A Comparison of the Effect of two Combined Aerobic and Resistance Work-Outs on Energy Expenditure and Excess Post Oxygen Consumption.

By

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A dissertation submitted in part fulfilment of the requirement for the B.A. (Hons) Degree in Exercise and Health Studies.

April 2014

Waterford Institute *of* Technology

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Acknowledgments

Firstly I would like to say thank you to my supervisor Anna-Louise Muldoon, your help and guidance over the course of the months is greatly appreciated. A thank you also goes out to the rest of the staff at WIT who have thought me over the 4 years, I've learned a lot from you all.

I would also like to say a big thanks to Aaron, Dan, and Sean for their help in the laboratory over the months and with bringing over equipment from the gym that helped get the work done, it was a long time in that lab but we're there now.

I've made some great friends along the way and ones that I'll always have, Aaron ''Mr. Physiology'' Grant, Dan Ryan, Tommy Kiely, Ray Harris, Sean O'Neill and Paul Coady to name a few, we've had some great times over the 4 years and it's been a pleasure to get to know you all.

It might sound soppy but I can't go without saying a huge thanks to my Mum Deborah for all her help and support over the 4 years, without her I wouldn't be sitting here just about to finish up a thesis so thank you for everything I appreciate it all.

'' I hated every minute of testing, but I said don't quit, suffer now and live the rest of your life as a post-graduate'' - Muhammad Ali/Craig Vernon

Abstract

Previous research has found that aerobic type exercise has more of a significant effect on energy expenditure during exercise, whereas resistance type exercise has a greater effect on excess post-exercise oxygen consumption (EPOC). The purpose of this study was to compare two work-outs that consist of both aerobic and resistance type exercise together performed at different intensities and durations, and to examine the effect both of these work-outs have on the energy expended during the work-outs themselves and also during the recovery phase of them both (EPOC).

Research Questions:

1) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on energy expenditure.

2) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on EPOC.

3) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on heart rate, RER, and RPE readings.

Six subjects took part in this study all of which were male. All subjects underwent pre physical examination testing before taking part in the study. Immediately after subjects completed each work-out they had their energy expenditure readings taken, this was done again at 1 and 2 hours during the recovery phase of each work-out to gather EPOC recordings.

Results of this study found that the high intensity and light resistance work-out had a more significant effect on energy expenditure during the work-out itself. It was also found that the low intensity running and heavy resistance work-out had a greater effect on energy expended during the recovery phase of the exercise (EPOC).

In conclusion it was found that a work-out which consisted of high intensity running and light resistance training had a greater effect on burning calories during the work-out, however more calories were burnt among subjects during the recovery phase of the low intensity running and heavy resistance work-out.

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Abbreviations:

EPOC – Excess Post-Exercise Oxygen Consumption

RER – Respiratory Exchange Rate

RPE – Rate of Perceived Exertion

VO2 – Oxygen Consumption

High-Low – High Intensity Running & Light Resistance Work-out

Low-High – Low Intensity Running & Heavy Resistance Work-out

Chapter 1 - Introduction

People engage in physical activity for numerous reasons as many people have different physical goals (Han-Wu & Charng Lin, 2006). Thornthon & Potteiger (2002) state that the majority of the world's population participate in exercise in order to lose or control their weight by expending as much energy as possible during that exercise. Aerobic exercise is the most popular form of exercise prescribed to individuals who have a long term aim of losing or controlling their weight (Sedlock et al., 1989). Aerobic exercise, also known as cardio, is physical exercise that depends primarily on the aerobic energy generating process (Melby et al., 1993). Aerobic simply means ''with oxygen'' and is a system which generates energy (ATP) from the consumption of oxygen. According to Boresheim & Bahr (2003) aerobic exercise is more effective than strength or resistance training in terms of energy expenditure as it plays a more significant role in energy expended during exercise. Aerobic training typically involves the use of large muscle groups in the body (Thornthon & Potteiger, 2002). The most common forms of aerobic training are walking, running, and cycling (Boresheim & Bahr, 2003).

Kraemer et al. (2002) state that the contribution resistance training makes to energy expenditure cannot be undermined. Poehlman & Melby (1998) suggest that resistance training should be an important part of any exercise programme for people aiming to expend energy and lose weight. Resistance training is a common type of strength training that is known for developing strength and size of skeletal muscle and can be performed using various types of equipment such as weighted bars, dumbbells, or weighted stacks (Kraemer et al., 2002). This type of training can be beneficial for individuals who are bodybuilders, weightlifters or power lifters. In popular sports such as soccer, rugby, and basketball, weight is being included as an important part of the conditioning element of these sports (Poehlman & Melby, 1998). It's not only in sports that resistance training is becoming more popular,as stated by Elliot et al. (1992), there has been a significant growth in the number of people participating in resistance training as a form of exercise due to the significant energy expenditure associated with it. In the late nineties Hunter et al. (1998) noted a rise in the use of weight training as a mode of exercise for people who were aiming to lose weight.

According to Hunter et al. (1998) both aerobic and resistance type training play an important role in energy expenditure. Elliot et al. (1992) suggest that aerobic and resistance training

both have different roles to play when it comes to energy expenditure. Haddock & Wilkin (2006) stated that aerobic exercise has more of a significant effect on energy expenditure during the exercise itself and that resistance training may not have as much of an effect during exercise as aerobic training does. This is supported by Elliot et al. (1992) who claims resistance training may not have as much of an effect on energy expenditure during the exercise bout when compared to aerobic type training, however the effect of resistance training on energy expenditure during the recovery period of an exercise session, also known as excess post-exercise oxygen consumption (EPOC), is more significant when compared to aerobic training.

This literature review will look at resistance and aerobic training and their effects on energy expenditure both during exercise and the recovery period of exercise (EPOC). Also reviewed are studies carried out that focus on different resistance and aerobic type training workouts of different/same intensities and duration.

Chapter 2 – Review of Literature

2.1 Energy Systems;

There are three energy systems in the body, these are the adenosine triphosphate (ATP) - phosphocreatine (PCR) system, the lactic acid system, and the aerobic system (Katch et al., 2011). The ATP-PCR system is responsible for providing immediate energy during exercise. Short duration exercise of high intensity bouts require immediate and rapid supplies of energy to the body, ATP and PCR are both high energy phosphates stored within the muscle that provide this source of energy (Mcardle et al., 2010). The lactic acid energy system is responsible for providing short term energy during exercise (Katch et al, 2011). In order for vigorous exercise to continue past a brief period the intramuscular phosphagens must be continuously resynthesized. During high intensity exercise intramuscular stored glycogen provides energy to phosphorylate adenosine diphosphate (ADP) during anaerobic glycogenolysis, resulting in the formation of lactate (Katchet a., 2011). Where there is an inadequate supply and utilization of oxygen all the hydrogen's formed in rapid glycolysis fail to oxidize, resulting in pyruvate being converted into lactate (Costill et al., 2012). This then allows the process of rapid ATP formation by anaerobic substrate – level phosphorylation. Anaerobic energy for ATP resynthesis from glycolysis can be seen as reserve fuel which is activated when the oxygen demand: oxygen utilization ratio exceeds 1:0 (Costill et al., 2012). The third energy system is the aerobic system, which provides long term energy. Glycolysis releases anaerobic energy rapidly, however only a small amount of ATP results from this pathway (Katch et al., 2011). In contrast, the aerobic metabolic reactions allow a greater portion of energy transfer especially when exercise is carried out for more than 2-3 minutes. Oxygen uptake increases quickly during the first few minutes of exercise, it then remains stable throughout the remainder of the exercise. This plateau of oxygen uptake identifies the steady rate of anaerobic metabolism, which is a balance between the energy required by the body to perform the exercise and the rate at which aerobic ATP is being produced (Costill et al, 2012).

2.2 Respiratory Exchange Rate (RER):

Respiratory exchange rate (RER) is the ratio between carbon dioxide produced and oxygen consumed during exercise and nutrient metabolism (Goedecke et al., 2000). RER refers to the type of energy being used as fuel during exercise (Jamurtas et al., 2004). According to Goedecke et al. (2000) carbohydrates and fats are both used to produce energy by the oxidative energy system during exercise. RER increases with the increase in exercise intensity and when measured under a steady state condition can be commonly used to indirectly determine the contribution of carbohydrates and fats to the overall energy expenditure during exercise (Elliot et al., 1992). A high RER figure such as 1.0 or over indicates that carbohydrates are the main source of energy being used by a person during exercise. Whereas a lower RER figure of 0.7 suggests that fats is the predominant source of energy fuel being used (Borsheim & Bahr, 2003). Sedlock et al. (1989) state that the use of fat as an energy source decreases as a result of increasing the exercise intensity, as a result this places more of a reliance on carbohydrates to act as the main source of energy during exercise.

An example would be to take an individual who is running on a treadmill, while running at 6km the intensity may not be as challenging for this person therefore their RER reading may be under 1.0 and may read at 0.7 or 0.8 which indicates they are using fats only as their source of fuel. However if the intensity was increased to 15km the person would be running at a much faster pace and would be a lot more challenging, this would result in the RER reading being above 1.0 which indicates the person is working hard and using carbohydrates as their main source of energy to fuel their workout. RER can also be monitored following the completion of a workout to examine if a person continues to expend energy in the form of fats or carbohydrates during their recovery.

2.3 Energy Expenditure:

Total energy expenditure (TEE) is made up of three components, resting metabolic rate (RMR), the thermic effect of food and the thermic effect of physical activity (PAEE) (Katch et al., 2011). RMR is defined as the energy expenditure needed by the body to maintain daily physiological processes (Volp et al., 2011). RMR is the largest portion of TEE and it can account for approximately 60-70% of energy expended (Katch et al., 2011). The thermic effect of food refers to the increase in an individual's metabolic rate above resting levels due to food intake. When food is consumed the body utilizes energy in order to break down the food being consumed, this process corresponds to approximately 10% of TEE (Katch et al, 2011). The thermic effect of food process can result in the body expending energy up to 8 hours following the consumption of food. Physical activity energy expenditure (PAEE) is the most variable component of the three (Katch et al., 2011). This component refers to the amount of energy expended as a result of physical activity. In sedentary individuals the thermic effect of physical activity can account for approximately 15% of TEE (Volp et al., 2011).In physically active individuals it can reach up to 30%. All three components however are subject to change due to external factors. While physical activity may cause acute and chronic increases in TEE, these acute increases in energy expenditure would be due to the cost of energy required to perform the exercise session and also for the energy expended during the recovery period of the exercise session. These increases in TEE would have a significant effect on resting metabolic rate (Katch et al., 2011).

2.4 Excess Post-Exercise Oxygen Consumption (EPOC):

Excess Post – Exercise Oxygen Consumption (EPOC) refers to the oxygen consumption during the recovery period of an exercise session (Boresheim & Bahr, 2003). Following the completion of a workout the body continues to consume oxygen at an elevated rate which results in a person continuously expending energy for a period of time following that exercise (Elliot et al.,1992). Although aerobic and resistance type training do have an effect on EPOC, the duration of EPOC differs between the two. The intensity and duration of an exercise bout also play a key role in the magnitude of EPOC (Meirelles & Gomes, 2004). Several processes occur during the recovery phase of an exercise session as there is still an increased rate of oxygen consumption and energy expenditure (Reynolds & Kravitz, 2001).

Replenishment of energy resources occurs for the phosphagen system**.** Levels of muscle glycogen are also being restored**.** Re-oxygenation of blood and restoration of circulatory hormones is also part of the recovery process. During exercise large amounts of oxygen are used to break down food for energy (Reynolds &Kravitz, 2001)**.** The body then continues to expend energy after exercise to re-oxygenate the blood. In the post-exercise period the levels of circulatory hormones that increases during exercise are restored to the normal rates once again (Reynolds & Kravitz, 2001). According to Williams & Wilkins (2011) the thermogenic effects of elevated core temperature and restoration of oxygen to blood, tissue fluids and myoglobin are causes of excess EPOC response.

During exercise energy is expended from the exercising muscle tissues, resulting in an elevated core temperature. Therefore after the exercise is finished core temperature decreases once more and energy is expended as a result (Williams & Wilkins, 2011)**.** Post exercise oxygen is also used to oxidize lactic acid. Lactic acid is produced during exercise and then travels via the blood stream to the kidneys, cardiac muscle and liver. An increased amount of oxygen is needed to convert this lactic acid back to pyruvic acid at these locations (Reynolds & Kravitz, 2001)**.**Heart rate is returning to its pre-exercise rate which also contributes to a continued energy expenditure process after exercise is complete (Meirelles & Gomes, 2004).Elliot et al. (1992) state that it can take anywhere from 15 minutes up to 48 hours for the body to fully recover to a resting state following exercise. Boresheim & Bahr (2003) reported similar findings and claim that EPOC can last up to a number of hours after the cessation of the exercise session. However others have concluded that EPOC is transient and does not last for a significant period of time (Meirelles & Gomes, 2004).

2.5 The Effect of Aerobic Training on EPOC:

Aerobic type training has a significant effect on energy expenditure during an exercise session, however the effect aerobic training has on EPOC is not as significant as that of resistance training (Han- Wu & Charng Lin, 2006). According to Elliot et al. (1992) resistance training is becoming more popular as a form of training as it can lead to a greater prolonged increase in energy expenditure during the recovery period of an exercise session compared to aerobic training. Boresheim & Bahr (2003) examined the duration and magnitude of EPOC following aerobic type training. Subjects cycled for a period of 5-20 minutes at three different intensities 50%, 65%, and 80% of VO_{2max}. It was found that there was an increase in EPOC immediately after each cycling session, however there was no EPOC found beyond the 35 minute mark of each recovery period. Freedman et al. (1985) also examined the duration and magnitude of EPOC after aerobic exercise by engaging participants in 20-40 minutes of aerobic treadmill exercise. Their results were similar to those of Boresheim & Bahr (2003) with no significant increase in EPOC beyond the 40 minute mark during the recovery period evident.

Another study examined the effect of four 20 minute cycling bouts at 35-55% of VO_{2max}, again results showed there was a continued increase in energy expenditure during the recovery period for up to 40 minutes however beyond this point there was no increase evident (Elliot et al.,1988). It’s clear from these studies that aerobic type exercise when performed for short durations does not have that much of a prolonged effect on EPOC. Hermansen et al. (1984) conducted a study focusing on high intensity aerobic training for longer durations and its effect on EPOC. Male participants cycled for 80 minutes at 75% of VO_{2max}. Twelve hours following the completion of the exercise there was an increase in EPOC evident in participants and this was still evident 24 hours afterwards.

Maehlum et al. (1986) conducted another study examining the effect of high intensity aerobic training for longer durations and the subsequent effect on EPOC. For this study 8 male participants cycled for 80 minutes in periods of 10-30 minutes at 70% of their VO_{2max}. There were 5 minute breaks in between cycling bouts. Results showed that a mean EPOC of 26L was recorded and that VO2 was still increased by 5% up to 24 hours after completing the exercise. Many studies have examined the different effects aerobic training can have on EPOC by performing the exercise at different intensities/durations. It is clear that aerobic exercise when performed at a higher intensity for a longer duration has more of a significant

effect on EPOC compared to aerobic exercise performed at a lower intensity for shorter durations.

2.6 The Effect of Resistance Training on EPOC:

As stated previously resistance training has more of an effect on energy expenditure during the recovery period of an exercise session (EPOC) rather than during exercise (Thornton & Potteiger, 2002).Poehlman & Melby (1998) support this as they state that resistance exercise has more of an effect on EPOC compared to aerobic exercise. According to Boresheim & Bahr (2003) this greater effect associated with resistance training on EPOC is due to the greater metabolic disturbance and breakdown of muscle tissue that occurs during the exercise session. Reynolds & Kravitz (2001) claim that there is a longer EPOC associated with weight training because of the longer period of time needed by the body to return to homeostasis. During the recovery period of resistance exercise restoration of ATP and PCR is occurring along with the repair of damaged tissue and the replenishment of oxygen stores in both blood and muscle, however few studies have investigated the effects of resistance training on EPOC (Vella & Kravitz, 2004). The research that has been done has suggested that resistance training produces a greater effect on EPOC when compared to aerobic training due to the breakdown of muscle tissue and the greater metabolic disturbance associated with resistance training.

Although it is difficult to equalize resistance training and aerobic training, Elliot et al., (1992) conducted a study to examine the difference in energy expenditure during exercise and the recovery period between aerobic training, heavy resistance training, and light resistance circuit training. The aerobic training consisted of cycling at 80% of maximal heart rate, light resistance circuit training was performed at 50% of 1RM where four sets of 8 exercises were completed, and the heavy resistance training consisted of 3 sets of 8 exercises performed at 80-90% of 1RM. Results of this study showed that immediately after the three modes of exercise were complete there were significant increases in EPOC, however this EPOC remained elevated for a longer period of time following the completion of the heavy resistance training. Heavy resistance training did not have as much of an effect on energy expenditure during the exercise as greater amounts of oxygen consumption was associated with the aerobic exercise and light resistance high intensity exercise (Elliot et al., 1992).

EPOC remained elevated for a period of 2 hours following the heavy resistance workout, while EPOC levels of the aerobic workout began to decrease once again after 30 minutes and 45 minutes for the light resistance circuit training respectively.

Burleson et al (1998) also cited similar findings and claim that resistance exercise has a more significant effect on energy expenditure during the recovery period of exercise. This was proven by conducting a study that compared the duration and magnitude of the energy expended during the recovery period of exercise sessions between a typical resistance exercise session and an aerobic exercise session of the same duration (30 minutes) and intensity (45% of VO_{2max}). Results showed that EPOC remained higher for up to 90minutes after the completion of the resistance session compared to a period of 30 minutes after the aerobic session. Meirelles & Gomes (2004) state that many variables related to resistance exercise can have an effect on the results of the energy expended during the recovery period of an exercise session. Factors such as number of repetitions, rest intervals between sets, and the number of sets performed all play their role in influencing the energy expenditure during and after a resistance training session.

2.7 The Effect of Exercise Intensity on Energy Expenditure during and after Exercise (EPOC):

Volume of work has been identified as a main contributor to increased energy expenditure (Elliot et al., 1992). Volume consists of variables such as duration and intensity of the exercise (Hunter et al., 1998). A high volume of work performed at a high intensity will be most effective in increasing energy expenditure during exercise (Meirelles & Gomes, 2004). As stated by Han-Wu & Charng Lin (2006) resistance training and aerobic training are both popular forms of training in exercise programmes for individuals who have all types of different physical goals. The popularity of resistance training as a form of exercise for people with the aim of weight loss/management is growing rapidly as its effect on energy expenditure during the recovery period of an exercise session is greater compared to aerobic training (Meirelles & Gomes, 2004). As stated previously aerobic training has more of an effect on energy expenditure during exercise however it may not have as much of an effect on the energy expenditure during the recovery period of exercise compared to resistance training (Hunter et al, 1998). Han-wu & Charng Lin (2006) state that high intensity resistance and aerobic training may have greater benefits for those with the aim of weight loss/management as a greater amount of energy can be expended. Sedlock et al. (1989) also have similar views on the matter as they suggest performing low intensity exercise may not have as much of an effect on energy expenditure compared to high intensity exercise. This is proven across numerous studies that have compared high intensity aerobic and resistance training with low intensity aerobic and resistance training. These studies have found that a greater EPOC is associated with resistance training, and that aerobic training must be performed at a high intensity for a long duration in order to achieve an increase in EPOC for a longer period of time (Thornthon & Potteiger, 2002).

It is clear that the higher the intensity, the more energy needed to perform an exercise (Elliot et al., 1992).Han-Wu & Charng Lin (2006) state that 22% more of energy is required to perform the same amount of bike work for the same duration but at a higher intensity. While three times more energy is required to perform one repetition of a resistance exercise at 80% of an individual's 1RM compared to four repetitions performed at 20% of 1RM. This indicates clearly that intensity and volume play a key role in the amount of energy expended during an exercise session (Han-Wu & Charng Lin, 2006).A number of studies have been carried out to investigate if energy expenditure is increased post exercise when it is

performed at a high intensity, for example Han-Wu & Charng Lin (2006) state that energy expenditure during the recovery period (EPOC) of an aerobic exercise session can increase by 5-15 % for a period of 24-48 hours when performed at an intensity of at least 70% of an individual's VO_{2max}. Han-Wu & Charng Lin (2006) also highlight that this increase in energy expenditure would not be achieved following an aerobic exercise session performed at a lower intensity of 50% VO_{2max}. However, Meirelles & Gomes (2004) do not ignore the positive benefits of a low intensity exercise program as improvements in energy expenditure can be achieved. Although aerobic training as stated before may not have as much of an effect on EPOC as resistance training does, a greater EPOC is associated with aerobic exercise performed at a high intensity rather than a lower intensity. Resistance training does not necessarily have to be performed at a high intensity to achieve a prolonged increase in EPOC. A heavy resistance training session performed at a low intensity (longer rest periods) for example 3 sets of 8 reps at 80% 1RM with 90 second rest periods between each set can have a greater effect on EPOC compared to a light resistance session performed at a higher intensity (shorter rest periods) which may consist of 3 sets of 15 reps at 40% 1RM with 30second rest periods between sets.

Han-Wu & Charng Lin (2006) conducted a study that focused on the effect of intensity of resistance exercise on excess post-exercise oxygen consumption (EPOC). Subjects performed two separate resistance exercises. The first consisted of 3 sets of 8 exercises for 10 reps performed at 75% of 1RM. The second was a low intensity resistance session consisting of 4 sets of the same 8 exercises performed at 50% of each subjects 1RM for 15 reps. There was a rest period of 2 minutes between each working set of the heavy resistance session, whereas a rest period of 1 minute was provided after each light resistance working set. EPOC was recorded at three stages following the completion of each session. At 0 minutes, 60 minutes, and 120 minutes after the exercise sessions were complete. Results of this study showed that EPOC recorded after the high intensity resistance session was significantly higher and lasted for a longer period of time compared to the low intensity session. However, the low intensity resistance training that had shorter rest periods and a higher number of sets and reps had a greater effect on energy expenditure while the exercise was being performed. This outlines how number of sets, rest periods and volume of the exercise can play a significant role in energy expended both during and after the exercise is complete.

2.8 Rationale

It's well documented that aerobic training has more of a significant effect on energy expenditure during exercise when compared to resistance training (Boresheim & Bahr, 2003). However, resistance training is recognised for having more of an effect on energy expenditure during the recovery period of an exercise session (EPOC) when compared to aerobic training (Elliot et al., 1992). Numerous studies have been carried out to compare the differences in energy expenditure both during and after exercise between aerobic and resistance type workouts. However the number of studies that compare resistance and aerobic training together as a typical gym session workout is limited. Many studies focus on having 2 or 3 workouts where a resistance exercise session is compared to an aerobic exercise session separately.

The purpose of this research project is to have two exercise sessions both consisting of resistance and aerobic type exercise in the form of a typical gym session where aerobic exercise is performed first followed by resistance exercises. Different intensities will be selected for both sessions as the first session will consist of high intensity aerobic running followed by light resistance training in a circuit format. The second will consist of low intensity aerobic running followed by high intensity resistance training. It's of interest to examine the effects both workouts will have on energy expenditure both during and after they are performed. The overall aim of this project is to examine which exercise session has the most significant effect on energy expenditure both during the exercise and during the recovery period of that exercise.

Chapter 3 - Methodology

3.1 Research Design:

The research design used was a quasi-experimental design. In this case it was used to measure and compare energy expenditure during the two separate exercise sessions that contained a combination of both aerobic and resistance training exercise of different durations and intensities, among physically active Exercise and Health studies students. Excess post-exercise oxygen consumption (EPOC) was measured to compare the energy expenditure between both sessions once they were completed.

3.2 Study Population and Sampling:

The intervention was conducted in the human performance laboratory at Waterford Institute of Technology. The study sample consisted of 6 physically active Exercise and Health studies students. Exercise and Health studies students were selected as previous experience of aerobic and resistance training was required. The subjects were recruited by emails, phone calls and other social contacts and were briefly informed of what the test included.

3.3 Variables:

Variables measured were as follows;

Maximal Oxygen Uptake (VO_{2max}):

Subjects completed a VO_{2max} test before the testing started. A VO_{2max} test helped give an insight into the maximum capacity of an individual to transport and use oxygen around the body during incremental exercise, which reflected the physical fitness of each subject. The VO_{2max} test scores also gave an indication of the correct intensities to be chosen for each subject for the aerobic phases of both workouts.

Maximum Strength Levels (1RM):

A 1 repetition maximum (1RM) test was carried out by each subject before the testing begun. The 1RM test included a maximal lift for each exercise to be performed in both workouts. The results from the 1RM test helped in selecting the correct amount of resistance to be applied for each subject during the resistance phases of both workouts.

Resting Metabolic Rate (RMR):

Resting metabolic rate (RMR) was measured from each subject before both workouts. RMR readings gave an insight into the oxygen consumption levels of each subject at rest, it also gave an indication of the rate at which each subject expends energy at rest by examining the respiratory exchange rate (RER). Heart rate was also monitored.

Energy expenditure:

Energy expenditure was measured immediately after both workouts where RER, VO2 consumption and heart rate readings were examined to see the effects both workouts had on each subject and the rate at which each subject expended energy during the workouts.

EPOC:

EPOC was measured at 1 hour and 2 hours after each workout where RER and VO2 consumption levels were recorded to examine the rate at which each subject continued to expend energy during the recovery periods of both workouts.

3.4 Data Collection Procedures:

Subjects arrived at the Human Performance Laboratory at Waterford Institute of Technology at proposed dates during January to complete a number of data collection procedures. Firstly adequate informed consent was obtained from each subject before any data collection took place. Participants were provided with information to ensure they knew and understood the purpose and risks associated with the experiment. Each subject was given the opportunity to ask questions about the procedure and were all provided with information about the experiment. Firstly each subjects resting metabolic rate (RMR) was measured.

RMR was measured by taking the following steps:

- Record subjects measurements – height, weight, age and gender
- Have participant lie down and relax for a minimum of 15 minutes
- Prepare Moxus while subject is resting
- Submit subject data
- After 15 minutes of rest place headpiece on subject
- Have subject sit on a chair on the treadmill
- Begin the test
- Take recordings for resting HR, VO2 (ml/kg/min), RER after 5 minutes
- Safely remove headpiece from subject

Once subjects RMR were recorded they took part in a VO_{2max} test in order to determine their aerobic fitness capacity.

VO_{2max} tests were conducted taking the following steps:

1. Record subjects measurements – height, weight, age and gender
2. Familiarise subject with the treadmill and with mouthpiece.
3. Apply heart rate monitor, mouthpiece and nose clip.
4. Sit subject on the treadmill on a chair.
5. Allow subject to rest quietly for up to 5 minutes.
6. Record resting VO2 (ml/kg/min), VO2 (L/min), VCO2 (L/min), RER and Heart rate.
7. Remove chair from treadmill and stand up the subject.
8. Increase treadmill speed to pre-determined level and allow subject to walk for 1 minute.
9. Record RPE, HR, VO2 (ml/kg/min), VO2 (L/min), VCO2 (L/min) and RER during the last 15 seconds.
10. Increase treadmill speed to next predetermined exercise intensity for a further 1 minute.
11. Repeat step 9 for the last 15 seconds.
12. Repeat steps 10 & 11 until the subject can run no longer and is at exhaustion
13. At exhaustion record and take all measurements.
14. End of test: Remove mouthpiece and nose clip and allow subject to exercise for 3 minutes at a low intensity to cool down.

* These VO_{2max} recordings will help in selecting the appropriate intensity required for the two aerobic phases of each exercise session by focusing on each subjects RER scores.

Maximal Strength Test (1RM):

The 1RM tests were conducted in the gymnasium at Waterford Institute of Technology from the week starting 20th January. Subjects were familiarised with the exercises to be performed and informed that they will be performing their maximal lifts on each exercise. The exercises to be tested on were the squat, bench press, deadlift, and shoulder press. Firstly subjects done a light warm up to get all muscles in the body prepared, this is important as they were going to be lifting heavy amounts of weight and a good warm up was essential. Subjects started with the bench press exercise, starting off at a light weight and gradually building up to their maximal lift by increasing the weight each time. All lifts each subject performed were recorded separately. This data collection helped clarify the correct amount of weight that was to be lifted for the resistance exercises of the experiment for each subject as a percentage of their 1RM. This 1RM procedure is following the same procedure from a study conducted by Elliot et al., (1992).

Testing Procedure:

There were two separate workouts, each workout consisted of aerobic and resistance training exercise performed at different intensities and duration. The first workout included 10 minutes of running on the treadmill at a moderate pace, the intensity chosen for each subject was taken from their VO_{2max} scores where a speed at which the subject was running where their RER reading was under 1.0 was selected. This was then followed by heavy resistance exercises at 80% of the subjects 1RM, the exercises performed focused on the large muscle groups of the body such as the squat, bench press, deadlift and shoulder press. 3 sets of 8 repetitions were performed of each exercise during the first workout. Following the completion of the 10 minute moderate running there was a 2 minute rest period before subjects began the resistance phase. There was a 1 minute break between each working set of the resistance exercises.

The second workout consisted of beginning with 10 minutes of aerobic running at a more vigorous pace, like the first workout the speed for the 10 minutes running was selected from each subjects VO_{2max} score. However, for this work out a speed where each subjects RER was above 1.0 was chosen. This was followed by light resistance exercise, the light resistance exercises were the same exercises performed for the first workout. However, this session will

consist of 3 sets of 14 repetitions performed at 45% of each subjects 1RM. Like the first workout there was a 2 minute rest period after the running, however subjects only had 30 seconds of rest in between working sets of the light resistance phase.

Both workouts were carried out in the Human Performance Laboratory at Waterford Institute of Technology. Subjects were connected up to the Moxus system (AEI Technology) for both the aerobic and resistance training stages of each workout so oxygen uptake could be monitored throughout. Each workout was assisted by 2-3 people in order to ensure a smooth process regarding changing weights once working sets were finished. Once each workout was completed subjects rested for 1 hour before getting the first EPOC reading, and again for another hour before recording the 2 hour EPOC readings. This was achieved by connecting the subject to the Moxus system once again and taking VO2 and RER figures for 5 minutes.

3.5 Data Analysis:

Results gathered were inputted into SPSS and were analysed in order to provide answers to each of the research questions. Variables such as age, height, weight, RER and heart rate were all submitted into SPSS. Descriptive statistics was used to measure oxygen consumption at rest, 0 (immediately after each exercise session), 1hour, and 2 hours after each workout. Differences in energy expenditure during and after each workout (EPOC) at both 1 and 2 hours were also measured and compared.

3.6 Ethical Considerations:

Each participant was provided with an informed consent form outlining what exactly the experiment involved, confidentiality for each person was respected and rights of each participant were outlined. Participants had the right to leave from this experiment at any time. Private health information regarding previous medical history or results from this test remained confidential. A screening form to evaluate the health conditions of each subject was also provided.

Chapter 4 - Results

4.1 Introduction:

This chapter includes all the main findings of the results and data gathered from the testing of this study. The results presented aim to provide the answers to the three research questions.

4.2 Descriptive Statistics:

There were a total of 6 subjects that took part in this study, all of which were male. The table below outlines the difference in age, height, and weight among the 6 subjects all of which were calculated using descriptive statistics.

4.3 Table 1. Characteristics of Subjects

	Subjects (Average)	Standard Deviation
Number	6 (male)	-
Age	23.8	2.041
Weight	79.67	4.227
Height	178cm	3.847

4.4 Table 2: Average VO_{2max} Scores;

The mean VO_{2max} of the 6 subjects was 45.6 ml/kg/min which was achieved at an average of 10 minutes.

Subject	VO_{2max} ml/kg/min	Time to Max in Minutes	Fulfilled Criteria for VO2max Testing
1	47.7	9 Mins	3/5
2	42.8	10 Mins	4/5
3	53.9	12 Mins	4/5
4	35.7	8 Mins	4/5
5	46.8	10 Mins	3/5
6	47.1	11 Mins	4/5
Average	45.6	10	

Results showed that there was a significant difference in VO2 consumption during both work-outs. (P = 0.015).

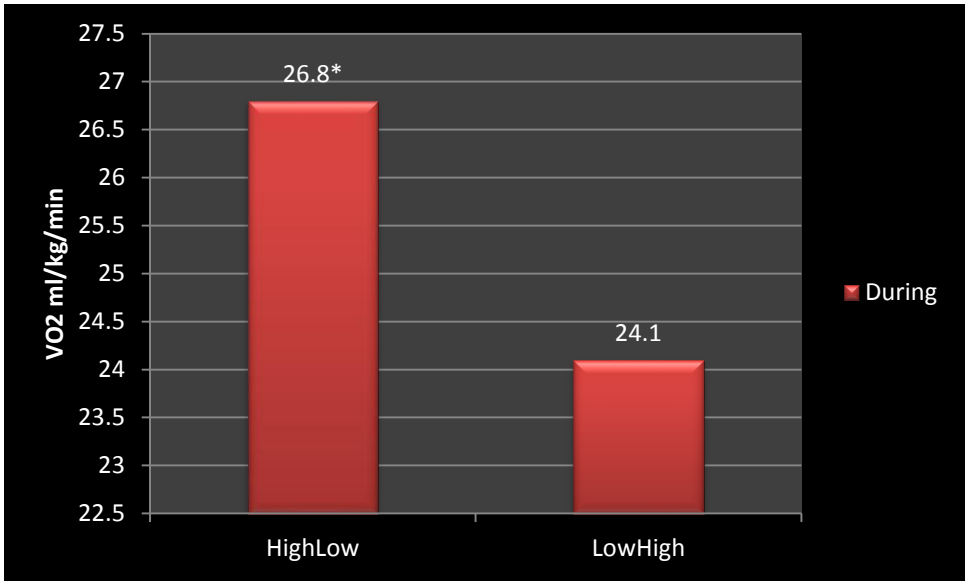

Fig 1: **VO2 (ml/kg/min) consumption during both work-outs.**

Below illustrates the significant difference in average calories burnt by each subject during both work-outs (P = 0.01).

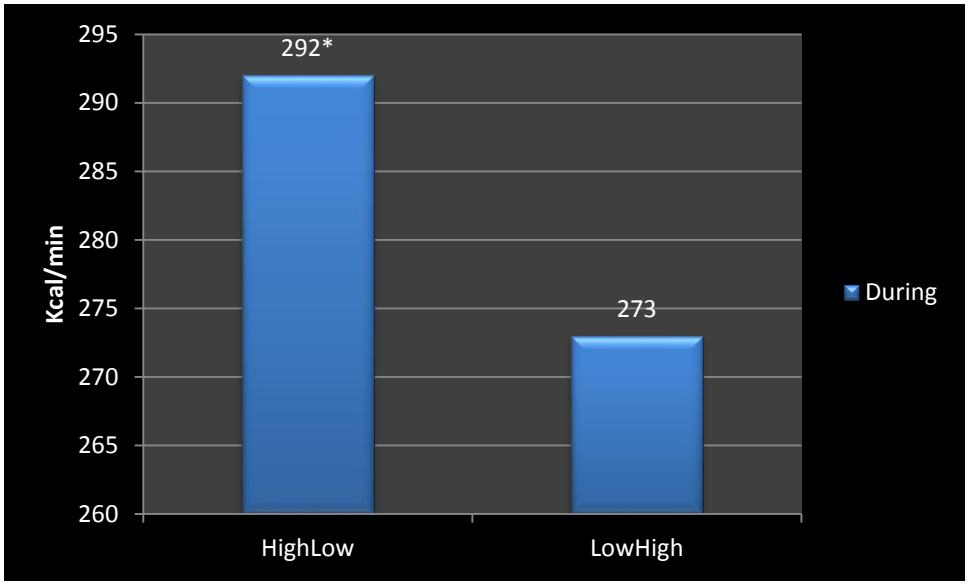

Fig 2: Average for calories burnt by subjects during both work-outs.

Results reveal there was a significant difference at the 1 hour EPOC recordings between both work-outs (P = 0.02). However there was no significant difference found between work-outs at the 2 hour recordings (P = 0.800).

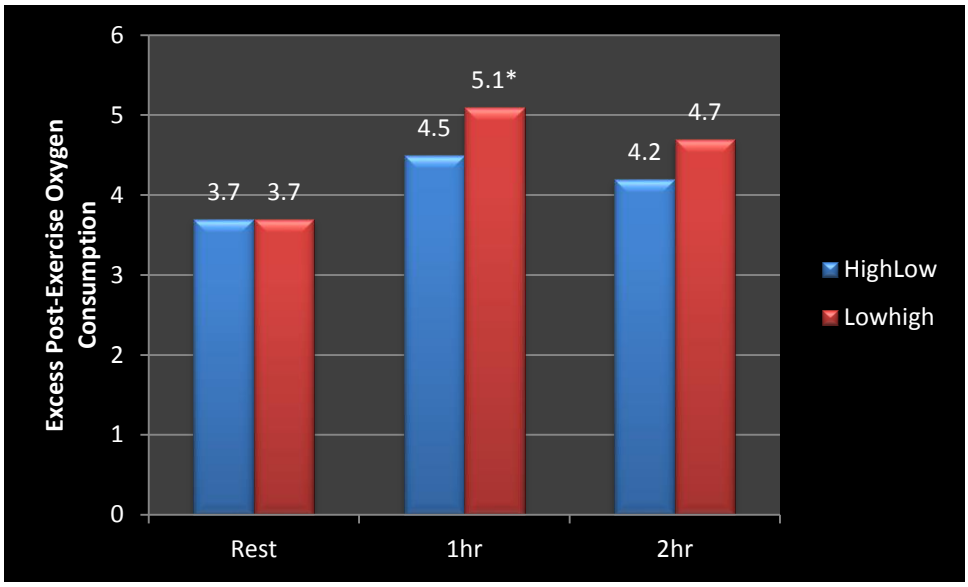

Fig 3: VO2 consumption levels during the recovery phase of both work-outs (EPOC).

There was a significant difference between the amount of calories burnt by subjects at the 1 hour recording (P = 0.03). However, no significant difference was found between both 2 hour recordings (P = 0.357).

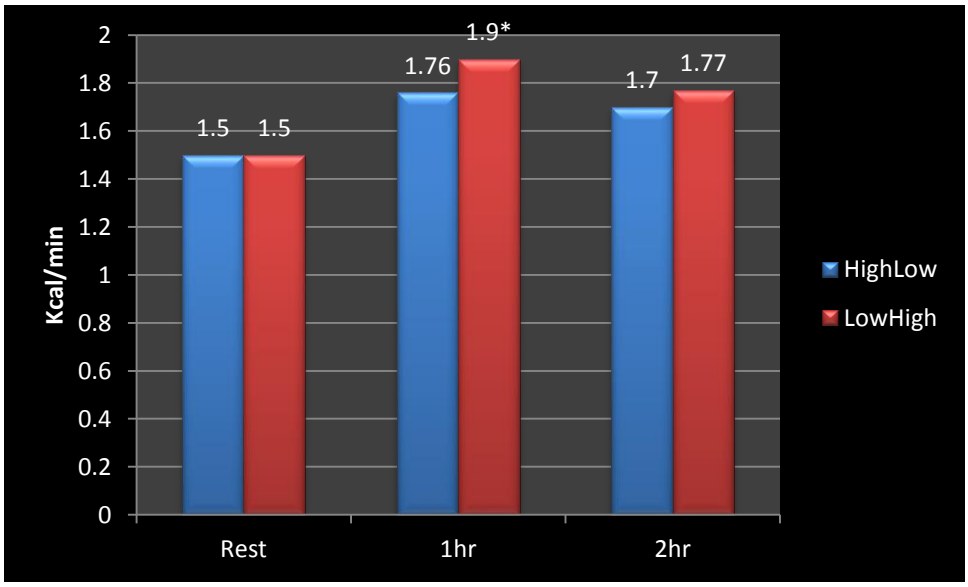

Fig 4: Average Kcal/min burnt by each subject at rest, 1 hour after, and 2 hour after each work-out

Results show a significant difference in RER figures during both work-outs (P = 0.001). However there was no significant difference between RER figures at 1 hour (P = 0.315) and 2 hour (P = 0.282)

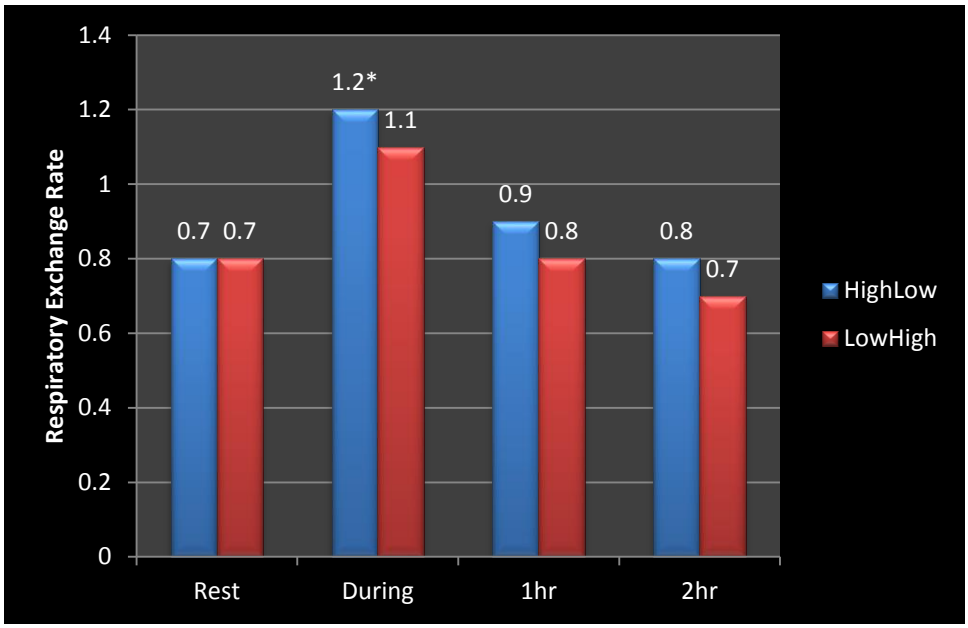

Fig 5: **RER figures for before, during, and after both work-outs.**

Results show that there was a significant difference in average heart rate among subjects during both work-outs (P = 0.06).

Fig 6: Average heart rate at rest and during both work-outs.

Results show a significant difference in RPE readings between both work-outs (P=0.03).

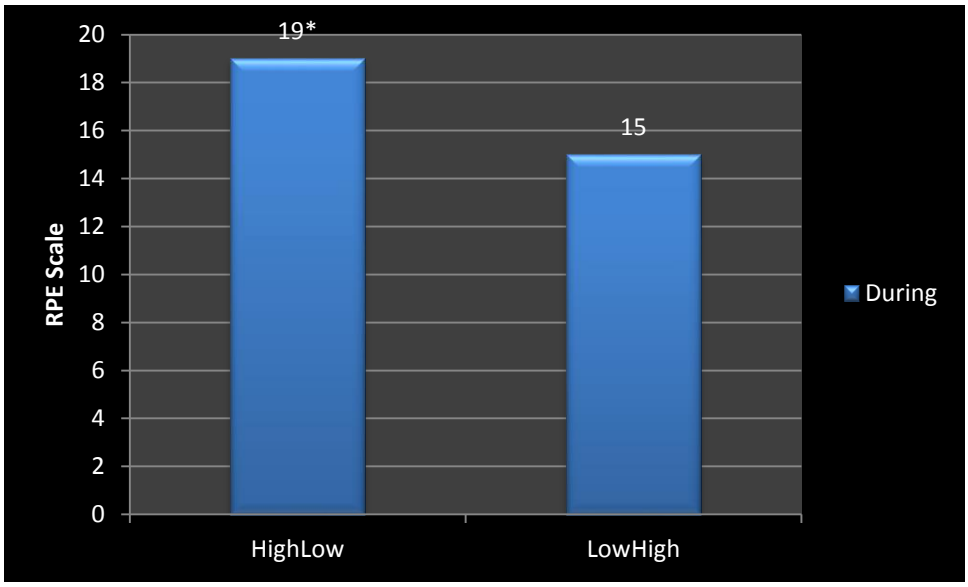

Fig 7: Average RPE readings gathered from subjects for both work-outs.

Chapter 5 - Discussion of Results:

5.1 Introduction:

The purpose of this study was to compare two separate work-outs that consisted of both aerobic and resistance type exercise performed at different intensities and duration and to examine the effect both work-outs had on energy expenditure both during and after both work-outs were complete. Previous research has proven that aerobic exercise when performed on its own at a high intensity has more of a significant effect on energy expenditure during exercise when compared to a heavy resistance training work-out. Research has also found that resistance training has more of a significant effect on energy expenditure during the recovery phase of a workout (EPOC). So it was of interest to have two separate work-outs that consisted of both aerobic and resistance training together and examine their effects on energy expenditure among subjects during the exercise and also during the recovery period (EPOC).This study also took into consideration factors such as heart rate, RER and RPE and examined how all were affected across both work-outs.

5.2 Research Questions:

1) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on energy expenditure.

2) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on EPOC.

3) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on heart rate, RER, and RPE readings.

5.3 Main Findings:

- There was a significant difference in VO2 consumption found during both work-outs (P = 0.015)
- There was a significant difference between the number of calories subjects burnt during both work-outs (P= 0.01)
- There was a significant difference between EPOC findings associated with both work-outs at the 1 hour recording (P = 0.02)
- There was a significant difference found between calories burnt per minute (Kcal/min) during the recovery phase of both work-outs at the 1 hour recording (P = 0.03)
- There was a significant difference in RER figures during both work-outs (P = 0.001)
- There was a significant difference in figures for heart rate during both work-outs (P = 0.06)
- There was also a significant difference in RPE readings from both work-outs (P = 0.03)

5.4: RQ1) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on energy expenditure.

The first research question focused on comparing the amount of energy expended during both work-outs. Energy expenditure was recorded by examining the VO2 ml/kg/min each subject consumed during each work-out. By finding this VO2 ml/kg/min figure the amount of calories burnt by each subject during each work-out could be calculated by using specific formulas. When the results of both work-outs were compared a significant difference between the two was found. The first work-out which consisted of high intensity running followed by light resistance circuit training resulted in a greater VO2 ml/kg/min consumption among subjects when compared to the second work-out which consisted of low intensity running followed by heavy resistance training. These findings did not come as a surprise as previous research has found that high intensity aerobic exercise has more of an effect on energy expenditure during exercise when compared to heavy resistance training (Elliot et al., 1992). Therefore the high intensity running when combined with light resistance circuit training was expected to result in a greater VO2 ml/kg/min consumption and as a result had subjects expend more energy during this work-out.

The high intensity running phase of the first work-out was selected from each subjects VO2max scores by choosing a speed where the subjects RER reading was over 1.0. This highlighted that the subject was working at a reasonably tough intensity and was burning 100% carbohydrates in the process. This running phase when compared to the second work-out running phase where the intensity was selected by choosing a speed where the subjects RER reading was comfortably below 1.0 was always going to result in a greater VO2 ml/kg/min simply because subjects were running at a faster pace and were working harder. The light resistance circuit phase of the work-out involved subjects completing exercises at 45% of their 1RM, and although the volume of this resistance phase was light, the short rest periods resulted in it being rather challenging for subjects. Subjects were breathing heavy and it was evident that they were working hard. It also must be taken into consideration that before subjects engaged in this light resistance phase that they had already completed 10 minutes of high intensity running which made the light resistance phase even more challenging.

The running phase of the second work-out was performed at a lower intensity and the heavy resistance phase of that work-out consisted of longer rest periods and although the volume was higher than the light resistance phase the longer rest periods between working sets resulted in a lower VO2 ml/kg/min figure associated with this work-out. There was also a significant difference found in the number of calories burnt between both work-outs. As expected the high intensity running and light resistance work-out that resulted in a greater VO2 ml/kg/min showed to burn more calories among subjects during the work-out itself. Once the VO2 ml/kg/min figures were recorded the amount of calories each subject burnt was calculated. A higher number of calories burnt was associated with this work-out simply because they found this work-out more challenging and were working at a higher intensity. The purpose of combining both aerobic and resistance type exercise in both work-outs was to examine if the heavy resistance work-out when combined with low intensity running could result in a greater energy expenditure among subjects while performing the exercise itself. However the overall findings relate to those found among other studies that have been carried out previously. Elliot et al. (1992), Haddock & Wilkin (2006), and Kraemer et al. (2002) all found that aerobic exercise results in a greater energy expenditure in comparison to resistance training and although the combination of aerobic and resistance training in this study aimed to result in different findings in comparison to those previously found it was not successful in doing so.

5.5: RQ2) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on EPOC.

The second research question focused on comparing the amount of energy subjects continued to burn during the recovery phase of both work-outs (EPOC). A number of studies have been carried out previously that examined the different effects aerobic and resistance type exercise has on energy expenditure during the recovery phase of a work-out (EPOC). Aerobic training is well-documented for having a more significant effect on energy expenditure during a work-out in comparison to resistance training which has a greater effect on EPOC (Elliot et al., 1992, Boresheim & Bahr 2003, & Han-Wu & Charng Lin 2006). Findings of this study found a significant difference between both 1 hour recordings of EPOC among subjects. The second work-out that consisted of low intensity running for 10 minutes followed by heavy resistance training at 70% of subjects 1RM proved to result in a greater 1 hour EPOC reading compared to the high intensity running and light resistance circuit work-out, and although the recordings taken at the 2 hour mark were not significant the EPOC still remained higher for the second work-out in comparison to the first.

These findings were interesting as it highlights that even though subjects might have worked harder during the first work-out and burned a greater amount of calories during the exercise, it does not necessarily mean they will continue to burn more calories during the recovery phase of that work-out. The EPOC findings recorded show that during the recovery phase of the light running and heavy resistance work-out subjects continued to consume more oxygen and as a result burned more calories per minute when compared to the high intensity running and light resistance work-out. When considering the findings of this study and comparing them to other study's it could be said that the figures found did not come as a surprise. In studies conducted by Elliot et al.,(1992), Boresheim & Bahr (2003) and Han-Wu & Charng Lin (2006) where aerobic exercise of different intensities were compared to resistance exercise of different intensities all came to the conclusion that resistance training when performed at a higher percentage of a subjects 1RM resulted in a greater EPOC reading among subjects.

This study aimed to examine the differences in EPOC between two work-outs that had a combination of both aerobic and resistance exercise and to see if any differences could be found in comparison to the studies mentioned above. And although EPOC readings from this study at the 1 hour and 2 hour mark did result in higher figures compared to the 1 hour and 2

hour findings among the studies mentioned the overall finding was that the second work-out that included heavy resistance training resulted in the greater EPOC recording. It is important however to mention why the EPOC readings in this study were significantly greater than figures recorded in previous studies. In the study carried out by Elliot et al. (1992) where three separate work-outs were compared a greater EPOC was found after the heavy resistance work-out when compared to the light resistance work-out or the aerobic work-out, however the duration of the EPOC associated with the aerobic and light resistance work-out in that study were not as long as figures found here. This primarily comes down to the fact there was a combination of aerobic and resistance exercise in the same work-out in this study, and even though the EPOC recorded wasn't as high as the heavy weight work-out it did prove to last longer than figures recorded in previous studies.

Why these figures were found comes down to the effect heavy resistance training has on the body. As stated by Boresheim & Bahr (2003) the greater effect on EPOC associated with heavy resistance training is a result of the greater metabolic disturbance and breakdown of the muscle tissue that occurs which in return results in a longer period of protein resynthesis and a longer period required for the body and muscle to return to homeostasis. Although there was a light resistance training phase in the first work-out of a rather higher intensity than the heavy weight phase of the second work-out the load wasn't as great and as a result didn't place as much stress and breakdown of the muscle. Another factor that must be taken into consideration is the rest periods between working sets during the heavy resistance phase of the second work-out. In studies previous conducted rest periods during the heavy resistance phases were set at 90 seconds. However in this study a 60 second rest period between working sets was set for subjects which resulted in it being more challenging. This can be seen as the factor that not only accounts for the significant difference in EPOC readings between both workouts, but also the reason as to why the EPOC readings associated with this heavy resistance and aerobic workout were greater than figures recorded in previous study's.

5.6: RQ3) To compare the effect two separate work-outs that consist of both aerobic and resistance type exercise have on heart rate, RER, and RPE readings.

The third and final research question focused on the effect both work-outs had on subject's heart rate, respiratory exchange rate (RER), and RPE readings. Figures recorded from each work-out were compared to examine which was more significant. There were significant differences found between RER figures during each work-out, heart rate during each work-out, and RPE readings among subjects for both work-outs. Firstly looking at RER and these figures gave an indication towards how hard subjects were working during each work-out and also what source of energy they were using to fuel them with energy while performing the exercise. The high intensity running followed by light resistance circuit training resulted in a greater RER reading among subjects during the work-outs. This did not come as a surprise as previous results for this study found that subjects consumed a greater amount of VO2 ml/kg/min and also burned more calories during this work-out compared to the low intensity running and heavy resistance work-out which indicated they worked harder and also used 100% carbohydrates for fuel during the high intensity running and light resistance circuit work-out.

Heart rate was another factor taken into consideration and subjects got a resting heart rate recording before performing both work-outs. There was a significant difference found between the heart rate of each subject. A higher heart rate was recorded among subjects while they performed the high intensity running and light resistance circuit training in comparison to the low intensity running and heavy resistance work-out. Reasons for this is because the 10 minute running phase was performed at a high intensity over the RER reading of 1.0 and the light resistance phase that followed had short rest periods between exercises which resulted in subjects not having much time to recover during the work-out itself. Whereas the low intensity running phase of the second work-out was not as challenging for subjects and although a greater load was associated with the heavy resistance phase subjects had longer rest periods between working sets to recover. It's interesting to note that a higher resting heart rate figure was associated with the high intensity running and light resistance circuit work-out, this may be accounted for subjects knowing they were about to engage in high intensity running which had them more anxious and possibly being the reason for the higher heart rate recording. RPE was recorded to allow subjects perceive how challenging they found each work-out. RPE was taken from each subject immediately after each work-out was completed

by placing an RPE scale in front of them and they selected a number between 1 – 20 to determine how difficult they found the work-out with 1 being very easy and 20 being extremely hard. As expected subjects found the high intensity running followed by light resistance circuit training the harder of the work-outs and there was a significant difference found between the two.

5.7 Limitations:

A number a limitations were encountered during the process of this study;

Equipment: During both work-outs subjects had a mouth piece and nose clip on, however during a couple of the running phases in particular the high intensity running phase where subjects were sweating a lot the nose clip slipped off a couple of times resulting in the subject having to stand on the side of the treadmill while the nose clip was fixed back on. This may have resulted in some of the recordings during the work-out being inaccurate. It would have been more suitable if a face mask was given to subjects were no nose clip was needed and where no stoppages were required to fix the equipment.

Sample Size: Another limitation was the sample size, 6 subjects were selected for this study however a larger number was desired but with the high number of testing required for each subject such as 1RM tests, VO2max tests, and the work-outs themselves time and availability of the laboratory was a factor to getting all the testing protocols complete if a larger sample size was chosen. A larger sample size may have provided more reliability and validity of results.

Resting Values: Ideally it would have been appropriate for subjects to fast 12 hours before participating in each work-out, and although subjects were informed not to consume any food 12 hours before the work-outs not all followed these guidelines. As a result resting figures such as RER and VO2 ml/kg/min may not have been as accurate as they should have been. Another factor that limited the resting values was heart rate, ideally all subjects should have rested at least 30 minutes in a supine position before getting their heart rate and other resting values recorded. However some subjects had to leave at certain times due to classes and also the availability of the lab resulted in some subjects not having the 30 minutes of complete rest before being connected having their recordings taken.

EPOC recordings;

EPOC recordings were taken at 1 and 2 hours after the completion of each work-out. However before the study took place it was of interest to have a 24 hour EPOC reading also where subjects would come in 24 hours after completing the work-out and have their resting recordings taken to see if there was any difference in RER and VO2 ml/kg/min readings at this time.

Duration of work-outs: Both work-outs did have the same duration for the running phases however the different rest periods in the resistance phases of both work-outs resulted in one work-out being longer than the other. The high intensity running and light resistance work-out with short rest periods between working sets took subjects 27 minutes to complete whereas the low intensity running and heavy resistance training work-out with longer rest periods took subjects 32 minutes to complete. If this study was to be carried out again both work-outs would take the same amount of time to complete.

Combination of Work-outs: Although the purpose was to combine aerobic and resistance training together in the form of two separate work-outs the combination of the two could have been done better. At the beginning of the study the aim was to have one work-out consisting of high intensity running and light resistance, and a second work-out consisting of low intensity running and heavy resistance. However a better approach may have been to have one work-out consisting of high intensity running and low intensity resistance and the second work-out low intensity running and high intensity resistance. The reason for this is because although the first work-out had high intensity running followed by light resistance training the light resistance training was also executed at a high intensity which resulted in the whole work-out itself being performed at a higher intensity compared to the second work-out. Ideally both work-outs should have had a low intensity and a high intensity phase and if this study was to be done again this would be the process used.

Chapter 6 - Conclusion of Results:

6.1 Conclusion

Analysis of this study found that a work-out carried out for 27 minutes which consisted of high intensity running followed by a light resistance training circuit resulted in a greater effect on energy expenditure during the exercise itself in comparison to a work-out carried out for 32 minutes which consisted of low intensity running followed by heavy resistance training. A greater VO2 ml/kg/min was associated with the high intensity and light resistance circuit training work-out along with greater RER, RPE, calories burnt per minute, and heart rate readings during the work-out. However the low intensity running followed by heavy resistance training work-out showed to have a greater effect on energy expenditure among subjects during the recovery phase of the work-out which resulted in subjects continuously burning more calories per minute for up to two hours following the completion of the low intensity running and heavy resistance work-out.

The overall conclusion of this study highlights that even though subjects worked harder during the high intensity running and light resistance work-out and did burn more calories during this work-out, it doesn’t mean they will continue to burn more calories during the recovery phase of this work-out. Subjects found the low intensity running followed by heavy resistance training the easier of both work-outs however this work-out was associated with a greater number of calories burnt during the recovery phase.

6.2 Recommendations for future research:

From conducting this study a number of recommendations can be provided to future researchers who are looking to research this area;

Sample size; This study had 6 subjects to complete both work-outs, and although time and availability was a factor in having more subjects taking part in the study future researches should aim to recruit a higher sample size in order to provide more reliability and validity to results.

Combination of Work-outs; The combination of aerobic and resistance exercise in both work-outs should be altered by future researchers. A combination of both high and low intensity exercise phases should be included in both work-outs.

Resting Values; Before having subjects take part in the work-outs ensure that no foods are consumed 12 hours before hand. This will result in more accurate resting values among subjects. Also ensure each subject rests for 30 minutes in a supine position in order to record accurate resting heart rate readings.

EPOC Recordings; Although this study did have both 1 and 2 hour EPOC recordings it was unable to have a 24 hour recording. This would have given an insight into the physiological effects both work-outs had on subjects a full day after completing the work-outs. Future researchers should aim to have this 24 hour EPOC recording included into their study.

Appendix A

Subject 1 $VO2_{max}$ Test:

SPEED	HR	VO2 ml/kg/min	RER	RPE
8km*	142	23.2	0.90*	6
9km	151	28.8	0.90	6
10km	161	32.9	0.93	7
11km	167	34.2	0.96	8
12km*	175	39.9	1.01*	9
13km	179	41.4	1.04	10
14km	181	42.3	1.06	12
15km	183	45.1	1.07	13
16km	187	47.7	1.15	15

Subject 2 $VO2_{max}$ Test:

SPEED	HR	VO2 ml/kg/min	RER	RPE
8km*	144	22.7	0.89*	6
9km	153	23.1	0.90	6
10km	168	25.6	0.93	8
11km	174	28.2	0.96	10
12km*	177	30.1	1.00*	12
13km	184	34.6	1.03	13
14km	186	35.3	1.04	16
15km	188	36.4	1.08	17
16km	192	41.1	1.12	18
17km	193	42.8	1.15	19

Subject 3 $VO2_{max}$ Test:

SPEED	HR	VO2 ml/kg/min	RER	RPE
8km*	108	15.2	0.81*	6
9km	124	18.0	0.89	6
10km	128	23.5	0.90	8
11km	141	25.0	0.92	9
12km	149	26.5	0.95	10
13km	153	29.3	0.97	11
14km	163	33.2	0.98	13
15km*	167	35.1	1.01*	13
16km	175	39.3	1.03	14
17km	178	42.6	1.05	15
18km	180	45.7	1.08	17
19km	189	53.9	1.10	18

Subject 4 VO2max Test:

SPEED	HR	VO2 ml/kg/min	RER	RPE
8km*	119	19.4	0.81*	6
9km	129	18.9	0.83	6
10km	140	24.4	0.89	6
11km	149	27.4	0.94	7
12km	165	26.7	0.95	7
13km	176	31.3	0.97	7
14km*	186	34.8	1.03*	8
15km	192	35.7	1.05	10
16km	198	33.2	1.09	13
17km	199	35.2	1.11	17

Subject 5 VO2max Test:

SPEED	HR	VO2 ml/kg/min	RER	RPE
8km*	125	22.6	0.84*	6
9km	145	25.9	0.93	6
10km	164	28.5	0.98	7
11km	167	31.7	0.96	8
12km	178	34.8	0.99	9
13km*	183	37.8	1.01*	11
14km	189	41.3	1.05	13
15km	193	43.0	1.06	14
16km	196	46.3	1.11	17
17km	201	46.8	1.16	18

Subject 6 VO2max Test:

SPEED	HR	VO2 ml/kg/min	RER	RPE
8km*	146	17.1	0.86*	6
9km	154	23.0	0.87	6
10km	160	25.4	0.89	7
11km	166	26.1	0.95	8
12km	173	29.0	0.99	11
13km*	179	32.8	1.01*	13
14km	182	35.7	1.05	14
15km	187	38.7	1.07	15
16km	191	41.0	1.12	16
17km	193	43.7	1.15	17
18km	196	47.1	1.16	19

*Intensity for running phase of the high intensity running & light resistance work-out
*Intensity for running phase of the low intensity running & heavy resistance work-out

Appendix B

Table 3 - 1RM Scores:

	Squat	Bench	Dead-lift	D.B Shoulder Press
Subject 1	130kg	110kg	130kg	35kg
Subject 2	120kg	110kg	140kg	35kg
Subject 3	90kg	85kg	100kg	30kg
Subject 4	130kg	120kg	130kg	30kg
Subject 5	90kg	100kg	110kg	30kg
Subject 6	125kg	115kg	130kg	35kg

Appendix C

Workout 1: High Intensity Running & Light Resistance Circuit (45% of 1RM/ 3 sets of 14 reps – 30 seconds rest between working sets)

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 1	12km	60kg	50kg	60kg	12.5kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 2	12km	55kg	50kg	65kg	12.5kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 3	15km	40kg	37.5kg	45kg	10kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 4	14km	60kg	55kg	60kg	10kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 5	13km	40kg	45kg	50kg	10kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 6	13km	57.5kg	52.5kg	60kg	12.5kg

Workout 2: Low Intensity Running & Heavy Resistance (70% of 1RM/ 3 sets of 8 reps – 1 Minute rest between working sets)

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 1	8km	90kg	77kg	90kg	25kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 2	8km	85kg	77kg	100kg	25kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 3	8km	65kg	60kg	70kg	20kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 4	8km	90kg	85kg	90kg	20kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 5	8km	65kg	70kg	77kg	20kg

	10mins running@	Squat	Bench Press	Dead-lift	Shoulder Press
Subject 6	8km	87kg	80kg	90kg	25kg

Appendix D

WATERFORD INSTITUTE OF TECHNOLOGY RESEARCH-INFORMED CONSENT FORM

Project Title

To compare the effect of two combined Aerobic and Resistance work-outs of different duration and intensities on Energy Expenditure and EPOC.

Introduction to this study

You are being asked to participate in this research study. This research will be conducted in the Human Performance Laboratories in Waterford Institute of Technology. The study will involve the following process;

- Engaging in two separate work-outs that consist of both aerobic and resistance type exercise and examining the effect the work-outs have on your energy expenditure, EPOC, RER, heart rate, and rate of perceived exertion (RPE) readings.

Waterford Institute of Technology will protect all the information disclosed in this study. Personal information will be kept in the upmost of confidence and will not be used in any other studies. The only people to view these results will be my dissertation supervisor and I. The study findings will form the results and methodology of my 4th year dissertation.
If you do wish to take part in this research, you may withdraw at any point. There will be no obligation to stay for all stages of testing. I have read and understood the information disclosed to me. Any questions may be asked and will get answered in a professional manner. Therefore, I consent to take part in this research study:

Signed: _____

Date: _____

Witness: _____

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