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Comparison of Physiological Adaptations in Highly Trained Aerobic Endurance Athletes and Highly Trained Resistance Athletes

Sarah Falbo
The University of Akron, saf70@zips.uakron.edu

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Sarah A. Falbo

University of Akron

ABSTRACT

Purpose: To compare the physiological differences between highly trained resistance and aerobic athletes (who perform five or more hours per week of resistance or aerobic exercise).

Methods: Participants had resting heart rate, blood pressure and lactate taken before entering the BOD POD to get body fat percentage. Then a five minute warm up on a cycle ergometer before doing the VO2 max treadmill test following the Bruce Protocol. At the completion of the VO2 max treadmill test, participants had heart rate recorded from the heart rate monitor, blood pressure and lactate were taken immediately after the max test. The sample size was n=9 for AG and the sample size for RG was n=8.

Results/Conclusion: All variables were compared among AG (aerobic group), RG (resistance group). The AG VO2 max average was 2.6ml/kg/min higher than the RG, with their max VO2 max result 6.4ml/kg/min higher than the max RG VO2 result. The AG body fat percent average was 4.3% higher than RG and percentile averages were 9.7 below RG averages. The AG resting systolic and diastolic blood pressure was about the same as the RG, however they had a higher final systolic blood pressure by 5mmHg on average and a lower final diastolic blood pressure by 11 mmHg on average. The AG had 10bpm lower resting and 5bpm lower final heart rate averages as well as lower minimum and maximums for both. The AG had a resting lactate level of double the RG (4.8mmol compared to 2.2mmol) and they both had the same final lactate level averages. However, the AG had a higher minimum and maximum resting and final lactate level. In conclusion, VO2 max and lactate levels increase with aerobic training while heart rate pre- and post-exercise decreases.

Key Words: cardiovascular, fitness, weight-lifting, exercise, lactate

INTRODUCTION

Aerobic and resistance training are the two main types of exercise done for various reasons, such as weight loss goals, strength gains, and increasing heart health. It is important to understand which type of exercise will help people more effectively reach their physiological goals. Controversy exists between aerobic athletes and resistance trained athletes regarding which type of exercise is better for overall health. However, health and fitness research on aerobic exercise and resistance training has primarily been done in special populations such as older adults, diabetics, obese or overweight individuals and individuals with some form of cancer (Pescatello, 2014). Few studies have been completed on healthy individuals who have maintained an exercise routine of high amounts of either aerobic endurance or resistance training. This study is aimed at comparing the effects of healthy individuals who perform high volume resistance training versus high volume aerobic. These individuals were recruited from the Akron Triathlon Club and Akron Barbell Club. The variables being compared in this study are VO2 max, body fat percent, resting and final blood pressure, resting and final heart rate, and resting and final lactate.

Aerobic exercise relies on oxygen for energy production, because it uses the aerobic metabolism for adenosine tri-phosphate (ATP) production, which is for longer activities at a lower intensity. The aerobic metabolism uses glucose and fat to resynthesize ATP, and produces 32 molecules of ATP. Glycolysis (anaerobic metabolism) produces only 2 molecules of ATP. Aerobic exercise is also referred to as cardiovascular exercise, which increases heart health by making the heart more efficient at pumping blood which causes maximum volume of oxygen (VO2 max) to increase. Resistance training uses anaerobic metabolism with short, high intensity bursts. Glycolysis is used in the anaerobic metabolism which does not rely on oxygen for re-synthesis of ATP, and therefore does not increase the VO2 max as much as aerobic training.

With short, high intensity bursts of exercise, blood pressure increases much more than longer, less intense aerobic exercise, especially with higher load resistance workouts.

Past research has consistently shown that as aerobic endurance increases, the VO2 maximum results increase, meaning the maximum amount of oxygen a person could utilize per minute increases. The onset of blood lactate accumulation (OBLA) was analyzed to determine which form of exercise—resistance or heavy aerobic training—elicited the greatest improvements in overall health (Chmura, 2010). The study, conducted by Chmura (2010), concluded that heavy aerobic training increased exercise tolerance because of its influence on metabolism, as well as facilitated psychomotor performance during heavy aerobic exercise. This means that the aerobic athletes had higher lactate levels, but also had a higher lactate threshold and tolerance. Another study showed that endurance trained athletes exhibit higher aerobic capacity when compared to resistance trained athletes. This is believed to be because of the variation in adaptations developed during training. A further study conducted by the American College of Sports Medicine (ACSM) stated high–aerobic intensity endurance training is significantly more effective than moderate- and low-intensity training in improving VO2max (Pescatello, 2014).

The body changes blood pressure depending on the frequency, intensity, time, and type of exercise. Blood pressure consists of two numbers: the top is systolic and the bottom is diastolic. Systolic blood pressure is the pressure in the heart during contraction, and diastolic is during relaxation. Acute exercise causes a decrease in systolic blood pressure because the stroke volume (the volume of blood pumped from the left ventricle per beat) decreases during exercise, which means there is less pressure in the arteries during contractions. Diastolic pressure has been shown to increase immediately following resistance training (Stohr, 2017). However, after chronic exercise, the heart adapts and increases stroke volume, because it becomes more efficient with each contraction as it strengthens with exercise. Dimeo (2012) explained that aerobic exercise reduces resting systolic and diastolic blood pressure, even in people with resistant hypertension who have tried to control their blood pressure with three or more antihypertensive medications. Although it is clear that resistance training and aerobic training decrease risk for hypertension, what is unclear is how the body adapts to chronic aerobic or resistance training when looking at resting blood pressure and post-exercise blood pressure.

Body composition consists of fat free mass (non-adipose tissue) and fat mass. To have lower body fat percent, Sanal (2013) has shown that incorporating resistance training into your weekly workout routine is most effective because it helps reduce the amount of fat free mass loss and increase resting metabolic rate to burn more fat. When comparing body compositions of people who do only aerobic training and those who do aerobic training with resistance training, those who incorporated resistance training into their workouts had lower percent of fat and more fat free mass (Sanal, 2013).

The purpose of this study is to compare the physiological differences in aerobic endurance athletes and highly resistance trained athletes. The hypothesis is that the first variable, the VO2 max test results, will be higher for aerobic endurance trained athletes due to the physiological adaptations their bodies have made in response to high volume aerobic exercise. The next variable, resting heart rate is hypothesized to be lower in aerobic trained athletes because as aerobic training volume increases, resting heart rate decreases since cardiac output increases. Resting lactate levels, the …variable, will be lower in the aerobic group (AG) because of muscular adaptations. In highly resistance trained athletes the hypothesis is their body composition will be lower since resistance training increases metabolism for a longer period of time after training when compared to aerobic training. Body composition will be lower because excess post-exercise oxygen consumption (EPOC) is when the body accumulates a debt of oxygen which forces it to work harder post-exercise to maintain homeostasis. In order for the body to do this, the metabolism increases after a workout, especially after heavy weight training with large muscle groups (Chmura, 2010).

METHODOLOGY

Participants:

Participants were recruited from the Akron Triathlon Club and Akron Barbell Club through club emails and individual emails. All of the participants who volunteered were asked to follow standard pre-test instructions that include the following: no eating, drinking, or exercise for two hours prior to testing, wear minimal tight clothing, and all extra weight (jewelry, watches, etc.) were removed. In order to be in the aerobic group, participants had to report five hours or more per week of running, biking, or swimming at moderate to vigorous intensity. To be placed in the resistant group, subjects had to perform five hours or more per week of resistance training or weight lifting. The sample size was n=9 for AG and the sample size for RG was n=8.

Procedure:

Participants were assigned a code number to maintain anonymity. Anthropometric measurements taken included height, age, sex, and weight. Participants sat in the BOD POD[1] chamber for two consecutive tests, each lasting approximately 45 seconds. Resting blood pressure was measured with a stethoscope and sphygmomanometer after being seated for at least five minutes prior to entering the BOD POD. Resting heart rate was measured using a heart rate monitor on the chest in the seated position. Lactate levels were measured using the handheld lactate analyzer with a finger stick in the same seated resting position prior to performing the BOD POD and VO2 maximum test. After all resting measurements were taken, each participant cycled for five minutes at 1.0kp at 55rpm on the cycle ergometer to warm up before performing a

VO2 max test. The warm up was five minutes on the bike in order to warm up their body for the VO2 max test. After the VO2 max test is complete, another lactate measurement and blood pressure was taken within one minute after the end of the max test.

Once all resting measurements were taken, and the participant had properly warmed up, they performed the VO2 max using the Bruce Protocol. The Bruce protocol is broken down by the following stages:

Stage	**MPH**	**% Grade**	**Time in Minutes**
1	1.7	10	3
2	2.5	12	6
3	3.4	14	9
4	4.2	16	12
5	5.0	18	15
6	5.5	20	18
7	6.0	22	21
8	6.5	24	24
9	7.0	26	27

Table 1: Bruce Protocol for VO2 maximum treadmill testing with each stage, mph per stage, % grade and time in minutes.

The means of each group +/- the standard deviation were used as a comparative measure. This study is an experimental cohort study because two groups of people with defining characteristics (AG and RG) are being compared.

RESULTS

The purpose of this study was to compare the physiological differences in aerobic endurance athletes and resistance trained athletes. The hypothesis was that aerobic endurance athletes would have lower resting and final heart rates, lower resting and final blood pressure, resting and final lactate about the same as resistance athletes as well as body fat percent about the same, but much higher VO2 max.

#	A hrs/wk	R hrs/wk	Sex	Age (yrs)	Height (in)	Weight (lbs)
1	4	6	F	21	62.2	137
2	4.5	6.5	F	22	65.0	137
3	4	6	M	24	69.3	169
4	0	6	M	22	63.0	143
7	1.5	7	M	20	68.9	163
10	4	8	M	21	71.0	168
15	0	10	M	25	69.0	194
17	0	6	M	20	71.6	183

Table 2: Anthropometric data for Resistance Group (RG).

#	A hrs/wk	R hrs/wk	Sex	Age (yrs)	Height (in)	Weight (lbs)
5	7	4.5	F	23	66.0	143
6	6	4	F	23	66.0	132
8	8	1	M	20	71.7	199
9	8	0	M	25	65.4	125
11	8	1	F	20	62.6	128
12	10	4.5	F	20	66.5	136
13	6	0	M	19	68.0	143
14	10	0	M	19	71.3	227
16	5	0	F	21	63.0	126

Table 3: Anthropometric data for Aerobic Group (AG).

Resistance																
Name	A hrs	R hrs	VO2 max	VO2 Norm	VO2 %	% Fat	BF Norm	BF %	RS	RD	FS	FD	RHR	MHR	RL	ML
4	0	6	40	Poor	31	16.6	Fair	50	115	70	130	62	70	197	1.7	10.1
1	4	6	39.5	Good	60	27.7	Poor	23	110	60	132	68	84	188	0.7	1.7
2	4.5	6.5	45	Excellent	84	18.7	Good	68	110	67	140	76	72	185	1.5	12.9
7	1.5	7	49.5	Good	76	12.4	Good	72	122	64	130	62	83	178	1.9	22.5
3	4	6	51.4	Excellent	83	15.4	Fair	57	118	70	140	74	66	186	1.1	9.5
10	4	8	56.1	Superior	96	12.9	Good	68	118	74	150	60	63	177	7.6	12
15	0	10	50.6	Excellent	78	5.6	Very Lean	97	122	72	160	58	80	203	0.6	18
17	0	6	51.9	Excellent	85	2.8	Very Lean	99	120	70	153	48	86	186	NA	23.3
Mean	**2.3**	**6.9**	**48.0**		**74.1**	**14.0**		**67**	**117**	**68**	**142**	**64**	**76**	**188**	**2.2**	**13.8**
StDev	**2.0**	**0.4**	**5.4**		**22.2**	**5.8**		**19**	**5**	**4**	**5**	**7**	**8**	**7**	**0.5**	**7.5**
Min	**0.0**	**6.0**	**39.5**		**31.0**	**2.8**		**23**	**110**	**60**	**130**	**48**	**63**	**177**	**0.6**	**1.7**
Max	**4.5**	**10.0**	**56.1**		**96.0**	**27.7**		**99**	**122**	**74**	**160**	**76**	**86**	**203**	**7.6**	**23.3**

Table 4: Raw data from the RG including the group mean, standard deviation, minimum and maximum. A hrs= Aerobic exercise hours per week, R hrs= Resistance hours/week, RS= Resting systolic blood pressure, Rd= resting diastolic blood pressure, MHR= maximum heart rate, RL= Resting lactate, ML= maximum lactate.

Aerobic																
Name	A hrs	R hrs	VO2 max	VO2 Norm	VO2 %	% Fat	BF Norm	BF %	RS	RD	FS	FD	RHR	MHR	RL	ML
16	5	0	51.7	Superior	97	29.1	Poor	18	115	58	148	40	66	196	9.1	11.6
14	10	0	46.7	Good	65	28.4	Very Poor	7	122	68	158	50	78	183	NA	17.4
13	6	0	58.6	Superior	98	7	Very Lean	93	125	62	140	48	64	174	7.9	15.9
12	10	4.5	38.1	Fair	54	19.9	Good	60	118	80	150	60	63	164	4.1	8.3
11	8	1	42.7	Good	76	25.8	Poor	39	110	76	158	58	66	191	6.6	11.7
9	8	0	62.5	Superior	99	4.2	Very Lean	99	110	64	126	42	58	175	4.5	25
8	8	1	55.9	Superior	95	12.8	Good	68	118	64	140	60	56	201	1.9	9
5	6	0	NA	NA	NA	19.3	Good	63	120	65	NA	NA	68	NA	1.7	NA
6	7	4.5	48.7	Superior	94	18.7	Good	67	115	70	148	64	72	183	2.5	11.5
Mean	**7.6**	**1.2**	**50.6**		**84.8**	**18.4**		**57**	**117**	**67**	**146**	**53**	**66**	**183**	**4.8**	**13.8**
StDev	**1.7**	**1.9**	**8.2**		**17.4**	**8.9**		**31**	**5**	**7**	**11**	**9**	**7**	**12**	**2.8**	**5.5**
Min	**5.0**	**0.0**	**38.1**		**54.0**	**4.2**		**7**	**110**	**58**	**126**	**40**	**56**	**164**	**1.7**	**8.3**
Max	**10.0**	**4.5**	**62.5**		**99.0**	**29.1**		**99**	**125**	**80**	**158**	**64**	**78**	**201**	**9.1**	**25.0**

Table 5: Raw data from the AG including the group mean, standard deviation, minimum and maximum.

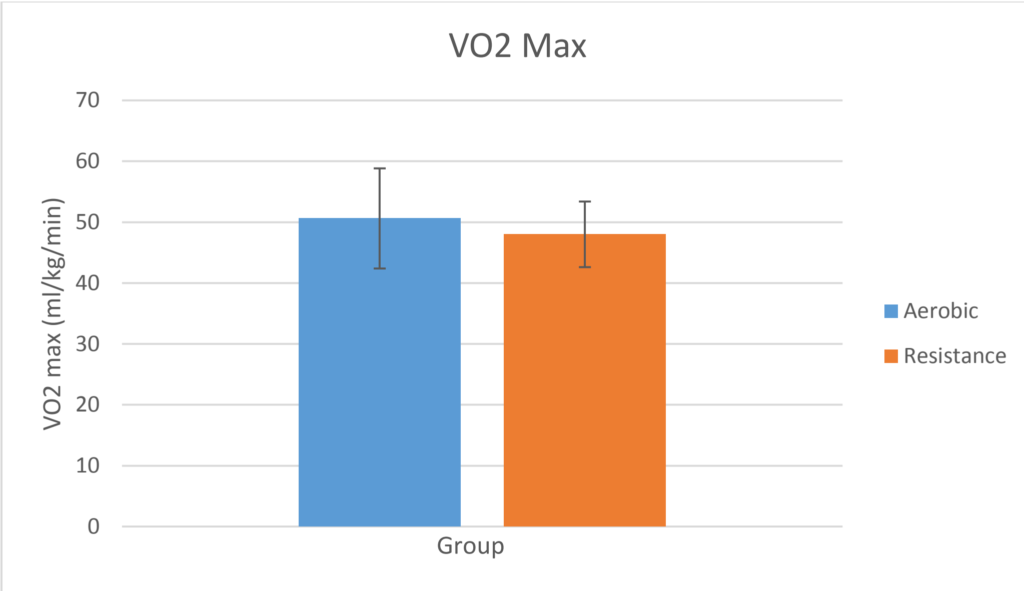


Figure 1: VO2 max means for AG=50.6 +/-8.2 ml/kg/min and RG=48.0 +/-5.4ml/kg/min.

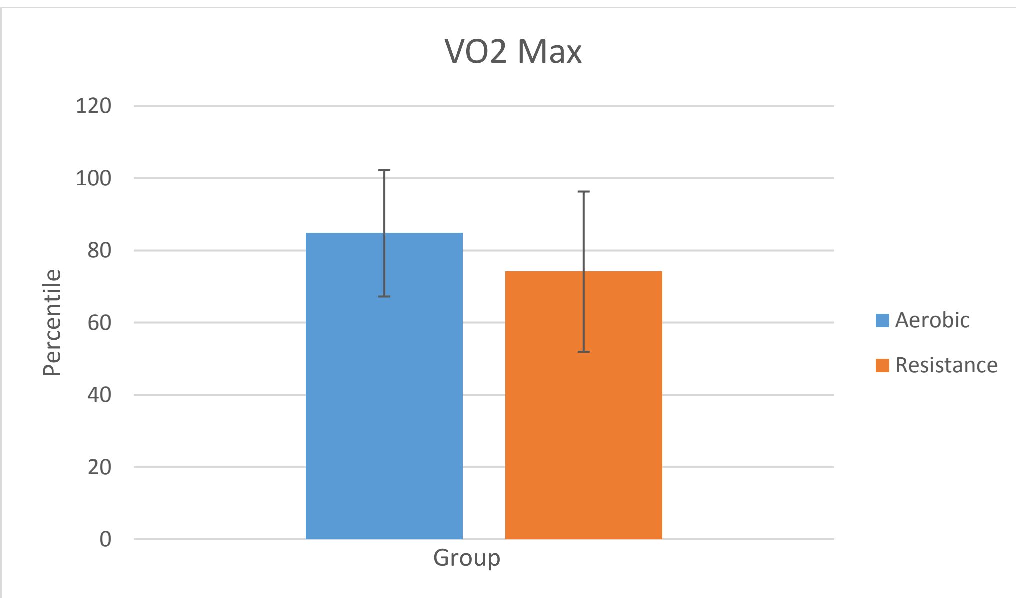


Figure 2: VO2 max percentile means with standard deviations were AG= 84.75+/- 17.5 and RG= 74.1+/- 22.2.

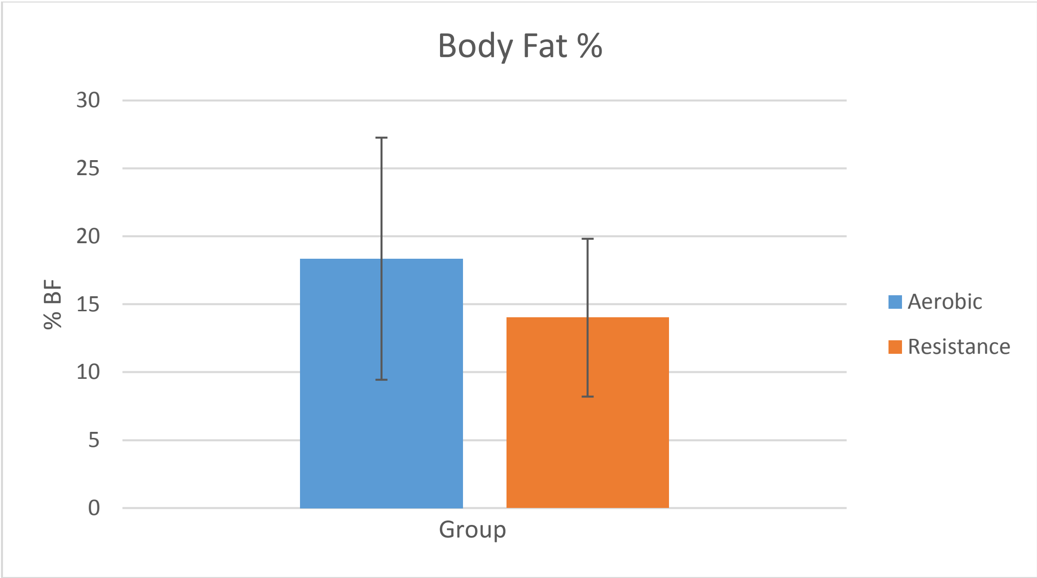


Figure 3: Body fat percent means with standard deviation were AG= 18.4 +/- 9.1% and RG=14.0+/- 5.8%.

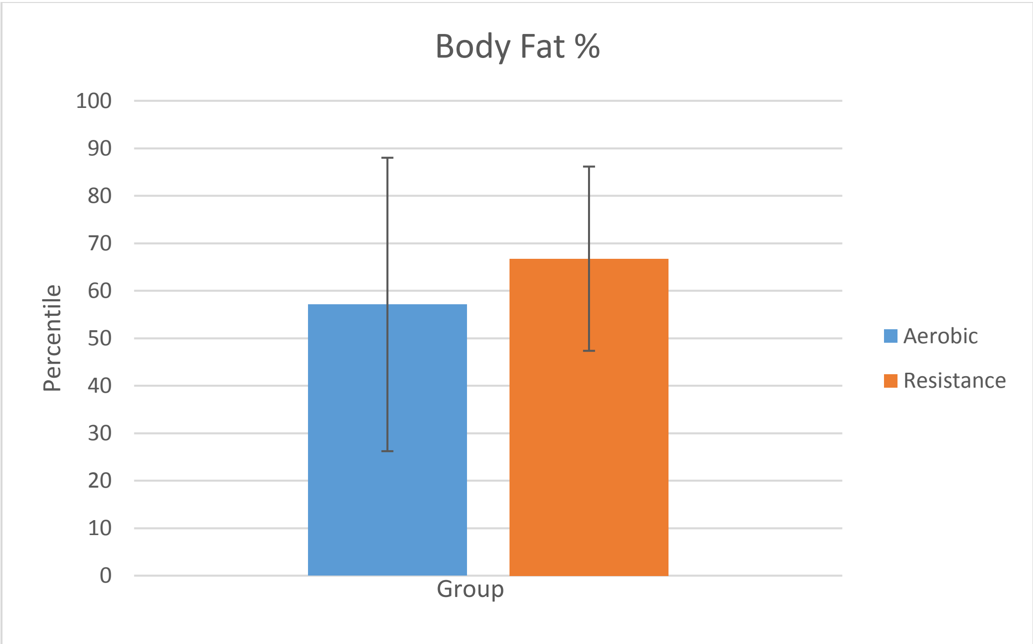


Figure 4: Body fat percent percentile means according to normative data and standard deviations were AG=57.1+/-31.1 and RG=66.8+/-19.4.

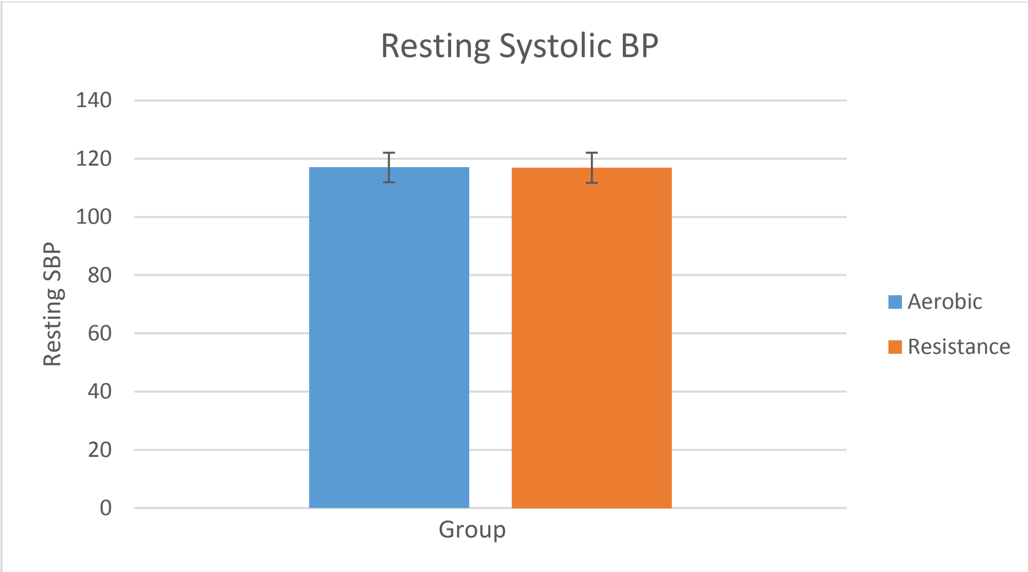


Figure 5: Resting systolic blood pressure means with standard deviations were AG=117.0+/-5.1 mmHg and RG= 116.9+/-5.2 mmHg.

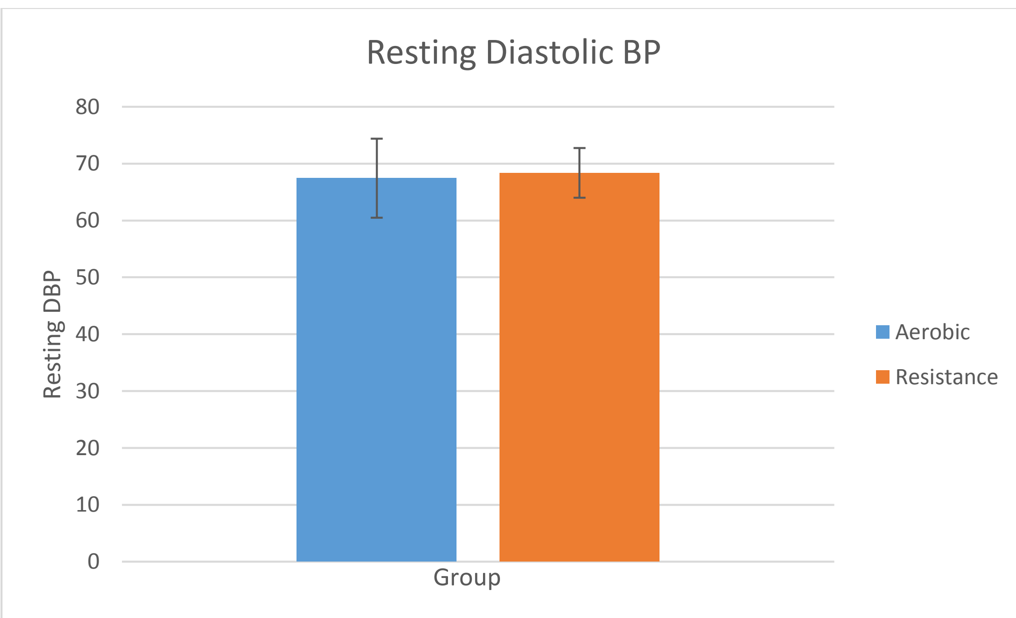


Figure 6: Resting diastolic blood pressure means with standard deviations were AG=67.4+/-6.9mmHg and RG=68.4+/-4.3mmHg.

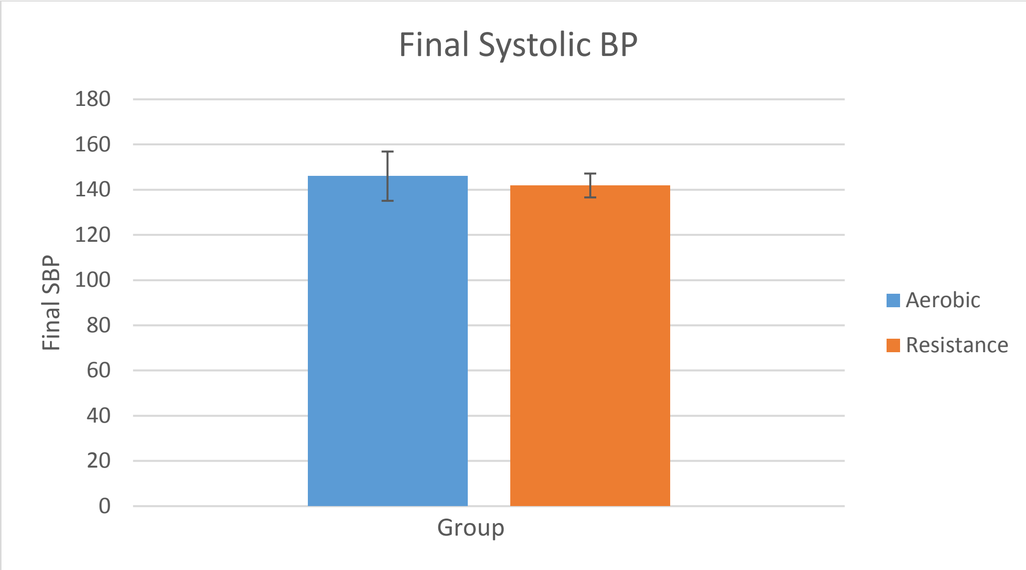


Figure 7: Final systolic blood pressure means with standard deviations were AG=146.0+/-10.6 mmHg and RG=141.9+/-5.2 mmHg.

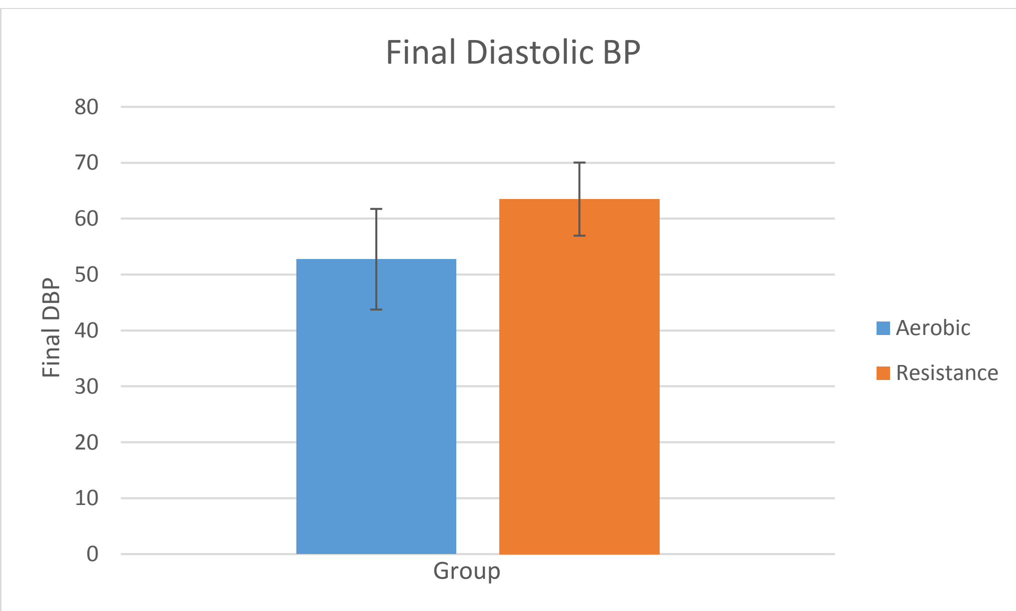


Figure 8: Final diastolic blood pressure means with standard deviations were AG=52.8+/-9.0 mmHg, RG=63.5+/-6.5mmHg.

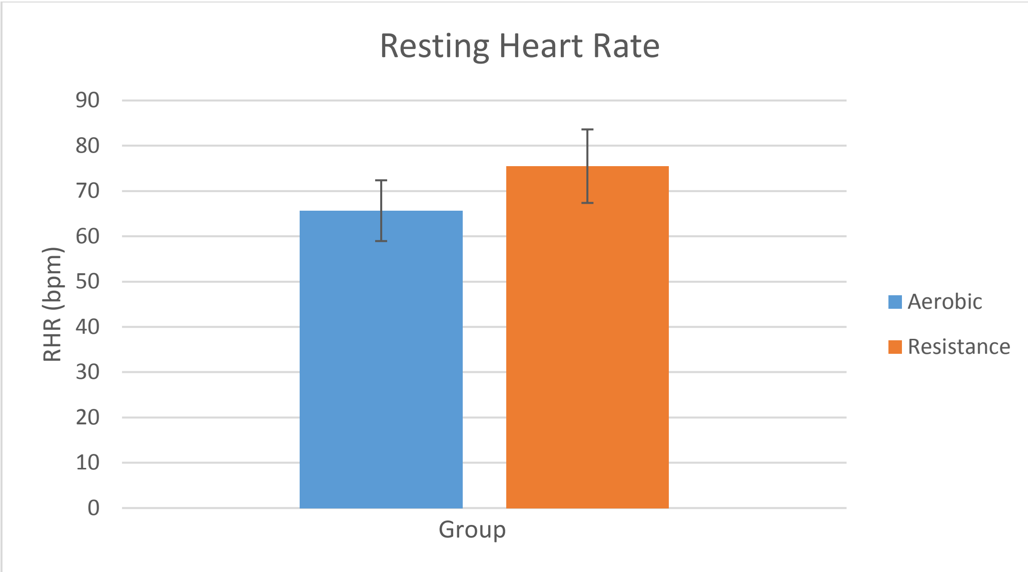


Figure 9: Resting heart rate means with standard deviations were AG=65.7+/-6.7 and RG=75.5+/-8.1.

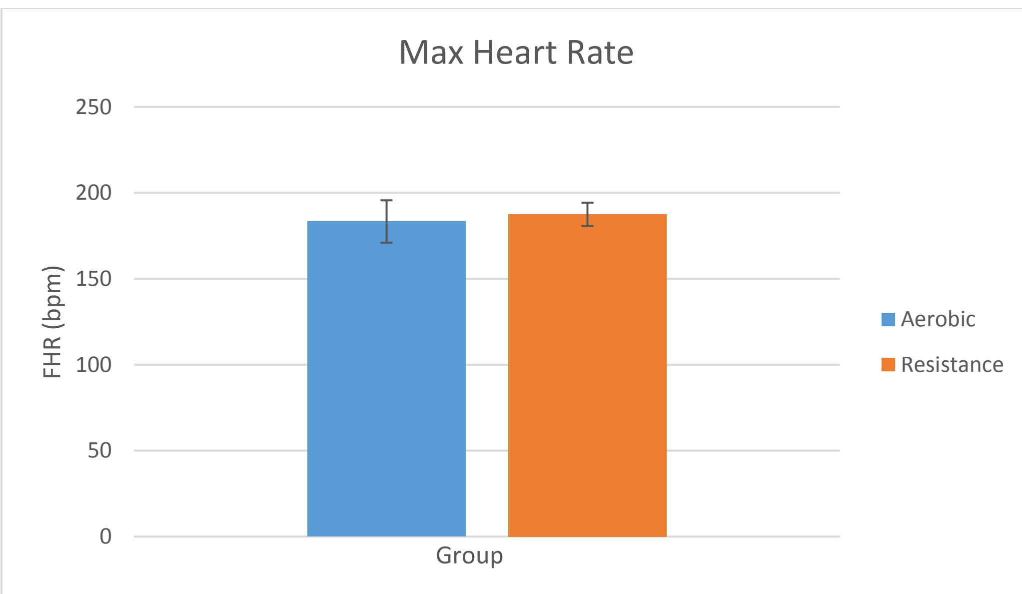
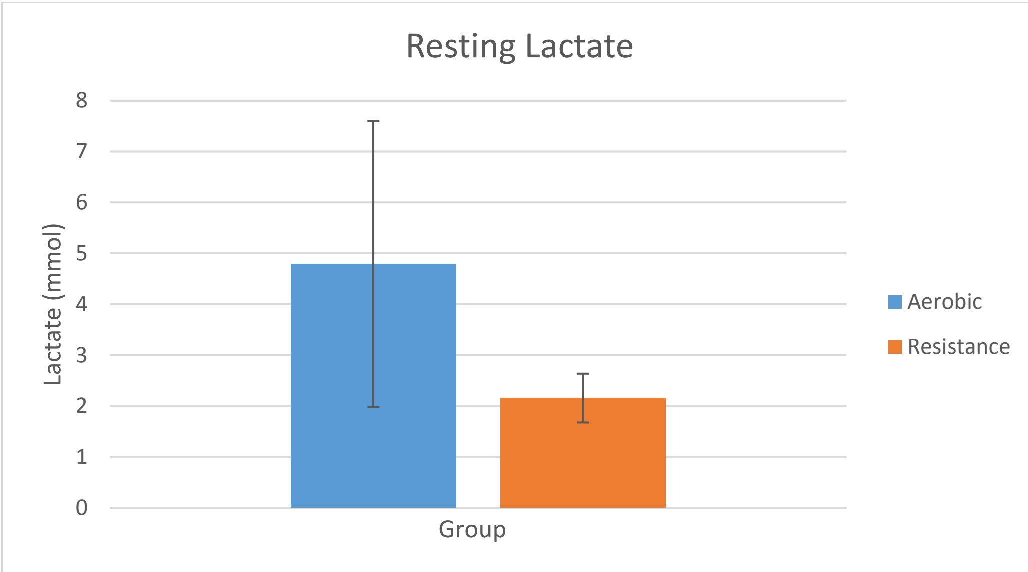
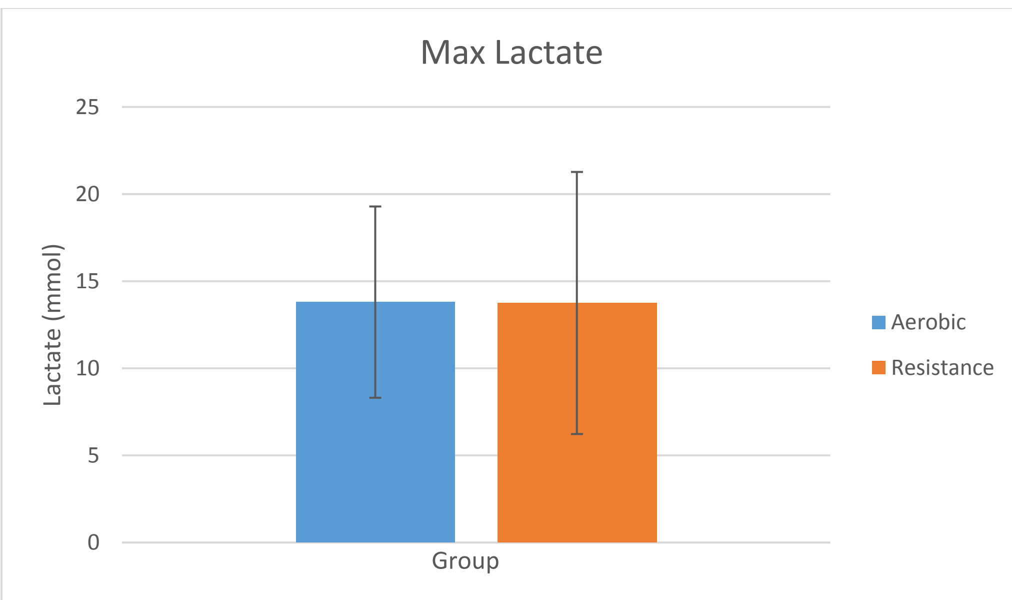


Figure 10: Maximum heart rate means with standard deviations were AG=183.4+/-12.3 and RG=187.5+/-6.8.



<u>Figure 11:</u> Resting lactate level means with standard deviations were AG=4.8+/-2.8 and RG=2.2+/-0.5.



<u>Figure 12:</u> Maximum lactate level means with standard deviations were AG=13.8+/-5.5 and RG=13.8+/-7.5.

The AG VO2 max average was 50.6 ml/kg/min with a maximum value of 62.5 ml/kg/min. The RG VO2 max average was 48.0 ml/kg/min with a maximum value of 56.1 ml/kg/min (Figure 1). The AG VO2 max percentile of normative results was a higher percentile by 10 than RG on average, with the minimum of 54 for AG and 31 for RG (Figure 2).

The AG body fat percent average was 18.4% with a maximum of 29.1%. The RG body fat percent average was 14.0% with a maximum of 27.7% (Figure 3). The AG body fat percentile average was 57 with a maximum of 99. The RG body fat percentile average was 67 with a max of 99 as well (Figure 4).

The AG resting systolic (Figure 5), final systolic (Figure 7), resting diastolic (Figure 6) and final diastolic (Figure 8) blood pressure averages were 117 mmHg, 146 mmHg, 67 mmHg, 53 mmHg respectively and for RG 117 mmHg, 142 mmHg, 68 mmHg, and 64 mmHg respectively.

The resting heart rate averages were 66bpm for AG and 76bpm for RG (Figure 9). Max heart rate averages were 188bpm for RG and 183bpm for AG (Figure 10).

Resting lactate value averages for RG and AG were 2.2 mmol and 4.8 mmol respectively (Figure 11). Maximum lactate value averages for RG and AG were both 13.8 mmol (Figure 12).

DISCUSSION

To properly compare the VO2 max and body fat percent the percentile is important to take into consideration the age and sex of the participants. This creates a larger difference in the two groups because there were more females in the aerobic group than in the resistance group, which would skew the data without taking norms into consideration. The VO2 max results were still higher even without taking the percentiles into consideration. The highest values in each group for VO2 max was 62.5 ml/kg/min (AG) and 56.1 ml/kg/min (RG). When also comparing the percentiles for VO2 max, the AG average was 84.8 while the RG was 74.1. By comparing both of these values, it shows AG has a much higher average percentile and maximum VO2 max.

The AG body fat percent average was 18.4%, and RG was 14.0%. The percentile average for AG was 57 and RG was 67. AG had 4.3% higher body fat than RG and percentile averages were 9.7 below RG averages. Meaning even when taking into account the sex and ages of the participants in each group, the AG had higher body fat than the RG.

The AG resting systolic and diastolic blood pressure were about the same as the RG, however they had a higher final systolic blood pressure by 5mmHg on average and a lower final diastolic blood pressure by 11 mmHg on average.

The AG had 10 bpm lower resting heart rate and 5bpm lower final heart rate averages. Also, AG had lower minimum and maximum resting and final heart rates. Overall the AG group's hearts were more efficient based on the results because they had higher VO2 max results with lower maximum heart rates.

Interestingly, the AG had a resting lactate level of double the RG (4.8mmol compared to 2.2mmol) and they both had the same final lactate level averages. However, the AG had a higher minimum and maximum resting and final lactate level. Two outliers (one in each group) skewed the data because their final lactate levels were so high. One participant from AG had a lactate level after the VO2 max that was higher than the maximum lactate analyzer level (25mmol). Also, one participant from RG had a final lactate measurement of 23.3mmol.

When compared to the information found in other studies, the data supports the hypothesis and previous research showing that a) as aerobic training increases, VO2 max increase b) high cardiovascular fitness levels indicate lower heart rates pre and post-exercise and c) aerobic athletes have higher lactate levels than resistance athletes (Chmura, J., & Nazar, K. 2010). However, the data does not support the hypothesis that aerobic athletes would have lower body fat percent, and lower overall blood pressures when compared to resistance trained athletes.

Seiler, Haugen and Kuffel (2007) found that in general, aerobic trained athletes have lower body fat percent and pre and post exercise blood pressures when compared to resistance trained athletes. This could be due to the small sample size and high fitness levels of both groups.

Limitations and Future Research

The importance of this study is to show how high training volumes of cardio or weight lifting changes the body. Some limitations to this study included the small sample size and the limited population. Future research should include a larger number of participants who have done more hours of aerobic or resistance training to see a more significant difference in the means of the two groups' physiological adaptations. Future research should include a lactate level measurement after the VO2 max test 20 minutes into their recovery. Additionally, more restrictions on the sample population beforehand, such as participants who only do aerobic exercise or only do resistance exercise should be ensured. One way to be sure each group is limited is by creating a survey for the participants to take before participating. Then they could be placed into categories of resistance or aerobic. By doing this, more comprehensive results would be gathered with larger differences in the results of each group.

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