Comparing Ventilatory Thresholds in Combination Trained and Untrained Healthy, College-Aged Males

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This project makes no effort to suggest generalizability. Instead, it was designed to demonstrate competency using lab equipment, capacity to integrate knowledge with application, and understanding of the scientific method.

Introduction

Ventilatory threshold (VT) is the point where ventilation increases disproportionately to the increase in oxygen consumption (McArdle, Katch, & Katch, 2015). At VT the excess ventilation that occurs is due to the expulsion of carbon dioxide in order to buffer the increase in lactate. VT occurs at a point where there is an increase in reliance upon anaerobic metabolic pathways (McArdle et al., 2015). Studies suggest that ventilatory threshold is reached when the respiratory exchange ratio (RER) exceeds 1.00 (McArdle et al., 2015). RER is the ratio of oxygen consumption to carbon dioxide production during rest or exercise (McArdle et al., 2015). RER is a useful tool that can help determine which metabolic system is primarily being used to fuel the body and the substrate that is being consumed during differing levels of activity (McArdle et al. 2015). VO_2/kg, or relative VO_2 max, is the total volume of oxygen that an individual consumes relative to their body weight in kilograms (Scribbans, Vesey, Hankson, Foster, & Gurd, 2016). Although Relative VO_2 cannot be used in comparing multiple individuals, it is still helpful in assessing a specific individual based on their size (Comana, 2018). Ventilation is known as the result of tidal volume times breathing frequency (Witte, Thackray, Nikitin, Cleland, & Clark, 2003). Ventilation can changed based on the variation of tidal volume and breathing frequency when the intensity of exercise changes (Witte et al., 2003). FECO2 is recorded as a fractional measurement of carbon dioxide during exercise (Nalbandian et al., 2017). $FECO_2$ is normally seen alongside FEO_2 because both are variables in respiratory gas exchange. Heart rate is defined as the number of times the heart beats per minute (D'souza et al., 2014). Resting heart rate is found to be between 60 and 100 beats per minute, which is determined by electrical impulses from the sinoatrial node (D'souza et al., 2014). RER is defined as respiratory exchange ratio (McArdle et al., 2015). RER can help to indicate which substrate is being used depending on exercise intensity and must be calculated during a state of rest or steady state exercise (McArdle et al., 2015). According to Ghosh (2004), training at or slightly above anaerobic threshold intensity improves the anaerobic threshold level. Loat and Rhodes (1993) show that several studies concluded that ventilatory threshold is highly correlated with endurance performance. While Kido et al. (2013) records that in combination training groups, ventilatory threshold will increase after training. From this, it is hypothesized that individuals who are trained using combination training will have an increased ventilatory threshold compared to untrained individuals.

Methods

First, the ParvoMedics TrueOne 2400 Metabolic Measurement system will be turned on in order to be warmed up for 30 minutes before each subject's arrival. Next the ParvoMedics TrueOne 2400 Metabolic Measurement system will be calibrated and the data for each individual subject will be inputted into the system before the beginning of each test. The Bike will be plugged into both power and the computer and set to manual mode. The subject will also be asked if there is any resistance present. The subjects arrive fifteen minutes prior to start of experiment in order to be prepped. The height and weight of each individual subject will be measured using the Detecto beam scale and anthropometer in order to be inputted into the ParvoMedics TrueOne 2400 Metabolic Measurement system in later steps. Upon arrival the subjects masks will have been assembled in order for the subject prep phase and a 24 hr recollection of each subject's food and drink intake will be collected. Each subject will be prepped with both a Polar heart rate monitor and a mask. Administrators will have gloves on with spit tubes and paper towels nearby for subjects. A heart rate road map will be calculated for each subject using the Tanaka heart rate equation in order to calculate the 90% max heart rate for each subject. The bike will be adjusted to the subject's height and the pedals adjusted. The test begins with a three minute rest stage in order to receive baseline data for each subject. Next, the subject begins cycling for three minutes at 50 watts and will maintain 60-70rpms. Wattage will be increased by 50 every 3 minutes. At the midpoint and end of each stage RPE will be collected. Once the subject reaches a 90% maximum heart rate they will continue to cycle for 30 seconds. After 30 seconds at 90% maximum heart rate the wattage will be reduced by 75 watts and the subject will continue to cycle for two minutes. After the two minutes are up, the wattage will be increased by 25 and the subject will cycle for 1 minute. Once the minute is reached, the test is completed. The mask will be taken off of the subject. The subject will then be shadowed by one of the test administrators for five minutes while the other administrators begin clean up and preparation for the next subject.

Results

Subjects 1 and 4 are combination trained college athletes and subjects 2 and 3 are untrained college aged men. Table 1 represents the submaximal data for the four subjects tested. The mean for ventilation between the four subjects ranged between 60.08L/min to 24.34L/min. The highest ventilation was recorded by Subject 1 and the lowest was recorded by Subject 3. The standard deviation for ventilation ranged from 15.60L/min, recorded by subject 2, to 38.51L/min, recorded by subject 1. An average standard deviation of 0.12 between the four subjects was recorded for RER.

Results (cont.)

The greatest and least mean RER values were 1.01 (subject 3) and 0.96 (subjects 1 and 4) respectively. Subject 3 recorded the greatest mean $FECO_2$ while subject 1 recorded the lowest. Subjects 1 and 3 mean $FECO_2$ values of 3.93% and subject 3 recorded a mean $FECO_2$ of 4.51% respectively.

Table 1

Submaximal Data from Subjects 1, 2, 3, and 4

		Mean	Standard Deviation	Range (low-high)
VO_2/kg (ml/kg/m)				
	1	28.82	14.59	2.10-52.81
	2	15.68	6.96	2.85-28.57
	3	10.35	4.43	2.71-17.61
	4	16.19	7.80	1.98-28.32
VE (L/min)				
	1	60.08	38.51	5.08-141.61
	2	31.39	15.60	6.06-57.83
	3	24.34	24.34	8.22-43.83
	4	36.75	17.97	7.01-70.35
$FECO_2$ (%)				
	1	3.93	0.50	3.11-4.96
	2	4.39	0.46	3.47-5.04
	3	4.51	0.51	3.33-5.17
	4	3.94	0.46	2.84-4.62
HR (bpm)				
	1	121	33	63-174
	2	128	29	82-173
	3	115	52	84-172
	4	128	30	81-173
RER				
	1	0.96	0.11	0.72-1.14
	2	0.97	0.14	0.68-1.15
	3	1.01	0.13	0.79-1.26
	4	0.96	0.10	0.74-1.11

VO_2/kg= Volume of oxygen consumed per kilogram of body weight, VE= ventilation, $FECO_2$= fraction of carbon dioxide in expired air, HR= heart rate, RER= respiratory exchange ratio, bpm= beats per minute, L/min= liters per minute, ml/kg/m= milliliter per kilogram per meter

Table 2 includes the VT of subjects 1, 2, 3, and 4. Subjects 1 and 4 show greater values in all variables. Subjects 2 and 3 reached their VT at heart rates of 107bpm and 116bpm, whereas subjects 1 and 4 reached their VT at heart rates of 142bpm and 149bpm.
A large difference between the trained and untrained subjects can be seen in VO2 at VT. Subject 1 had the greatest VO2 value at VT of 3.36L/min, while subject 3 recorded the least VO2 value at VT of 0.85L/min.

Table 2

VT Thresholds of subjects 1, 2, 3, and 4

Subjects	Time (min)	VO2 (L/min)	%$VO2_{max}$	HR (bpm)
Subject 1	15.17	3.36	74	149
Subject 2	6.2	1.31	46	116
Subject 3	4.7	0.85	41	107
Subject 4	10.2	2.05	65	142

VO2/kg= volume of oxygen consumed per kilogram, %$VO2_{max}$ = percent of VO2 max, HR= heart rate, min= minute, L/min= liters per minute, bpm= beats per minute

Figure 1. Shows the relationship between VO2/kg and VCO2/kg over VE for the untrained subjects. The correlation between VO2/kg and VCO2/kg is an r-value of r = 0.98. Figure 2 includes the relationship between VO2/kg and VCO2/kg over VE for the trained subjects. The correlation between VO2/kg and VCO2/kg is an r-value of r = 0.99. The trained subjects were greater in all three variables than the untrained athletes.

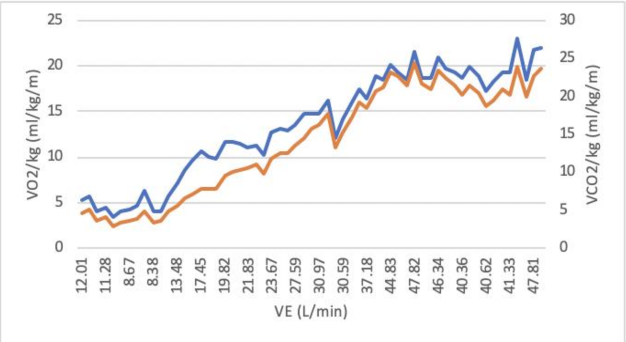

Figure 1. Relationship between VO2/kg and VCO2/kg over VE in untrained subjects

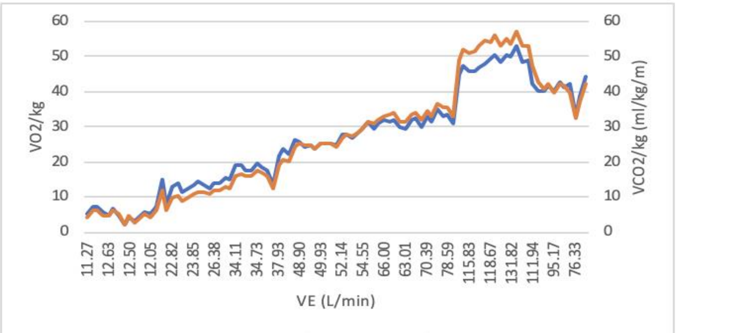

Figure 2. Relationship between VO2/kg and VCO2/kg over VE in trained subjects.

Discussion

During exercise, tidal volume and respiratory rate increase, causing O_2 consumption to increase along with aerobic CO_2 production. During anaerobic work, CO_2 production increases further because of buffering. According to Burton et al. (2004), VE increases abruptly with the beginning of exercise, levelling off and becoming a more gradual increase as exercise continues. This trend was consistent, as each subject's VE increased sharply at the beginning of exercise and began to steadily increase as the subjects continued through the test. Additionally, ventilation increases throughout exercise as tidal volume and respiratory rate increase in order to meet the increased oxygen demands in active muscle and increases linearly during submaximal exercise (Burton et al., 2004). In this study, each subject recorded increasing VE values as exercise intensity increased.

According to Burton et al.(2004), ventilation increases from 5-6 L/min at rest to greater than 100 L/min during exercise. No subject tested recorded a 30 second average greater than 100 L/min. Similarly, Blackie et al. (1991), male subjects recorded a mean VE of 97 +/- 25 L/min at the end of maximal exercise. While this test was not maximal, subjects in this sample are within the normative VE range. Subject 1 recorded a peak VE value of 141.61 L/min, greater than the range provided by Blackie et al. (1991). This increased VE of subject 1 can likely be attributed to his training experience.

Anaerobic work yields CO_2 as part of buffering out excess H+ through expiration. (McArdle et al., 2015). Therefore, $FeCO_2$ increases with increasing exercise intensity. Each subject's $FeCO_2$ increased as exercise intensity increased, showing that subjects were beginning to work anaerobically. According to McArdle et al. (2015), the normative range for $FeCO_2$ is 3-5% at all times. Subjects 2 and 3 recorded peak $FeCO_2$ values of 5.04 and 5.17% respectively during exercise, which is considered abnormal. However, subjects 1 and 4 (trained subjects) recorded peak $FeCO_2$ values of 4.96 and 4.62% respectively. It is likely that subjects 1 and 4 recorded decreased peak and mean $FeCO_2$ values when compared to subjects 2 and 3 because their experience in training at anaerobic intensities. Furthermore, anaerobic work increases Pa_{CO2} as , causing VE to increase with preference to exhalation (Burton et al., 2004). Therefore, subjects who begin to work anaerobically at lower intensities will ventilate more at lower intensities, because of decreased efficiency when compared to individuals with increased aerobic capacity.

VE increases to maintain pH, exhale CO_2 and meet increasing oxygen demand of active muscles (Burton et al., 2004). The correlation between relative VO_2 and VE is positive (r=0.99). The variables increase and decrease together. Figure 1 includes the relationship between relative VO_2 and relative VCO_2 compared to VE. $FeCO_2$ increases during exercise as a result of H+ and HCO_3 buffering buffering (Burton et al., 2004). This increase in CO_2 production during exercise has a great effect on VE, as VE increases in order to maintain pH. VE increased disproportionately to VO_2. According to McArdle et al. (2015), this point is known as the ventilatory threshold and is thought to indicate increasing anaerobic work. Table 2 provides data that supports the hypothesis that combination training increases ventilatory threshold. Trained subjects recorded ventilatory thresholds at 74 and 65% of their predicted VO_{2max} while untrained subjects recorded their ventilatory thresholds at 46 and 41% of their predicted VO_{2max}. Furthermore, trained subjects reached their ventilatory thresholds at 76% of their max heart rate on average while untrained subjects did so at 59% of their average max heart rate. These results support the hypothesis that combination training increases ventilatory thresholds in healthy, college-aged males. These results also follow the expected results as outlined by Kido et al. (2013), as trained individuals reached ventilatory thresholds at greater VO_{2max} % and heart rate max %.

Conclusion

An individual's training status is one factor that can determine the point at which ventilatory threshold is reached. The factors that can help determine when this point is reached are VE, FEO_2, $FECO_2$,VO_2, and VCO_2. It was noted in the experiment that combination trained individuals had values of these factors that corresponded with the ability to reach ventilatory threshold at higher intensities. Understanding that combination training has a positive effect on ventilatory threshold provides a program that can be beneficial to both athletes and untrained individuals for further improving exercise capabilities. One possibility for improving this experiment could be adding a preliminary test for each subject to find their VO_2 max in order to find a more accurate ventilatory threshold. Another possible improvement could be restricting the participants intake of heart rate stimulants such as caffeine up to 24 hours before the test. This study proved that individuals trained in combination programs have an improved VT over untrained individuals. Further studies with an increased sample size could ensure more accurate data collection between the two groups.

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