Peak Fat Oxidation Rates in Males with Obesity during Treadmill Walking With Body Weight Support

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Abstract

Purpose: *To determine if a reduction of body weight (BW) from 100% to 75% while walking on a lower body positive pressure (LBPP) treadmill affects peak oxygen consumption ($\dot{V}O_{2peak}$), fat oxidation (FO) and peak fat oxidation (PFO) rates in men with obesity.* ***Methods:*** *Fourteen men with obesity walked on the LBPP treadmill at 100% and 75% of their body weight at 3.3 mph, 3% to 15% grade. FO, PFO, $\dot{V}O_2$ were measured using indirect calorimetry.* ***Results:*** *$\dot{V}O_{2peak}$ was significantly higher at 100% compared to 75% BW and fat oxidation rates were significantly lower at 100%. Fat oxidation rates decreased rapidly for the 100% BW group and decreased steadily for 75% BW, and at 75%, PFO plateaued at 47% - 62% of $\dot{V}O_{2peak}$.* ***Conclusion:*** *Unweighting on the LBPP treadmill is an optimal exercise modality for this population and meets the recommendations for the American College of Sports Medicine for moderate intensity.*

Keywords: lower body positive pressure treadmill, AlterG, fat oxidation, maximal oxygen consumption, obesity

1. Introduction

Data from the Behavioral Risk Factor Surveillance System (BRFSS) of the Centers for Disease Control and Prevention (CDC, 2014) on measured heights and weights (BMI) of young adults indicates that the prevalence of obesity has significantly increased throughout the U.S. over the last 20 years. Projections support that 42% of Americans may end up obese by 2030 (up from 36% in 2010), with 11% being severely obese, roughly 100 or more pounds over a healthy weight (vs. 6% in 2010) (CDC, 2014). Obesity does not discriminate and is threatening the health of people of all ages, ethnicities and socioeconomic backgrounds across the United States.
Therefore, treatments are of great interest to all health-care and fitness professionals. Regular physical activity has been recommended as a strategy in the prevention and management of obesity and can be a challenge for fitness professionals to determine appropriate modalities and to define exercise intensities to insure safety, biomechanical efficiency, improve exercise adherence and motivation.

It is well established that obesity or excess body fat, is associated with an increased risk of multiple chronic and metabolic diseases, as well as orthopedic and psychosocial problems (CDC, 2014). Although many factors are involved in weight regulation, historically obesity has been viewed as an imbalance of energy intake (food consumption), energy expenditure (physical activity) and energy storage (Hill, 2008). Treatment and management of obesity has typically been to modify energy intake and energy expenditure to yield a negative energy balance. Evidence-based clinical guidelines on obesity management support that physical activity is an important tool for improving insulin sensitivity, lipid profile and blood pressure given that it supports the reduction of body weight, body fat, and waist circumference, and can improve maximal aerobic capacity ($\dot{V}O_{2max}$) (ACSM, 2014; NHLBI, 2012; WHO, 2010; Wing, 1999).

Mechanisms that trigger some of the favorable outcomes of exercise in obese individuals are the effect of exercise training on substrate utilization, which is how the body burns fats and carbohydrates to fuel a muscle contraction. Exercise training and substrate utilization is well documented in normal weight individuals (Jeukendrup, Saris, & Wagenmakers, 1998; Kanaley, Weatherup-Dentes, Alvarado, & Whitehead, 2001; van Loon, Jeukendrup, Saris, & Wagenmakers, 1999), where fat is the preferred energy source at rest and low to moderate intensity exercise of long duration (Brooks & Mercer, 1994; Romijn et al., 1993; Thompson, Townsend, Boughey, Patterson, & Bassett, 1998). A number of studies have indicated that individuals who are obese have an impaired ability to utilize fat as a fuel during exercise as well as after weight loss has been achieved (Achten & Jeudendrup, 2004; Blaak & Saris, 2002; Jeukendrup & Wallis, 2005). Stored in adipose (fat) tissue, triglycerides are the major source of energy derived from fat which then become available as free fatty acids (FFA). During exercise of long duration it is necessary to maintain adequate levels of circulating FFA to provide energy (Kanaley et al., 2001) and given that obese individuals possess greater fat stores, exercise may be an ideal impetus to mobilize and oxidize fats (Philllips et al., 1996).

It is well documented that the ability to utilize fat during exercise in normal weight individuals (Friedlander et al., 1998; Jeukendrup, Mensink, Saris, & Wagenmakers, 1997; Kanaley et al., 2001; Phillips et al., 1996; van Loon, Greenhaff, Constantin-Teodosiu, Saris, & Wagenmakers, 2001) and in obese populations (van Aggel-Leijssen, Saris, Wagenmakers, Senden, & van Baak, 2002) is increased following endurance exercise training. Therefore, exercise interventions to increase FFA oxidation in overweight and obese individuals may be important in weight management and may have the potential to reduce health risks (Achten & Jeukendrup, 2004; van Aggel-Leijssen, Saris, Wagenmakers, Hul, & van Baak, 2001). Although regular physical activity as a tool for management of overweight and obese individuals have proven health benefits, modes such as walking and running present, for many, a challenge due to the additional weight loads on the joints in the lower extremities, which frequently creates stress and results in secondary injuries (Browning & Kram, 2007). Weight bearing exercise with an excess of body weight may increase the potential for injury or exacerbate existing joint conditions and may further influence one's ability to exercise. The American College of Sports Medicine (ACSM, 2014) recommends non-weight bearing exercise to minimize injury, low to moderate intensity (40% to 65% $\dot{V}O_{2max}$) and long duration exercises (> 30 minutes) to increase fat oxidation for individuals who are overweight and obese. Based upon the possible negative outcomes associated with many weight-bearing exercises in those with obesity, further investigation of available non-weight bearing exercise is warranted.

In light of the ACSM (2014) requirement, a variety of non-weight bearing low impact exercise devices and protocols has emerged on the market and in the literature. More recently, a lower pressure positive pressure device (LBPP), the AlterG® anti-gravity treadmill, developed by NASA is currently being used in rehabilitation of lower extremity injuries, spinal cord, and stroke. The AlterG® contains an airtight chamber where a subject zippers the aperture attached to the treadmill to a pair of neoprene shorts with a kayak-style spray skirt at the waist. Once zippered in, an airtight seal is created from the subject's waist to the feet and a small increase in air pressure applies a lifting force to the subject's lower body allowing for the manipulation of unweighting up to 80% of an individual's body weight. The AlterG® eliminates the drag forces of the legs, allowing for similar gait patterns to normal weight land walking, does not impede circulation and is more comfortable, adjustable and can be used for extended periods of time (Grabowski, 2010). Recent investigations (Aaslund & Moe-Nilssen, 2008; Cutuck, et al., 2006; Figueroa, Manning, & Escamilla, 2011; Grabowski, 2010; Grabowski & Kram, 2008; Raffalt, Howgaard-Hansen, & Jensen, 2013) demonstrate favorable changes in physical activity levels, exercise tolerance with similar results in cardiorespiratory responses compared to over-ground walking. While these findings support anti-gravity training as having positive changes in health outcomes in healthy individuals, further investigation is required to assess its effectiveness in the overweight and obese individual.

1.2 Purpose of the Study

The purpose of this study was to compare the effects of walking on the AlterG® anti-gravity treadmill at 100% body weight (BW) compared to 75% BW on peak oxygen consumption ($\dot{V}O_{2peak}$), fat oxidation (FO) and peak fat oxidation (PFO) rates in men classified as obese.

2. Methods

2.1. Subjects

Eighteen men recruited for the present study were classified as overweight or obese (BMI > 25 kg/m^2, percent body fat > 22%) according to the Centers for Disease Control (2014) and ACSM (2014) respectively. Two participants did not meet the inclusion criteria and two ended up dropping out due to lack of time. Fourteen participants gave written informed consent after the experimental procedures were explained to them. The Institutional Review Boards of both Seton Hall University and William Paterson University approved this study. Physical characteristics of the study participants are summarized in Table 1.

To standardize the testing conditions and to insure safety of the subject, the following pre-test instructions were given to each subject before their first visit: (1) Abstain from eating 12 hours before the test (2) Abstain from consuming caffeine-containing products for a minimum of 12 to 24 hours before the test (3) Abstain from strenuous exercise for at least 24 hours before the test, and (4) Consult the researcher on the potential use of any over the counter medication as some may effect resting or exercise heart rate and may effect test accuracy.

To obtain a power of 0.8 at alpha < 0.05, the paired samples *t*-test for two treadmill conditions was based on a priori calculation that was determined in a pilot study. A sample size of 14 subjects was required to determine $\dot{V}O_2$, FO and PFO rates between two treadmill conditions of the same subject (G*Power Version 3.1.5).

2.2. General Design

The participants attended the laboratory for three sessions where the last two sessions were separated by at least three days but not more than seven days following the anthropometric and body density measurements. All sessions took place in the same laboratory where air temperature was 24.1 ± 3°C and relative air humidity was 20° ± 5%.

Session 1 - (Anthropometric Measurements and Body Density):

Participants reported to the Human Performance Lab at William Paterson University where they completed the informed consent and PAR-Q. Baseline measures of height, weight, waist and hip circumference were measured barefoot and in their underwear. Body composition was determined by measuring body density using underwater weighing.

Session 2 and 3: Exercise Test:

During both sessions subjects were familiarized with the equipment and procedures. The subjects reported to the laboratory after a 12-hour overnight fast and at approximately the same time for each of the two sessions to avoid variations in their circadian rhythms. Resting blood pressure was recorded and then the subjects were prepped for ECG placement to determine resting and exercise heart rates. Subjects were then fitted with a mask, which was connected to the metabolic cart (MMC) in order to analyze $\dot{V}O_{2peak}$, FO and PFO. This MMC uses an open circuit spirometry method to analyze the gas exchange of carbon dioxide and oxygen ($\dot{V}CO_2$ and $\dot{V}O_2$) on a breath-to-breath basis. The volume and gas analyzers of this system were calibrated using a 3-L syringe prior to each subject test and according to the manufacture's specifications. Subjects were then instructed to put on the neoprene shorts and then they were zipped in to the treadmill aperture. Before the test, the air pressure in the chamber adjusted to apply the proper lifting force for each subject by way of a built in pressure feedback system. The treadmill tests were randomized where the subject began on either the AlterG® at 100% or 75% of their body weight.

After the calibration process a warm up of 2.0 mph for 3 minutes at 100% body weight was performed. The participants in random order (100% or 75% BW) began to walk at 3.3 mph at 0% grade. The speed was held constant for the duration of the test whereas the gradient increased every 3 minutes by 3% up to 15% grade. Heart rate (HR) and Rating of Perceived Exertion (RPE) were recorded during the last 5 seconds of each stage and blood pressure was recorded during the last 30 seconds of each stage. The test was terminated if the participant experienced adverse signs or symptoms (ACSM, 2014) or requested to stop. Additionally, participants were believed to have reached their true $\dot{V}O_{2max}$ if the following conditions were met: (a) a plateau in $\dot{V}O_2$ (b) a heart rate within 5-10 beats of their age-predicted maximal heart rate (220-age × .85), (c) RPE of 18-20 and (d) a respiratory exchange ratio (RER) of 1.10.

2.3. Indirect Calorimetry Calculations

Indirect calorimetry was done to estimate fat oxidation during walking and was calculated according to the Stoichiometric equations of Jeukendrup and Wallis (2005), assuming that urinary nitrogen was negligible.

$$\text{Fat oxidation (g/min)} = 1.67 \times \dot{V}O_2 - 1.67 \times \dot{V}CO_2$$

Average values for $\dot{V}O_{2peak}$ were recorded at the completion of each three-minute stage. Values of $\dot{V}O_2$ (ml/min) and $\dot{V}CO_2$ (ml/min) were averaged over the last two minutes of each stage to calculate fat oxidation and fat oxidation rates.

2.4. Statistical Analysis

Kolmogorov-Smirnov & Shapiro Wilk tests for normality were completed on all variables to determine homogeneity of variances. Differences between the two treadmill conditions (100% BW & 75% BW) for $\dot{V}O_{2\ peak}$, FO, and PFO rates were performed using a paired samples t-test. PFO rates were determined by the highest rate of fat oxidation during each condition and expressed as a percentage of $\dot{V}O_{2peak}$. The results are presented as mean ± standard deviation and level of significance was set at $p < .05$. All data were recorded and uploaded into Microsoft® Excel (version 14.4.1) and statistical analysis was performed using the SPSS IBM statistical package (v. 19, Chicago, IL). All effect sizes for Cohen's d were classified as small (0.1), medium (0.3) and large (>0.5) and were analyzed in G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009).

3. Results

3.1. Peak Oxygen Consumption ($\dot{V}O_{2peak}$)

Oxygen consumption peaked at 23.07 ml/kg/min in the 100% BW group and peaked at 17.69 ml/kg/min in the 75% BW group. A paired samples *t*-test showed the difference in $\dot{V}O_{2peak}$ between the 100% BW and 75% BW condition were statistically significant, ($t(13) = 3.97$, $p < 0.05$), 95% *CI* (2.45, 8.31), $d = 1.06$. The effect size of 1.06 and was found to exceed Cohen's (1988) convention for a large effect ($d = .80$) suggesting a high practical significance. Figure 1 shows the difference between the two treadmill conditions where participants in the 100% BW group reached a higher $\dot{V}O_{2peak}$ ($M = 23.07$, $SD = 4.23$) than the 75% BW group ($M = 18.70$, $SD = 3.72$).

3.2 Fat Oxidation (FO) and Peak Fat Oxidation (PFO)

As exercise intensity for the 100% BW condition increased, fat oxidation rates decreased from 0.22 g/min to below 0 and at 75% BW decreased from 0.23 g/min to 0.03 g/min. Fat oxidation at 0 or below represents an RER of 1 or higher indicates 100% reliance on CHO. A paired samples *t*-test showed a difference in FO rates between the 100% BW condition and the 75% BW condition were statistically significant, ($t(13) = -3.56$, $p < .01$), 95% *CI* (-.37, -.09), $d = .95$. Further, Cohen's effect size value ($d = .95$) suggested high practical significance. Table 2 depicts the mean and standard deviation for $\dot{V}O_{2peak}$ and rates of FO where Figure 2 shows the difference between the two treadmill conditions where participants in the 100% BW group had lower fat oxidation rates ($M = -0.19$, $SD = .40$) than the 75% BW group ($M = .04$, $SD = .40$). Furthermore, PFO rates plateaued at 48 - 58% of $\dot{V}O_{2peak}$ (0.22 g/min at 9.21 ml/kg/min) in the 100% BW condition then rapidly declined. At 75% BW, PFO rates plateaued at 47 to 62% of $\dot{V}O_{2peak}$ (0.23 g/min, 0.23 g/min at 17.69 ml/kg/min) and slowly declined (Figure 3).

4. Discussion

The purpose of the present study was to determine the differences between walking at 100% BW and 75% BW in $\dot{V}O_2$, FO, and PFO rates. The primary findings were that there were significant differences in all dependent variables when walking on the AlterG® anti-gravity treadmill at 100% BW compared to 75% BW. The main finding of this study was that fat oxidation rates in the decreased BW condition, was observed at a low intensity (47 to 62% $\dot{V}O_{2peak}$) indicating a safe alternative for men with obesity who complain of too much body weight on their joints. Another important finding was that fat oxidation rates are higher and stay elevated longer during the 75% BW condition compared with the 100% BW condition allowing an individual to exercise longer. If one is able to exercise longer, there is the potential to oxidize more fat, ultimately improving body composition, energy expenditure and experience the joy of moving in a safe and pain-free environment. Exercise intensity is one of the most important factors that determine fat oxidation rates during exercise. Exercise intensity in most studies is expressed as %$\dot{V}O_{2max}$. In a study done on fat oxidation rates over a wide range of intensities, maximal rates fat oxidation ranged from approximately 47 to 52% $\dot{V}O_{2max}$in the general population (Achten & Jeukendrup, 2004).

Bogdanis, Vangelakoudi, and Maridaki(2008) reported that in overweight sedentary men and women maximal fat oxidation was observed at a low intensity (50 % and 40% respectively). Furthermore, Fat_{max} has also been found at low to moderate intensities that range from 33 to 65% of $\dot{V}O_{2max.}$ (Friedlander et al., 1998; Romijn et al., 1993; van Loon et al., 2001; Venables, Achten & Jeudendrup, 2005). Optimal intensity for fat oxidation is approximately 50% of $\dot{V}O_{2max}$ for untrained individual (Achten & Jeukendrup, 2004; Jeukendrup & Wallis, 2005) where activities of intensities higher than maximal fat oxidation have shown that fat oxidation rates decrease markedly (Achten & Jeukendrup, 2003). Fat oxidation rates in the current study peaked at 40% of the subjects $\dot{V}O_{2peak}$ (0.22 g/min at 9.21 ml/kg/min, respectively) which occurred in the first three minutes of the exercise session at 100% BW then decreased dramatically. In the 75% BW condition fat oxidation rates peaked at 47 to 62% of the subjects $\dot{V}O_{2peak}$ (0.23 g/min at 17.69 ml/kg/min) and occurred in the first 6 minutes of the exercise session. Fat oxidation rates in the current study of young men are consistent with the studies of Bogdanis et al. (2008) and O'Deriaz et al. (2001) that used middle-aged obese men.

Peak fat oxidation rates in the current study are also consistent with the 62% reported for moderately trained athletes who participated in a running protocol compared to a cycling protocol (Achten & Jeukendrup, 2003). Furthermore, according to van Aggel-Liejssen et al. (2002) low intensity training at 40% of peak $\dot{V}O_2$ demonstrates an increase in total fat oxidation in obese men, where training at 70% of $\dot{V}O_{2max}$ did not affect total fat oxidation. The exercise intensity in the current study is in agreement with and Bogdanis et al. (2008), O'Deriaz et al. (2008) and van Aggel-Liejssen et al. (2002) where peak fat oxidation occurred at approximately 40% - 62% of $\dot{V}O_{2peak}$. It is suggested based on past and current research, to keep the percent (%) gradient at the level of maximal fat oxidation (3% grade), which may lead to greater fat being oxidized over a longer period of time. Fat oxidation rates began to decrease steadily at the second stage of exercise (6 minutes, 3.3 mph, 3% grade) to below 0 where CHO become the dominant fuel. At approximately 9 minutes fat oxidation began to decrease at approximately 70% of the participants $\dot{V}O_{2peak}$ which is consistent with the literature where fat oxidation become negligible at intensities >70% (Jeukendrup & Wallis, 2005; van Aggel-Leijssen et al., 2002; Venables & Jeukendrup, 2008).

The mode of exercise also has an effect on fat oxidation where fat oxidation has been shown to be higher for a given oxygen uptake during walking and running compared to cycling (Achten & Jeukendrup, 2004). Most studies have used cycling where fat oxidation is 30% lower compared to treadmill walking and has been suggested that this is due to the power output per muscle fiber in cycling compared to running (Achten & Jeukendrup, 2003).

Three studies that determined peak fat oxidation during walking all used a speed that may not be desirable for the overweight/obese sedentary population (Achten & Jeukendrup, 2003; Venables et al., 2005; Venables & Jeukendrup, 2008) where two studies (Bogdanis et al., 2008; O'Deriaz et al., 2001) used a speed that was desirable for the overweight/obese population. O'Deriaz et al. (2001) used a walking speed of 2.7 mph with three gradients (3%, 5% and 6%) with his 58 middle-aged obese male participants and found that PFO occurred at 42% of the $\dot{V}O_{2max}$. Furthermore, Bogdanis et al. (2008) studied inactive overweight men and women approximately 36 years old and used a walking speed that was closer to the self-selected speed by overweight and obese individuals as determined by Browning & Kram (2007). The treadmill speed in the present study (3.3 mph) was similar to the self-selected speed of walking according to Browning and Kram, (2007) and Minetti, Boldrini, Brusamolin, Zamparo, and McKee (2003) (3.2 mph). Walking is a low intensity exercise and may be a preferable mode of exercise for overweight and obese individuals compared to cycling due to their large musculature of the legs and buttocks, which makes the body position uncomfortable. Moreover, walking at 75% BW demonstrated that the contribution of fat metabolism to energy expenditure at the same exercise intensity was greater than when compared to the 100% BW condition. Several studies have recommended that overweight individuals need to participate in low intensity exercise compared to normal weight individuals (Perez-Martin & Mercier, 2001; van Aggel-Leijssen et al., 2002).

Several studies have shown that total fat oxidation during exercise was greater in obese than in normal weight individuals (Goodpaster, Wolfe, & Kelley, 2002; Kanaley et al., 2001). In contrast, fat oxidation at different intensities in overweight/obese individuals showed a lower rate of fat oxidation than normal weight individuals (Bogdanis et al., 2008; Perez-Martin & Mercier, 2001). In the present study, those who were in the reduced BW group showed an increase in fat oxidation at a lower intensity, which began to decrease as intensity, increased.

It has been shown that fat oxidation rates can be reproduced in one individual however; several studies indicate there is a large inter-individual variation as to where maximal fat oxidation occurs (Venables et al., 2005). A cross sectional study demonstrated that large differences exist in the ability to oxidize fat during exercise (Venables et al., 2005). In the same study, fat oxidation rates have been shown to range from 0.18 to 1.01 g/min. It was concluded that lean body mass, physical activity levels, $\dot{V}O_{2max}$, gender and fat mass accounted for 35% of the variation in peak fat oxidation rates, however 66% of the variance could not be explained. Although diet is likely to explain some the variance there is still a large part of the variance that remains unexplained.

5. Summary and Conclusions

Fat oxidation is important in controlling body weight in both trained and untrained individuals. In a recent meta-analysis, it is well confirmed that training at maximal fat oxidation (3 times per week) decreases fat mass, body weight and improves cholesterol (Romain et al., 2012). Furthermore, there has been a lot of interest in how to maximize fat loss for the purpose of weight control. The present study was the first study to be done on fat oxidation rates on a treadmill where one can unweight a body. The results of the present investigation provide practical implications for an optimal exercise prescription utilizing the anti-gravity treadmill. There also seems to be a large variation where peak fat oxidation occurs at a given intensity and has been suggested that this is a result of body composition, gender, and the type of exercise activity (Achten et al., 2003; Perez-Martin & Mercier, 2001; Tarnopolsky, 2008). Unweighting demonstrated the exercise intensity that promoted maximal fat oxidation occurred between 47% and 62% of $\dot{V}O_{2peak}$. Interestingly, a moderate intensity is suggested by ACSM (2014) for weight control and cardiovascular health in overweight and obese individuals.

There is also emerging evidence that LBPP devices appear to have a variety of benefits with no harmful effects in men, women and the elderly (Cutak et al., 2006). Therefore, LBPP training is a modality that is gaining popularity to study unweighting the body during exercise without altering gait, heart rate or blood pressure. In conclusion, if the goal when prescribing exercise to the overweight/obese population is to increase fat oxidation then based on the results of the present investigation, it would be suggested to unweight the body to 75% at an exercise intensity between 40 and 65% of $\dot{V}O_{2peak}$ with no increase in percent grade past 3%.

5.1 Limitations

It is important to acknowledge that this study involved healthy male subjects between 20 and 28 years old therefore, conclusions cannot be generalized to patient populations. Another limitation was that diet and activity levels were not monitored. Fat oxidation rates are affected by diet and activity and area valid reason to find ways to control these variables. Finally those who are characterized as extremely obese may not fit into the shorts.

5.2 Future Recommendations

Obesity research has become a priority, and is a national concern. The current research provides a starting point investigating LBPP and fat oxidation in overweight and obese individuals. Areas that require further investigation in the un-weighted environment are continued high quality research such as randomized control trials, in a variety of populations to validate recommendations for exercise training and fat loss. In addition future studies are needed to address the effects of LBPP on weight control in overweight or obese individuals for both walking and running. Furthermore, there is limited research on maximizing fat as a fuel for exercise compared to simply promoting total caloric expenditure and more studies are needed to identify optimal training protocols for weight reduction in overweight and obese individuals.

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Table 1: ***Descriptive statistics for 14 participants***

	N	Minimum	Maximum	Mean	SD
Age (y)	14	20.00	28.00	23.50	2.42
Height (m)	14	1.63	1.87	1.75	.07
Weight (kg)	14	88.50	145.82	111.59	16.37
Bodyfat (%)	14	25.50	44.00	37.02	6.19
BMI (kg/m^2)	14	30.9	44.10	36.51	3.82
Waist (cm)	14	88.9	125.00	104.30	9.73
HR_{max}(bpm)	14	192.0	200.00	196.86	2.44
HR_{85} (bpm)	14	163.0	170.00	167.25	2.00
Valid N	14				

Table 2: ***Mean ± SD values for peak VO2 and FO.***

	100% BW	75% BW	*p*
VO_2 (ml/kg/min)	23± 4	17 ± 3	0.002*
FO(g/min)	0.23 ± 0.4	0.03 ± 0.4	0.004*

Values are means ± SD. VO_2, oxygen consumption; RER, respiratory exchange ratio; FO, fat oxidation. ***p*< 0.05, 100% BW compared to 75% BW**

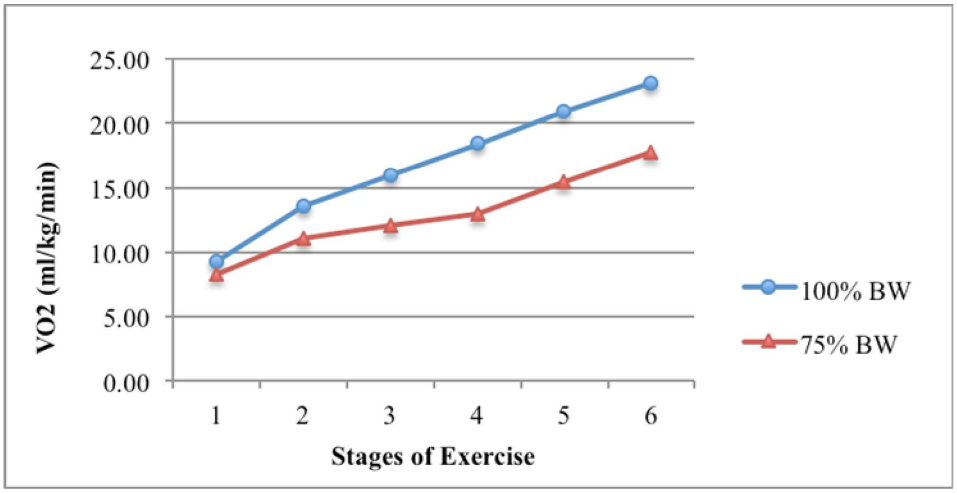

Figure 1. Oxygen consumption (VO2) measured during each three minute stage of exercise on the AlterG® at 100% BW and 75% BW. Graphic shows that as exercise intensity increases VO2 increases.

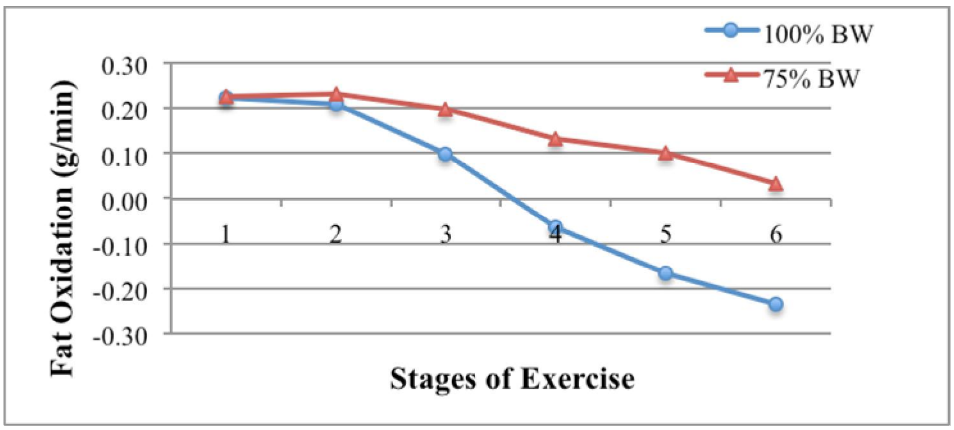

Figure 2. Graphic shows the rate of fat oxidation (g/min) at 100% BW and 75% BW as exercise intensity increases every three minutes.

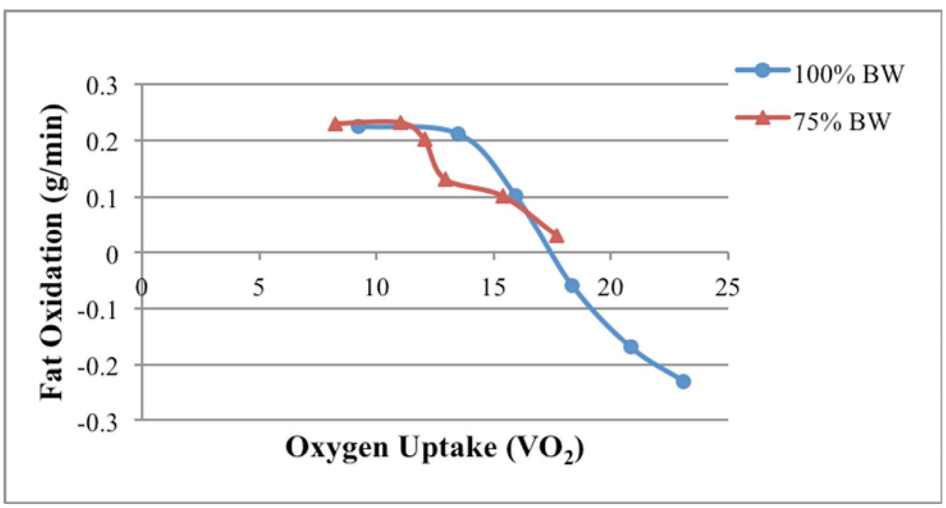

Figure 3.Graphic shows rates of peak fat oxidation relative to oxygen uptake for every three minutes of exercise.