during anaerobic training allow the buffering capacity to improve and ensure training practices to be sustained for a bit longer time. Adaptations to the relevant anaerobic training may be a major point for ensuring a relatively longer isocapnic buffer phase after the ventilatory threshold is exceeded and hence for enabling increased tolerance to the high-intensity exercise practices (Hasanli et al., 2015).
Additionally, in this study, a positive correlation, giving support to aforespecified findings, was determined between the VO_{2max} (ml/kg/min) values and minimum power (W/kg) values resulted from the Wingate anaerobic test, and a negative correlation between the values of VO_{2max} (ml/kg/min) and power loss (%) in the volunteers. The fact of having a negative correlation between the values of power drop (%) and VO_{2max} reflects that as the VO_{2max} values of the volunteers participated in the study increase, their fatigue levels, on the contrary, decrease. Aforesaid correlations between the VO_{2max} value and the Wingate test results suggest that the VO_{2max} level affects the resistance ability observed after entering the anaerobic threshold and that having both aerobic and anaerobic capacities at higher levels positively

affects the athletic performance. It has been declared, therefore, that the levels of increased lactate during isocapnic buffering phase were higher in anaerobic athletes than aerobic athletes (Hirakoba and Yunoki, 2002). Intense anaerobic exercises raise, according to Chicharro et al. (2000), the buffering capacity in metabolism and provide contributions to extend the duration of isocapnic buffer phase. Hirakoba and Yunoki (2002) have determined that the rises in blood lactate levels during the isocapnic buffer phase were at higher levels in sprinters than long-distance runners. Hasanli et al. (2015) have reported, meanwhile, that the isocapnic buffer phase was higher in anaerobic athletes compared to aerobic endurance athletes. The findings collected indicate similarities to the findings acquired in the present study.

A negative correlation was observed between the ventilatory threshold VO_2 (ml/kg/min) values and the values of both isocapnic buffer speed (sec) and hypocapnic hyperventilation rate (sec) in the female volunteers took part in the study. The study revealed a negative correlation between the ventilatory threshold heart beat (beats/min) values and the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation rate (sec), as well as a negative correlation between the ventilatory threshold speed (km/h) values and again the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation rate (sec). A negative correlation was, meanwhile, detected between respiratory compensation point heart beat (beats/min) values and the values of both isocapnic buffering speed (sec) and hypocapnic hyperventilation rate (sec), as well as again a negative correlation between the respiratory compensation point speed (km/h) values and the values of isocapnic buffering speed (sec) and hypocapnic hyperventilation (sec).

The data aforespecified point out that the rises in the amount of oxygen consumed at anaerobic threshold level in the female volunteers, as well as in male volunteers, cause significant increases also in the isocapnic and hypocapnic values. Therefore, whereas a positive correlation was observed between the VO_{2max} (ml/kg/min) values and the values of maximal power (W/kg), average power (W/kg), and minimum power (W/kg) collected from the results of Wingate test in the female volunteers, a negative correlation was detected between the values of VO_{2max} (ml/kg/min) and power drop (%).

It is considered, based on the data collected, that as the maximum oxygen consumption increases, also the amount of oxygen an athlete can consume goes up, and hence the time for an athlete to enter the anaerobic threshold takes longer. It has been considered, therefore, that the time required for athletes to reach the anaerobic threshold and the resistance capabilities of athletes after entering the anaerobic threshold, are directly correlated with VO_{2max}.

Relevant results collected from both the male and female volunteers support the fact that the rises in VO_{2max} level positively affect both the cardiopulmonary data and anaerobic power values of athletes. It has been clearly indicated that especially as the VO_{2max} level increases, the anaerobic permanence and power drop values of athletes are affected positively. Though the dominant energy requirements during exercise practices which house predominant anaerobic requirements are covered by the anaerobic system, the higher VO_{2max} levels reduce the load on anaerobic system in such exercise practices. Therefore, an athlete’s talents to maintain his/her performance for a longer period of time, can be improved (Beaver et al., 1986) Furthermore, the fact of having a negative correlation between maximum oxygen consumption and power drop (%), suggests that as the maximum amount of oxygen consumption increases, the rate of fatigue index decreases and so an athlete becomes exhausted later.

Conflicts of interest

The authors have no conflicts of interest to declare.

Authors' Contribution: Research Design- Metin Polat; Serkan Hazar; Burçin Okur - Data Collection- Metin Polat; Serkan Hazar; Emsal Çağla Avcu; Burçin Okur - Statistical Analysis: Metin Polat; Serkan Hazar - Preparation of the Article: Burçin Okur; Metin Polat; Serkan Hazar; Emsal Çağla Avcu.

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