# Cardiff School of Sport
## DISSERTATION ASSESSMENT PROFORMA:
### Empirical

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The Effect of Exercise Intensity on Substrate Metabolism and Energy Expenditure for Health Benefits

(Dissertation submitted under the physiology & health area)
THE EFFECT OF EXERCISE INTENSITY ON SUBSTRATE METABOLISM AND ENERGY EXPENDITURE FOR HEALTH BENEFITS
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I would like to thank my dissertation supervisor Carl Beynon for his support and guidance throughout this study. I would also like to thank the participants in this study for giving their time to take part in this study.
ABSTRACT

The purpose of this study was to determine the optimal exercise intensity for substrate metabolism and energy expenditure for health benefits, with a focus on fat metabolism. This study used a sample of 4 physically active and healthy subjects (3 women, 1 man; 21 ± 2.2 years; 175.7 ± 5.6 cm; 79.3 ± 13.5 kg; 47.2 ± 8.7 ml/kg/min VO₂peak), all of which were university students. Subjects attended 4 laboratory sessions, each separated by at least 24 hours. During the first sessions subjects completed a maximal oxygen consumption test using a treadmill, in which speed was increased by 1km/h until exhaustion. The following 3 sessions consisted of a 12-minute steady state exercise bout, at intensities 40%, 60% and 80% VO₂max. Respiratory gases and respiratory exchange ratio were recorded for the duration of each exercise condition to determine substrate metabolism and energy expenditure. A one-way repeated measures ANOVA test was used to determine significance of substrate metabolism and energy expenditure between exercise conditions, significance was set at $p<0.05$. Analysis identified a non-significant difference in fat metabolism between exercise conditions ($p<0.05$), with 40% VO₂peak identifying the greatest amount of fat metabolism (11.72 ± 2.95 g/l/min, $p<0.05$). A significant difference was identified in carbohydrate between exercise conditions ($p<0.05$), with 80% VO₂peak identifying the greatest carbohydrate metabolism (38.583 ± 7.818 g/l/min, $p<0.05$). A significant difference was also identified in energy expenditure between exercise conditions ($p<0.05$) with 80% VO₂peak identifying the greatest caloric energy expenditure (180 ± 45.4 kcal/l/min ($p<0.05$). These findings suggest that for health benefits subjects should exercise at lower intensities at steady state for maximal fat metabolism, with an ideal intensity of 60% VO₂max to ensure caloric energy expenditure for health purposes.
CHAPTER 1

INTRODUCTION

Substrate metabolism in the body is essential for energy production during exercise. Exercising is reliant on the correct energy system providing metabolised substrate in the form of fat (lipids) or carbohydrate (glycogen) primarily, to provide energy. It has previously been found that shorter duration higher intensity exercise, usually at an intensity of 60% VO$_2$max or above is reliant on the anaerobic energy system as it has fast capabilities to provide energy (McArdle et al., 2015). At higher intensities glycogen is the predominant supply of energy. Exercising at a high intensity for a short duration has been found to engage fast twitch muscle fibres for force production, which are linked with glycolysis in order to produce ATP (Bangsbo et al., 1992). Carbohydrate based energy production is however inhibited over long duration lower intensity exercise, as lipid metabolism is favoured here.

Lower intensity exercise has been found to derive energy from fat predominantly. Lower intensity exercise does not produce as greater demand on the energy systems for ATP production. The body stores fat in the form of triglycerides (TG), and energy production at lower intensities is reliant on lipolysis of TG to metabolise fatty acids for energy production (Kelley et al., 1999). Lower intensity exercise is more reliant on slow twitch muscle fibres due to a lower requirement of force production, opposite of anaerobic exercise, which uses predominantly fast twitch muscle fibres. Slow twitch muscle fibres have been found to contain a greater proportion of lipid than type 2 muscle fibres, and obese populations have been found to have lower proportions of slow twitch and higher type 2 muscle fibres (Kelley et al., 1999). This distribution of fibre type is important in relation to minimising obesity occurrences, and determining the optimal exercise intensity for obese populations to encourage maximal fat metabolism.

The amount of obesity and overweight individuals over recent years has increased dramatically and diet and lifestyle have been found to be key determinants of weight gain. Over indulgence in processed and fast foods have been found to increase obesity occurrences with statistics showing a 10% increase in obese men and women over a 17-year period (Zemaryalai et al., 2014). These findings are even more influenced when
energy intake is greater than energy expenditure, this is often linked to over indulgence in refined carbohydrates which, if not expended are stored as fat (Zemaryalai et al., 2014). Obesity is generally linked with a number of health concerns, some more serious such as cardiovascular disease (Zemaryalai et al., 2014). Therefore, it is essential to adhere to the maintenance of a healthy weight, and the reduction of additional weight. Obesity is also commonly linked with poor mobility and joint pain; therefore some obese individuals may struggle to lose weight as exercise can induce pain (Wadden et al., 2002). From these findings it can be acknowledged that exercise at lower intensities will be more beneficial for obese and overweight populations. The determination of this exercise intensity can be dependent on different individuals, as it has been previously found that different populations metabolise substrate such as fat and carbohydrate at different exercise intensities (Achten & Jeukendrup, 2004). Achten and Jeukendrup (2004) have previously identified a difference in exercise intensities for predominantly fat metabolism in trained and untrained populations. Fat metabolism is essential for weight loss, and a reduction in body fat. The rate of fat metabolism is dependant on a number of factors; physiological characteristics generally greatly determine the rate of metabolism in individuals. It has previously been acknowledged that overweight populations metabolise fat at different amounts and intensities to ideal weight populations (Bircher et al., 2005). Bircher et al., (2005) determined subjects 65% VO$_2$peak exercise intensity produced the greatest fat metabolism in obese men and women, although it was also found that the greatest amount of absolute energy derived from fat was found at 50%, this finding is corresponding with optimal exercise intensities for fat metabolism of trained individuals (47-52% VO$_2$max) (Achten & Jeukendrup, 2004).

The purposes of this study will be to investigate and determine the exercise intensity that metabolises the greatest amount of fat and caloric expenditure. Subjects will exercise at 3 conditions, 40% VO$_2$max, 60% VO$_2$max and 80%VO$_2$max to determine the intensity most suitable for maximum fat metabolism and caloric expenditure for health purposes. The exercise tests will be completed at these intensities, as a number of studies have identified maximum fat metabolism to be between any of these 3 intensities (Achten & Jeukendrup, 2004; van Loon et al., 2011; Bircher et al., 2005; Romijn et al., 1993; Achten et al., 2002).
1.1 Hypothesis
   1. There will be a significant difference in fat metabolism between exercise intensities. It is hypothesised that maximal fat metabolism will be found at the $40\% \text{ VO}_2\text{max}$ exercise condition.
   2. There will be a significant difference in caloric expenditure between exercise intensities. It is hypothesised that the $80\% \text{ VO}_2\text{max}$ exercise condition will elicit the greatest caloric expenditure.

1.2 Null Hypothesis
   1. There will be no significant difference in fat metabolism between exercise intensities.
   2. There will be no significant difference in caloric expenditure between exercise intensities.
CHAPTER 2

REVIEW OF LITERATURE

2.1 Energy Systems

An understanding of the optimal exercise intensity in which to elicit the greatest substrate metabolism rates is greatly beneficial for the purpose of improving the general health of the population by reducing risks of disease, illness and obesity. It is generally acknowledged that carbohydrate and fat are predominant suppliers of energy to the working muscles during exercise. The contribution of these substrates is often dependant on a number of contributing factors such as exercise intensity and duration (Friedlander et al., 1998; Achten et al., 2002; Achten & Jeukendrup, 2004).

Two main systems are responsible for the production of energy during exercise; these are the aerobic and anaerobic systems. The anaerobic energy system is predominantly used for high intensity short duration (around 6 seconds) exercise, whereas the aerobic system is used for lower intensity, longer duration exercise (McArdle et al., 2015).

It has previously been acknowledged that fatty acid uptake to skeletal muscle is reduced at high intensity exercise (Kitada et al., 2008). As exercise intensity increases long-chain fatty acid oxidation is reduced due to a reduction in transportation of long-chain fatty acid into the mitochondria (Venables et al., 2005; Sidossis et al., 1998).

2.2 Health and Weight Issues

Obesity is a common and growing issue in the United Kingdom. The current incidences of obesity are increasing yearly, also identifying a trend in the increase of health problems. Obesity is described as the excess of body fat, and is usually linked with a proportionally high Body Mass Index (BMI), and a number of health conditions (Wadden et al., 2002). The commonly found health problems linking with obesity are predominantly cardiovascular diseases, diabetes, and cancers.

According to the Welsh Health Survey (2013) statistics, it was found that 58% of adults (aged over 16 years) in Wales were classed as overweight or obese (a BMI of 30-35kg/m²), with 22% of these being classed as obese. Of this population it was found that only 29% of adults reported being physically active for 5 or more days a week. These more recent statistics can be compared to those of ten years previously, showing the population
classed as overweight and obese have increased by 4%. It can be seen from these statistics that a gradual increase in an overweight population is evident, and with no action on sedentary and obese populations this number will continue to grow as shown by Wang et al., (2011), predicting a large increase in obesity along with obesity related diseases. Wang et al., (2011) predict in the United States of America an additional 6-8.5 million diabetes cases, 5.7-7.3 million heart disease and stroke cases, and 492,000-669,000 cancer cases in the next 20 years. These findings provide a strong basis for research into the causes of obesity and determining factors in reducing obesity rates.

The most common methods for reducing obesity rates have generally found to be a healthy diet and suitable exercise. A poor diet of over indulgence in substrates such as carbohydrates, fats and sugars has been found to be a major cause of obesity and type 2 diabetes, studies have also found a reduction in immunity to be linked to obesity. Obese individuals have commonly been found to have a reduction in white blood cells for fighting infection in comparison to the general population (Jia et al., 2014; Myles, 2014).

Maintaining a healthy diet is of importance for the population as a whole, and especially obese populations. Zemaryalai et al., (2014) explain the importance of maintaining a healthy diet and suitable calorie intake to achieve weight loss. Zemaryalai et al., (2014) describe an ideal diet for health to avoid refined carbohydrates, and processed foods. Low calorie diets are discouraged although a dietary intake with a 600 kcal a day deficit has been found to be successful in aiding weight loss.

2.3 Warm-ups and Substrate Metabolism

Warming up before exercise is generally regarded a crucial step for minimising injury and encouraging performance benefits. The idea of a general successful warm-up is to raise the subject’s heart rate and stretch muscle groups in order to prepare for exercise. Previous studies have found participants that endure a warm-up process have a higher heart rate when beginning exercise than those not warming up (Brown et al., 2008). Brown et al., (2008) found no significant differences between warm-up and non-warm-up oxygen consumption, although the testing procedure used consisted of a 10-minute rest period after the initial warm-up, leading to a belief of higher oxygen consumption for a warm-up group before exercise with no rest period. The rest after the warm-up can be argued to be too long, as the subject’s heart rate will begin to reduce almost immediately after the
warm-up ends. This shows subjects will be returning back to their rested state and therefore the warm-up is not beneficial for exercise.

A study conducted by Bell (2014) consisted of similar principles, using active, passive and control groups for warm-ups. The study provides similar findings to that of Brown et al., (2008), although the study also includes fat metabolism analysis. Bell (2014) found a slight increase in fat metabolism with the active warm-up group, although no significance could be determined between each group’s results. These findings provide a basis for a warm-up protocol, and encourage that an accurate and suitable warm-up is used for preparing participants for exercise and increasing substrate metabolism depending on rest and duration times.

2.4 Physiological Factors of Substrate Metabolism

It has previously been found that obese and overweight individuals have an impaired ability to metabolise fat, which in turn induces weight gain (Tsujimoto et al., 2012). Tsujimoto et al., (2012) found weight loss encouraged by diet shows a direct relationship to the increase of maximal fat oxidation rate during exercise in obese men. Tsujimoto et al., (2012) provided a basis for research towards substrate utilisation at different exercise intensities as clear evidence of the health benefits and increased fat oxidation in relation to diet and exercise are displayed. Previous studies have found that significant differences are evident between obese and lean individuals. These studies show that respiratory exchange ratio is lower in obese males during steady state exercise, which provides evidence of an increase in the percentage of energy derived from fat. Goodpaster et al., (2002) provide evidence for these findings, and also clarify the increased free fatty acid oxidation in overweight individuals as found by Tsujimoto et al., (2012).

Age is also a factor that can affect substrate metabolism during exercise. It has commonly been found that, elderly populations show a regular decline in VO$_2$max in relation to age of between 0-1% (Kang, 2012). Although a number of causes can be evident for this reduction, the main contributors found have been reductions of maximal heart rate, maximal cardiac output and maximum ability to use oxygen for energy transfer to working muscles. Kang (2012) explain the reduced ability for the elderly to metabolise fat, due to a decrease in skeletal muscle size and/or oxidative ability. This further causes a reduction in the release of fatty acid and an increase of insulin resistance, which can lead to diabetes.
Solomon et al., (2008) have found that exercise training in the elderly has proven to increase substrate oxidation levels, thus reducing insulin resistance and encouraging the recognition of the importance of exercise in the elderly.

Another strong determinant of substrate metabolism during exercise is sex. Previous studies have often found that men and women metabolise substrates at different intensities and at different amounts. Tarnopolsky (2000) explained that during submaximal endurance based exercise, females have a lower respiratory exchange ratio and therefore elicit lower carbohydrate oxidation and higher fat oxidation. It has previously been found that regardless of training status, and when applied to a research design consisting of pre and post exercise testing that females have a lower RER (Friedlander et al., 1998). Dasilva et al., (2011) investigated substrate oxidation between men and women, but focused primarily on self-selected endurance pace. Dasilva et al., (2011) have found maximal fat oxidation was similar between sexes, although the zone at which men reached their maximal fat oxidation was lower than in women. Janyacharoen et al., (2009) were agreement of the findings of Dasilva et al., (2011) and enhance the findings of a higher carbohydrate metabolism and lower fat metabolism in men than in women.

2.5 Exercise Intensity and Substrate Metabolism

It is commonly accepted that dietary intake can effect substrate utilization before, during and after exercise. Studies have previously found that a recent ingestion of carbohydrates can affect an athlete’s substrate utilization, making carbohydrate the predominant energy source. Bergman and Brooks (1999) conducted a study focusing on the effects of fed and fasted exercise on substrate utilization. The study found that carbohydrate based food intake up to 3 hours before exercise, significantly increased RER values and carbohydrate metabolism for at least 1.5 hours of exercise. Achten and Jeukendrup (2004) enhance these findings, with evidence of a decrease in fat metabolism significantly in fed conditions when compared to a fasted state. The study also states that diets consisting of high fat ingestion can reduce fat metabolism rates.

It is acknowledged that a determination of the optimal exercise intensity for the greatest and most efficient fuel utilization is important for a number of things, a major factor being weight loss. Achten and Jeukendrup (2004) identified optimal exercise intensities for the
greatest fat oxidation as ranging between 59-64% VO$_2$max in untrained subjects, and 47-52% VO$_2$max in trained subjects.

The duration of exercise subjects are participating in accordance with intensity will largely determine the substrate metabolism. Takagi et al., (2014) studied fat oxidation, determining the optimal exercise intensity. Takagi et al., (2014) explained that during a steady state exercise test maximal fat oxidation rates were found towards the start of the test during shorter duration testing. However the testing protocol for the study combined multiple tests within one testing day, from which the researchers acknowledge a limitation in the research as the ramp test protocol used induced fat oxidation during the steady state test. It is also evident that multiple exercise bouts in one day will affect substrate metabolism, enhancing the metabolism of fat (Goto et al., 2007). The overall findings of Takagi et al., (2014) in regards to maximal fat oxidation were longer intensities showed greater oxidation rates, although contrasting findings have been evident in other studies. Achten et al., (2002) found no significant differences of maximal fat oxidation at short or prolonged duration exercise intensities. Achten et al., (2002) produced dissimilar findings to that of Takagi et al., (2014) in terms of exercise duration. Achten et al., (2002) focused predominantly on exercise intensity in regards to %VO$_2$max, and although both studies are focused around short time testing Achten et al., (2002) used short duration but staged maximal intensity tests to inhibit greater maximal fat oxidation. Achten et al., (2002) provide evidence of a protocol to elicit the greatest fat oxidation as being short duration but maximal intensity, although this finding is conclusive of other studies, this protocol could not be applied to wider a population. Untrained or overweight subjects for example could face health risks from working at maximal intensity, therefore the Takagi et al., (2014) study provides more relevant findings in regards to health purposes.

Longer duration exercise protocols are evident in many studies with mixed reviews regarding the significance their use. Meyer et al., (2007) conducted a study focusing on 5 different exercise intensities each lasting duration of 1 hour. The study found that no one exercise intensity could be determined that would provide maximal fat oxidation in a wide population, as subjects in the test metabolised substrates at different intensities and at different durations. The findings of Meyer et al., (2007) are contrasting of Achten et al., (2002) in relation to duration of exercise. Meyer et al., (2007) describe the purpose of a 60 minute duration was to replicate endurance training, the study provides clear findings of RER decreasing as exercise duration increased. A finding such as this encourages a longer duration of exercise for increased fat metabolism purposes although as stated in
the study it is tedious. Meyer et al., (2007) however were conclusive with the findings of Takagi et al., (2014) and Achten et al., (2002) in determining the exercise intensity where maximal fat oxidation is reached. The authors all provide evidence of maximal fat oxidation rates to be between 45-65% VO$_2$max, with some differs between results due to different testing protocols.

Romijn et al., (1993) analysed substrate use and exercise intensity over longer durations. The findings of this study explain the oxidation of fat at lower intensities, and the increase of participants RER as exercise intensity increased. For example, the lowest RER’s were found at 25% VO$_2$max averaging at 0.73. These findings differ from those previously stated, showing a much lower intensity for fat metabolism. The findings of 65% VO$_2$max, which was among the optimal level for substrate metabolism in other studies discussed, produced an average RER value of 0.83. These values show a greater percentage of energy during higher intensity exercise will be derived from carbohydrate, and therefore reducing fat metabolism and for health purposes is not useful for weight loss. However, although these findings are different to those previously found, again the exercise protocol is different and also the study is very dated. When compared to more recent studies the protocols of Romijn et al., (1993) differ slightly and methods are more advanced currently. Among other findings it is also evident that maximal fat oxidation rate is reached at lower exercise intensities, van Loon et al., (2001) investigated substrate utilization at 40%, 55% and 75% VO$_2$max for 3 bouts of 30 minutes during cycling. Again the study displays a significant decrease in fat oxidation rates at 75% VO$_2$max, with a lower percentage of energy being derived from fat and more from carbohydrate. The 40% VO$_2$max exercise intensity displays the greatest percentage of energy derived from fat at 31%, which is a 6% decrease of the 55% VO$_2$max intensity. This difference is not a significant one, such as that of the increase to 75% VO$_2$max. This finding is more conclusive to those of more recent findings as it displays optimal exercise intensity as between 40-55% VO$_2$max. Although, as with the findings from Romijn et al., (1993) the study is dated when compared to more recent findings.

Evaluations of current health and well-being statistics have revealed a vast increase in overweight and obese populations over the previous decade (Wang et al., 2011). In the interest of public health it is evident an encouragement of exercise and a balanced diet is important, and determining an exercise regime most suitable for enhancing weight loss will increase health benefits.
In reference to the current research regarding the many different factors of substrate metabolism and exercise intensity it is evident that many determinants affect the ways in which humans metabolise substrates.

For optimal benefits from exercise in encouraging substrate metabolism, diet should be limited at least 3 hours before exercise, such as either a fasted exercise session or no carbohydrate ingestion to encourage fat metabolism (Achten & Jeukendrup, 2004). A relevant warm-up has also been displayed to encourage substrate metabolism, adding to exercise duration and increasing the resting heart rate before exercise (Brown et al., 2008). Current individual weight has also been found to effect substrate metabolism, with overweight individuals using fat more predominantly as an energy source than lean individuals (Tsujimoto et al., 2012). Age has been found to affect substrate metabolism a number of ways such as a reduced cardiac output, and reduced oxygen transportation ability (Kang, 2012; Solomon et al., 2008). Men and women metabolise substrates at different intensities according to research, women have been found to oxidise fat maximally at a different zone than males, with duration being higher. At given intensities women have also been found to have lower RER values, encouraging lower carbohydrate and higher fat metabolism (Tarnopolsky, 2000; Dasilva et al., 2011).

The optimal exercise intensity identified by a number of studies for maximal fat metabolism is between 40-65% VO\(_2\)max, with a majority of these more towards 55% VO\(_2\)max. Exercise duration for these findings have been widely different, ranging from 3 minutes to 2 hours, although maximal fat oxidation rates have been displayed more around 15-60 minutes of exercise (Achten & Jeukendrup, 2004; Takagi et al., 2014; Achten et al., 2002).

2.6 Limitations in Research

A number of limitations are evident within research. A number of applicable articles found, although valuable are generally dated to which methods and protocols for testing are different to more recent findings. For example the research of Romijn et al., (1993) finds optimal exercise intensity to be at 25% VO\(_2\)max for substrate metabolism, yet the more recent study from Takagi et al., (2014) has found a more optimal exercise intensity for substrate metabolism to be around 55% VO\(_2\)max.

A number of studies determine optimal exercise intensity for substrate metabolism, it is evident that no particular exercise intensity has been determined between different populations. Wide ranges of results offer evidence for this, with untrained subjects showing maximum fat metabolism between 25-60% of VO\(_2\)max (Achten & Jeukendrup, 2004;
Achten et al., 2002; Romijn et al., 1993). These findings encourage the further research into different populations, as a number of factors affect the way in which they metabolise substrates and is often very different to trained athletes, who are often the sample used in studies.
CHAPTER 3

METHODOLOGY

Ethical approval for the study was received from Cardiff Metropolitan School of Sport Research Ethics Committee on 27/05/14.
Project reference number: 14/5/273U.

3.1 Subjects

Subjects were all university students participating in regular exercise weekly (3-5 days per week). Four subjects (M=1, F=3) participated in the study, subjects characteristics are displayed in Table 1. Subjects were all given study information sheets at the arrival of the first testing session, to provide subjects with an informed decision on taking part in the study (Appendix A). The information sheets detailed the experiment, what is required from subjects in the testing, and the purpose of the experiment. Subjects were also given an informed consent form (Appendix B) and a PAR-Q form (Appendix C) to complete before testing began. Subjects were informed to avoid alcohol for at least twenty-four hours before each testing session, and also avoid strenuous exercise for at least three hours prior. Subjects were also asked to avoid ingesting a high carbohydrate diet six hours prior to the testing period to ensure a similar diet between all subjects, as it has previously been found that carbohydrate ingestion enhances performance (Coyle, 1992; Mitchell, et al., 2013).

3.2 Experimental Design

On arrival of the first session subject’s height (Holtain Fixed Stadiometer, Holtain LTD, Crosswell, Crymych, Pembs), weight (SECA- Model 770, Vogel & Halke, Hamburg, Germany), age, sex and current exercise levels were recorded.
Subject’s age related maximum heart rate (HRmax) (Polar Electro RS4000, Kemple, Finland) was calculated using the equation:

\[ \text{HRmax} = 220 - \text{age} \]
Subjects attended a total of four laboratory sessions all separated by at least two days. The first session consisted of ethical considerations, health and safety preliminary checks, initial characteristic recordings (see Table 1.), and a maximal oxygen consumption test (VO\textsubscript{2max} test). The following three sessions consisted of steady state exercise sessions at 40\%, 60\%, and 80\% of subjects VO\textsubscript{2max} results.

3.3 VO\textsubscript{2max} Test

During the first laboratory session subjects took part in a VO\textsubscript{2max} test. A breath-by-breath gas analysis system (Oxycon Pro, Jaeger, Warwick, Warwickshire, UK) was used to monitor oxygen uptake (VO\textsubscript{2}) and carbon dioxide production (VCO\textsubscript{2}). The gas analysis system was set in accordance to ambient conditions, calibrated and prepared. Subjects began with a 2-minute warm-up on a treadmill (PPS 55 Sport, Woodway, Foster Ct, Waukesha) at a speed of 5km/h and the testing gradient of a 3\% incline. Subjects were familiarised with the equipment and facemask of the gas analysis system during the warm-up ready to begin the testing. The VO\textsubscript{2max} test began at an initial speed of 7km/h, and a gradient of a 3\% incline, the speed was then increased by 1km/h every minute. The speed increase continued until either the subject reached exhaustion and stopped the test (in which case test was deemed VO\textsubscript{2peak}) or the determinants of VO\textsubscript{2max} were reached (oxygen uptake plateaued and did not increase more than 150 ml·min\textsuperscript{-1}, failure of heart rate to increase with exercise, heart rate was within 5 b·min\textsuperscript{-1} of age predicted HR\textsubscript{max}, Respiratory Exchange Ratio (RER) was greater than 1.15) in which it was deemed VO\textsubscript{2max} was achieved. VO\textsubscript{2max} was measured in accordance with Heyward (2010), the procedure was adapted from general protocols as gradient was not increased at each stage and speed was increased at the end of every minute. The adaptation was due to the sample of participants, as all participants were regularly active.

3.4 Steady State Exercise Tests

The VO\textsubscript{2max} test was deemed VO\textsubscript{2peak} as all participants terminated the test before VO\textsubscript{2max} determinants were achieved. The VO\textsubscript{2peak} results were used to determine the exercise intensities for the steady state exercise tests. The tests were completed at 40\%, 60\% and 80\% of subjects VO\textsubscript{2peak}. A graph was plotted of VO\textsubscript{2} (ml·min\textsuperscript{-1}·kg) at the end of each minute against speed kilometres per hour from the VO\textsubscript{2peak} test. The trendline of the
graph was used to determine VO$_2$ and at each exercise speed, then percentage of VO$_2$max was calculated to identify VO$_2$ and speed at the given intensity.

At laboratory sessions subjects exercised at 40%, 60% and 80% VO$_2$peak respectively. The exercising time at each intensity was determined in regards to previous research where duration of tests were found to generally last between 3 - 60 minutes. A protocol of 12-minute duration tests was chosen, as it was most suitable for subjects and had previously been found to be effective in substrate metabolism determination (Achten et al., 2002). Subjects began each session with a 2-minute warm-up at 5km/h, and then proceeded to the designated exercise intensity speed. A 3-minute period was provided here to ensure subjects had reached their intensity given VO$_2$. During the 12-minute exercise bout, respiratory gases were recorded and subjects HR was recorded every minute. The respiratory gas recording was stopped at the end of the twelfth minute and the testing procedure was stopped. Subjects were then given a 2-minute cool down period on the treadmill at 4.5km/h.

3.5 Gas Analysis

The Oxycon software measured a number of variables during testing these were, Respiratory Exchange Ratio (RER), Ventilation Rate (VE), Oxygen consumption (VO$_2$), and Carbon dioxide production (VCO$_2$). These results were compared along a table using RER to determine substrate use and energy expenditure during each stage of exercise. (McArdle et al., 2015) (Appendix D).

3.6 Data Management and Statistical Analysis

Data output from Oxycon was obtained for each subject. From each output total fat metabolism and total carbohydrate metabolism were calculated using the following equation (fat metabolism used as an example):

\[
\text{Total fat metabolised (g) = [Mean fat metabolised (g) x mean VO}_2\,(l/min)] x \text{Duration (mins)}
\]

Caloric energy expenditure was also calculated from test outputs using the following equation:
Energy expenditure (kcal) = \[\text{Mean energy expenditure (kJ) x mean VO}_2 \ (l/min)) \times \text{Duration (mins)} / 4.184\]

Statistical analysis was completed using IBM SPSS statistics software version 22. A one-way repeated measures ANOVA test was used with subject variable output and exercise intensity set as factors for analysis to compare mean differences between groups. Bonferroni post-hoc analysis was used to determine specific significant differences between groups. Significance was set at $p<0.05$ for statistical analysis. Partial Eta Squared ($\eta_p^2$) was used to determine the proportion of variance between each of the main effects on a scale of 0-1.
CHAPTER 4

RESULTS

The mean values (±SD) of subject’s general characteristics are provided in Table 1., including subjects VO$_2$peak. VO$_2$max is termed VO$_2$peak as no participants met the number of given maximal determinants for the VO$_2$max test to be deemed as such.

Table 1. Mean (±SD) subject’s general characteristics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (Mean ±SD) (N=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21 ±2.2</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>175.7 ±5.6</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>79.3 ±13.5</td>
</tr>
<tr>
<td>VO$_2$peak (ml/kg/min)</td>
<td>47.2 ±8.7</td>
</tr>
</tbody>
</table>

4.1 Exercising Oxygen Consumption (l/min)

A One-way ANOVA$_{RM}$ revealed a statistically significant ($F_{2, 6} = 82.39$, $p = .000$, $\eta^2_p = 0.965$) difference in VO$_2$ (l/min) between exercise intensities (see Figure 1.). Post-hoc analysis identified that the observed mean difference between exercise condition 1 and 3, ($M_{diff} = 1.509 ± 1.067$ l/min) was significantly different ($p<0.05$). Observed mean difference between exercise condition 1 and 2, ($M_{diff} = 0.774 ± 0.547$ l/min), and exercise condition 2 and 3, ($M_{diff} = 0.735 ± 0.519$ l/min), were not significant ($p>0.05$).

Figure 1. Mean (±SD) VO$_2$ (l/min) for each exercise condition (%VO$_2$peak).
4.2 Respiratory Exchange Ratio

Participants RER increased alongside exercise intensity as expected (see Figure 2). The mean RER of participants showed a significant difference between exercise intensities. A One-way ANOVA$_{RM}$ identified a statistically significant ($F_{2, 6} = 14.98, p = .005, \eta^2 = 0.833$) difference in RER between exercise intensities (see Figure 3.). Post-hoc analysis identified that the observed mean difference between exercise condition 1 and 3, ($M_{diff} = 0.06 \pm 0.04$) was significantly different ($p<0.05$). Observed mean difference between exercise condition 1 and 2, ($M_{diff} = 0.05 \pm 0.04$), and exercise condition 2 and 3 ($M_{diff} = 0.11 \pm 0.08$), were not significant ($p>0.05$).

![Figure 2. Mean (±SD) RER for each exercise condition (%VO$_{2peak}$).](image)

4.3 Heart Rate (bpm)

HR (bpm) increased with exercise intensity, corresponding with work rate. Mean heart rates during exercise intensity (40%, 60% and 80% VO$_{2peak}$) are displayed in Figure 3. Statistical analysis using a One-way ANOVA$_{RM}$ identified a significant ($F_{2, 6} = 48.58, p = .000, \eta^2 = 0.942$) difference in HR (bpm) between exercise intensities. Post-hoc analysis identified that the observed mean difference between exercise condition 1 and 2, ($M_{diff} = 36 \pm 25$ bpm), exercise condition 1 and 3 ($M_{diff} = 56 \pm 40$ bpm), and exercise condition 2 and 3 ($M_{diff} = 20 \pm 14$ bpm), were all significant ($p<0.05$).
4.4 Total Fat Metabolism (g·min)

Total fat metabolism (g·min) during each 12-minute bout decreased with each exercise intensity increase. The greatest rate of fat metabolism (g·min) is evident at the 40% VO2peak intensity. Analysis using a One-way ANOVA_RM displayed a statistically non significant ($F_{2, 6} = 4.13, p = .074, \eta_p^2 = 0.579$) difference in fat metabolism (g·min) between exercise intensities (see Figure 4.). Post-hoc analysis identified that the observed mean difference between exercise condition 1 and 2, ($M_{diff} = 0.456 \pm 0.323$ g·min), exercise condition 1 and 3, ($M_{diff} = 2.363 \pm 1.671$ g·min), and exercise condition 2 and 3 ($M_{diff} = 1.907 \pm 1.348$ g·min), were not significant ($p>0.05$).
4.5 Total Carbohydrate Metabolism (g·l·min)
The decrease of fat metabolism (g·l·min) between exercise intensities was evident of an increase in carbohydrate metabolism (g·l·min), as exercise intensity increased carbohydrate metabolism (g·l·min) also increased. Further analysis using a One-way ANOVA$_{RM}$ identified a statistically significant ($F_{2, 6} = 37.50, p = .000, \eta^2_p = 0.926$) difference in carbohydrate metabolism (g·l·min) between exercise intensities (see Figure 5.). Post-hoc analysis identified that the observed mean difference between exercise condition 1 and 3, ($M_{diff} = 28.130 \pm 19.891$ g·l·min) and exercise condition 2 and 3 ($M_{diff} = 15.556 \pm 11.000$ g·l·min), were significantly different ($p<0.05$). Observed mean difference between exercise condition 1 and 2, ($M_{diff} = 12.574 \pm 8.891$ g·l·min), was not significant ($p>0.05$).

![Figure 5](image)

**Figure 5.** Mean (±SD) carbohydrate metabolism (g·l·min) for each exercise condition (%VO$_{2peak}$).

4.6 Total Energy Expenditure (kcal·l·min)
Caloric expenditure displayed an increase during exercise, and increased between exercise intensities. The greatest total energy expenditure (kcal·l·min) was evident at the 80% VO$_{2peak}$ intensity, with the lowest caloric expenditure at 40% VO$_{2peak}$. A One-way ANOVA$_{RM}$ revealed a statically significant ($F_{2, 6} = 80.15, p = .000, \eta^2_p = 0.964$) difference in calorie expenditure between exercise intensities (see Figure 6). Post-hoc analysis identified that the observed mean difference between exercise condition 1 and 2 ($M_{diff} = 47.2 \pm 33.4$ kcal·l·min), exercise condition 1 and 3 ($M_{diff} = 93.1 \pm 65.9$ kcal·l·min), and exercise condition 2 and 3 ($M_{diff} = 45.9 \pm 32.5$ kcal·l·min), were all significant ($p<0.05$).
Figure 6. Mean (±SD) energy expenditure (kcal/min) for each exercise condition (%VO_{2peak}).
CHAPTER 5

DISCUSSION

The aim of this study was to determine an exercise intensity that metabolises the greatest amount of substrate for health purposes, with a main focus of fat metabolism and caloric expenditure. The research testing protocol provided a number of significant findings ($p<0.05$) to determine the most suitable exercise intensity for health purposes. It was evident from the results that as exercise intensity increased carbohydrate metabolism also increased, as can be expected. This is due to the production of energy, as exercise intensity increases carbohydrate will become the predominant source of energy production as it can rapidly supply adenosine triphosphate (ATP) once metabolised. It has commonly been found that carbohydrate is the main energy source for higher intensity exercise. (McArdle et al., 2015; Brooks & Mercier, 1994). Furthermore statistical analysis identified a significant difference between carbohydrate metabolism and exercise conditions ($F_{2, 6} = 37.50, p = .000, \eta^2_p = 0.926$), with the 80% $VO_2$peak exercise condition displaying the greatest carbohydrate metabolism rate of $38.583 \pm 7.818$ g·l·min ($p<0.05$).

The present study found that fat metabolism decreased as exercise intensity increased respectively although no significance was found between intensities ($F_{2, 6} = 4.13, p = .074, \eta^2_p = 0.579$). This finding is in agreement with previous literature, giving evidence of an increased exercise intensity decreasing fat metabolism (Takagi et al., 2014; Bassami et al., 2007; Kang et al., 2007). The decrease in fat metabolism can be found to be due to a reduction in oxygen availability at higher intensities (Kang et al., 2007). The greatest rate of fat metabolism was found at the 40% $VO_2$peak exercise condition as $4.650 \pm 2.950$ g·l·min ($p>0.05$).

Caloric energy expenditure increased significantly with exercise intensity respectively ($F_{2, 6} = 80.15, p = .000, \eta^2_p = 0.964$), the greatest calorie expenditure was evident at the 80% $VO_2$peak exercise condition as $180 \pm 45.4$ kcal·l·min ($p<0.05$). Statistical analysis identified a significant difference between calorie expenditure at each exercise condition ($p<0.05$). Increased calorie expenditure in the present study is conclusive of previous studies, as it can be acknowledged that the increased metabolism of substrates is due to an increased demand for energy supply and therefore expended calorically (Dasilva et al., 2011).

The present study used exercising oxygen consumption as a parameter to determine substrate metabolism and caloric expenditure. As expected $VO_2$ increased with each
exercise condition, as intensity increased. A statistically significant difference was identified between VO$_2$ in each exercise condition ($F_{2, 6} = 82.39$, $p = .000$, $\eta_p^2 = 0.965$), as can be expected due to the increased exercise intensity. As with VO$_2$ increase, respiratory exchange ratio also significantly increased evident of the increased oxygen consumption ($F_{2, 6} = 14.98$, $p = .005$, $\eta_p^2 = 0.833$). RER provided a utilizable result in which to determine substrate metabolism and calorie expenditure. Analysis of RER results identified a statistically significant difference between exercise intensities, although this difference was not evident between correspondingly increasing exercise intensities. This finding was also evident with VO$_2$, the significant difference between exercise conditions was evident between exercise conditions 1 and 3 (40% VO$_2$peak 1.487 ± 0.426 l/min; 80% VO$_2$peak 2.996 ± 0.700 l/min)($p<0.05$).

Previous research has often questioned the optimal exercise intensity for substrate metabolism with many different suggestions for this intensity becoming evident. A number of studies have displayed findings for lower exercise intensities producing the greatest fat metabolism rates. The intensity for the greatest predominantly fat metabolism has previously been found to range between 25-60% VO$_2$max, which is in agreement with previous studies findings (Achten et al., 2002; Takagi et al., 2014; Meyer et al., 2007; Romijn et al., 1993). It was also found in the present study that fat metabolism after 60% VO$_2$peak did not differ greatly, revealing a small difference between metabolised fat at 60% VO$_2$ peak to 80% VO$_2$peak, this difference was not statistically significant ($p<0.05$). This finding indicates a maximum fat metabolism (Fatmax) intensity to be between the 40-60% VO$_2$peak intensities.

Jeukendrup and Achten (2001) describe that generally fat metabolism increases with exercise intensity, until fatmax is reached. The metabolism rate then begins to decrease as exercise intensity continues to increase. Jeukendrup and Achten (2001) here enhance the findings of this current study, and also enlighten the belief that fat metabolism at the 40% VO$_2$peak intensity may not have been at its highest. The findings of the present study compared to the findings of Jeukendrup and Achten (2001) enlighten the belief fat metabolism could have continued to increase between the 40-60% VO$_2$peak intensity until fatmax was reached. It can be seen in the results from the present study that fat metabolism does not change greatly between the 40-60% VO$_2$peak exercise conditions ($M_{\text{diff}} = 0.456 \pm 0.323$ g l$^{-1}$min). Furthermore this finding encourages current and previous research in identifying the optimal zone for fat metabolism.
It has become evident throughout analysis and comparison of similar research that duration of exercise is important for determining maximal fat metabolism rates. Many arguments have been presented for optimal exercise duration, the current study exercised subjects for 12 minutes at each exercise condition from which all subjects displayed expected metabolism rates at each condition. Interestingly Bassami et al., (2007) noted that as duration of exercise is elongated more energy is derived from fat, but the fatmax amount was shown at its highest at a lower intensity of exercise, provided as 50% \( VO_2 \text{max} \). The findings of Bassami et al., (2007) are derived from trained and untrained older males, therefore it can be argued that the given optimal fat metabolism intensity of 50% \( VO_2 \text{max} \) is not replicable in studies such as the present study due to the sample. Kang (2012) explain that elderly populations have an impaired ability to metabolise fat. This finding can explain why Bassami et al., (2007) produced the findings of the study. Although, Takagi et al., (2014) used a short and long duration testing period and in both cases fatmax was determined at just after 10 minutes of testing.

Takagi et al., (2014) suggest that exercising at fatmax intensity is not applicable over long duration exercise and is not beneficial for fat metabolism for large populations. This is contrasting to that of Bassami et al., (2007) who suggest fat metabolism is greater at an elongated intensity. Takagi et al., (2014) used a similar sample to the present study of young participants aged similarly. It can be argued that exercising at a lower intensity for a shorter duration using younger subjects (21 ±2.2 years) can metabolise a greater proportion of fat than compared to exercising at a higher intensity for a longer duration. This is supportive of the findings in the present study as all subjects exercised for 12 minutes at each exercise condition, but metabolised a significantly greater amount of fat at their 40% \( VO_2 \text{peak} \) than 80% \( VO_2 \text{peak} \) (\( p<0.05 \)). Lazzer et al., (2010) provide evidence similar findings to that of Takagi et al., (2014) when using an obese or overweight population. Lazzer et al., (2010) found that fat metabolism was significantly different between low and high intensity exercise in obese populations. This finding is therefore applicable to a wide sample of the population, as fat metabolism has been found to be significantly higher at lower intensities than higher intensities in a number of different population samples as indicated by literature (Lazzer et al., 2010; Zakrzewski & Tolfrey, 2012; Meyer et al., 2007; Takagi et al., 2014).

It has been acknowledged that different sexes produce different rates of substrate metabolism. The present study found the fat metabolism at each exercise condition to be less in women than in men, it was also found that women did not metabolise a greater
amount of fat than men at any given intensity. Kang et al., (2007) provide similar findings, identifying that men metabolised more fat than women, although this finding was only present at higher intensity exercise conditions, and the results did not differ greatly. Kang et al., (2007) found that at 40% VO\(_2\)max, women metabolised a greater amount of fat than men. Additional studies such as Dasilva et al., (2011) are conclusive of the findings of Kang et al., (2007). Dasilva et al., (2011) also identify that fatmax is lower in men than women. These findings are not consistent with the present studies findings, the cause of this could be due to the affects of sample size. Kang et al., (2007) used 22 subjects, 11 men and 11 females, with a range of different fitness levels. This can explain why the present study did not display similar findings as the ratio of men to women differed. The experimental protocol of Kang et al., (2007) was very similar to the present study, suggesting similar findings may have occurred if the sample was altered.

Carbohydrate metabolism was found to increase with exercise intensity, revealing a statistically significant difference between exercise intensities (\(p<0.05\)). Carbohydrate metabolism amounts were also greater in men than in women with 80% VO2peak showing the greatest rate of metabolism (38.583 ± 7.818 g\(\cdot\)min). This finding is in agreement with previous research, such as Dasilva et al., (2011) who found men metabolised greater amounts of carbohydrate throughout testing (\(p<0.05\)) and Kang et al., (2007) who show similar findings of higher carbohydrate metabolism in men than women, although the 70% VO\(_2\)peak intensity showed no significant difference (\(p>0.05\)). However, Dasilva et al., (2011) allowed subjects to self select an exercise intensity, here it can be argued that some subjects may work at higher intensities than others, and therefore encourage glycolysis. All subjects revealed the greatest carbohydrate metabolism amounts at 80% VO\(_2\)peak, previous literature supports this as when exercise intensity is increased more energy is derived from carbohydrate.

Janyacharoen et al., (2009) identify that individuals who ingest a large proportion of carbohydrate in their diet will respond physiologically different to exercise. In extreme cases as seen from Janyacharoen et al., (2009) individuals predominantly ingesting carbohydrate as an energy source metabolised more carbohydrate than fat at rest and at multiple exercise intensities. It has previously been identified that carbohydrate ingestion reduces maximal fat metabolism, the exercise intensity at which individuals reach their fatmax and the amount of energy derived from fat is reduced (Achten & Jeukendrup, 2003; Chu et al., 2011). It has previously been found that ingestion of high carbohydrate diets
increases insulin concentrations and the rate of lipolysis, therefore reducing the availability of fatty acid for oxidation (Achten & Jeukendrup, 2003). These findings are in agreement with that of the present study as although subjects were asked to refrain from carbohydrate ingestion before testing, a large amount of energy from each subject was derived from carbohydrate.

Energy expenditure was identified to increase with exercise intensity. All subjects showed an increase in calorie expenditure between each exercise condition. Statistical analysis of the results revealed a statistically significant difference between calorie expenditure at each exercise condition, with the 80% VO₂peak condition showing the greatest expenditure (40% VO₂peak, 86.9 ± 26.1 kcal·min⁻¹; 60% VO₂peak, 134.1 ± 37.6 kcal·min⁻¹; 80% VO₂peak, 180 ± 45.4 kcal·min⁻¹). It has previously been acknowledged and found that higher exercise intensities encourage greater energy expenditure. Treuth et al., (1996) identify greater energy expenditure at high intensity exercise as well as encouraging energy expenditure during a 24-hour period after exercise. These findings are similar to this study with the 80% VO₂peak intensity revealing the greatest energy expenditure. Treuth et al., (1996) also encourage the use of this intensity by identifying further energy expenditure over a post exercise period, although carbohydrate and fat metabolism were found to not differ in post exercise continuing metabolism between high and low exercise intensities. However the subject sample used by Trueth et al., (1996) consists of only women, as previously stated it has been found that women expend energy from substrates differently to men. The finding of Trueth et al., (1996) therefore may not be similar if men were to undergo the same experimental protocol. Melanson et al., (2002) provide slightly different findings in a similar study to Treuth et al., (1996), although energy expenditure is also found to be greater at a higher exercise intensity, 24-hour post exercise energy expenditure was not significantly affected by exercise intensity. This finding encourages the use of a lower intensity for optimal exercise intensity as it is more suitable for sedentary populations, and although calorie expenditure is lower fat metabolism is much higher. Furthering this point, Melanson et al., (2002) unlike Trueth et al., (1996) used a mixed sex sample. This enhances the findings of the present study using a sample of men and women, and therefore encouraging the belief of similar results to Melanson et al., (2002).

Lazzer et al., (2010) did not find a significant difference in energy expenditure between low and high intensity exercise. This finding is contrasting to that of the current study, as a significant difference was found between energy expenditure at each exercise condition.
The finding of Lazzer et al., (2010) could be due to the sample that was used for testing. The sample consisted of obese boys aged between 14 and 16 years, this indicates that exercise intensity may not influence energy expenditure greatly within the current tested population. Tsujimoto et al., (2012) provide a study in which it was found that obese individuals have an impaired ability to metabolise fat. The impaired ability to metabolise fat is linked to insulin resistance, which is common in obese populations. Insulin resistance therefore can cause a reduction in the uptake of muscle glucose which is usually enhanced by insulin (Goodpaster et al., 2012; Kelley et al., 1999) The subject sample used in the present study are all university students participating in regular exercise, it can therefore be acknowledged that the significant difference in energy expenditure revealed could not be replicated to a different sample, such as an obese sample.

In relation to substrate metabolism and energy expenditure the present studies results give a range of exercise intensities as an optimal intensity for each factor. Fat metabolism was seen to give its highest output at 40% VO$_2$peak (4.65 ± 2.950 g·l·min$^{-1}$), whereas carbohydrate metabolism and energy expenditure were seen at their highest output at 80% VO$_2$peak (38.583 ± 7.818 g·l·min$^{-1}$; 180 ± 45.4 g·l·min$^{-1}$, respectively). The determination of the exercise intensity to elicit maximum fat metabolism and maximum calorie expenditure is important to consider in relation to health purposes. A settlement of exercise intensity to propose maximal weight loss and health benefits would be at an intensity of around 60% VO$_2$max. Given the findings of the current study this would ensure individuals still derive a large proportion of their exercising energy from fat sources, whilst still expending a significant amount of calories. Kang et al., (2007) identify a significant difference in fat metabolism when expressed as kcal·min$^{-1}$ at the 60% VO$_2$peak, this finding is conclusive of the suggestion given here for an optimal exercise intensity in which calorie expenditure and fat metabolism are significant.

5.1 Limitations

A number of limitations in the current study are acknowledged. One limitation acknowledged by the researcher is sample size. The sample consisted of 4 volunteers, 3 women and 1 man. This is due to the availability and recruitment of participants. It is acknowledged that the number of participants and ratio of women to men could affect the findings of the study, in terms of its reliability and validity. The smaller sample may create a larger error margin in results (Hopkins, 2000). It has previously been found that men and women metabolise substrate and expend energy at different amounts, intensities and
durations (Kang et al., 2007; Dasilva et al., 2011). It would therefore be suggested in future research for a replicated study to involve more participants with an equal proportion of men and women. It would also be suggested in future research for an analysis of results between men and women to provide more accurate training intensity suggestions for men and women. It is acknowledged in this study that although participants were advised to avoid carbohydrate ingestion at least 6 hours prior to testing, it would have been more suitable for testing sessions to be first thing in the morning after an overnight fast to ensure maximum energy is derived from fat. It has previously been found that ingestion of carbohydrates 3 hours prior to exercise inhibits fat metabolism, due to the increased availability of carbohydrate as an energy source (Achten & Jeukendrup, 2004; Bergman & Brooks, 1999).

5.2 Future Research

In future research it would be suggested to exercise participants at more intensities. The inclusion of a 50% VO\textsubscript{2}max intensity for testing could be beneficial as it would be interesting and useful to see fat metabolism at this intensity as it has previously been noted that fatmax rates are reached between 40-60% of VO\textsubscript{2}max intensities. Further research regarding this topic could also use a different subject sample. If the testing sample were changed to an obese population it would give more relevant results in terms of health and weight loss purposes.
CHAPTER 6

CONCLUSION

It can be concluded from the study that as exercise intensity increased carbohydrate metabolism and caloric energy expenditure increase, with 80% VO₂peak providing the greatest rate of carbohydrate metabolism and caloric energy expenditure. It can also be concluded that as exercise intensity increased fat metabolism decreased respectively, with 40% VO₂peak providing the greatest rate of fat metabolism. It can be derived from this study and in relation to previous research that the fatmax intensity may be found between the 40% VO₂max and 60% VO₂max intensities. Therefore it is suggested that the optimal exercise intensity for fat metabolism and also a great amount of energy expenditure derived from fat is 60% VO₂max. In relation to health benefits this intensity is suitable for sedentary populations as the study shows high fat metabolism was evident during short duration exercise, this will encourage body fat reduction with low intensity short duration exercise.
REFERENCE LIST


APPENDICES

APPENDIX A

PARTICIPANT INFORMATION SHEET

Title of Project: The Effect of Exercise Intensity on Substrate Utilization and Energy Expenditure for Health Related Benefits

Participant Information Sheet

The study you have volunteered to participate in is entirely voluntary. You have no obligation to participate if you desire not to.

Background

This project involves a testing process in which a treadmill will be used. The study will provide yourself and the researcher with essential knowledge for health and performance benefits. The tests will provide the researcher with expiratory gas samples in which analysis will then occur to further the study. This study is concerned with determining the most effective exercise modality in order to produce the most efficient substrate utilization and energy expenditure amounts in men and women.

The study will have benefits to you as a participant. You will be made aware of what exercise modality whether it is high, moderate or low intensity exercise that provides you with the most efficient substrate utilization and energy expenditure, which therefore makes you aware of your optimal training zone for health purposes.

Participants must be university students with ages ranging from 18 to 30. Participants can be men or women. Participants must be free from any injuries that could affect performance and also any health problems. Participants must be in good general health.

Participants will be at risk of fatigue during the testing process as they are required to work until exhaustion in one test. The sessions will be tailored to suit both the participants and the researcher to ensure convenience.

Participants will be provided with refreshments during the study to ensure hydration is met. Your results will be used and your name will not be included although your personal characteristics will be found with your results. You will be referred to in the study as ‘subject’ followed by a number, ensuring anonymity of your results.

If you have any further questions please contact me:

Tamsin Richards, st20035384@cardiffmet.ac.uk
APPENDIX B

PARTICIPANT CONSENT FORM

Participant name or Study ID Number:

Title of Project: The Effect of Exercise Intensity on Substrate Utilization and Energy Expenditure for Health Related Benefits

Name of Researcher: Tamsin Richards

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. [ ]

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. [ ]

3. I agree to take part in a V0₂max test, in which I am required to run until exhaustion. [ ]

4. I agree to take part in a steady-state exercise test, and run at different intensities to measure substrate utilisation. [ ]

5. I agree to let the researcher use my information and data for the study. [ ]

6. I agree to take part in the study. [ ]

_______________________________________   ___________________
Signature of Participant                        Date

_______________________________________   ___________________
Name of person taking consent                   Date
APPENDIX C

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE – PAR-Q

Name:                                                      Height:
Date of Birth:                                              Weight:
Sex:

Please answer the following questions as accurately as possible. This questionnaire will determine the suitability of this exercise for you.

(Please delete answer accordingly)

1. Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor? YES/NO

2. Do you feel pain in your chest when you do physical activity? YES/NO

3. In the past month, have you had a chest pain when you were not doing physical activity? YES/NO

4. Do you lose you balance because of dizziness or do you ever lose consciousness? YES/NO

5. Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity? YES/NO

6. Is your doctor currently prescribing medication for your blood pressure or heart condition? YES/NO

7. Do you know of any other reason why you should not do physical activity? YES/NO

If yes, please comment:

Signed:

Date:
APPENDIX D

ENERGY EXPENDITURE, SUBSTRATE USE AND RER

Taken from McArdle et al., (2015).

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