

THE ACUTE EFFECTS OF HIGH INTENSITY RESISTANCE TRAINING ON
RESTING ENERGY EXPENDITURE AND RESPIRATORY EXCHANGE RATIO
IN OVERWEIGHT AND OBESE WOMEN

by

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List of Abbreviation

1RM: 1-repetition maximum

ACSM: American College of Sports Medicine

AE: Aerobic exercise

ATP: Adenosine triphosphate

BCM: Body cell mass

BMI: Body mass index

BMR: Basal metabolic rate

CT: Computed tomography

FFM: Fat free mass

HBE: Harris Benedict equation

HIRT: High intensity resistance training

MET: Metabolic equivalent

MRI: Magnetic resonance imaging

PA: Physical activities

RE: Resistance exercise

REE: Resting energy expenditure

RER: Respiratory exchange ratio

RMR: Resting metabolic rate

TEE: Total energy expenditure

TT: Traditional training

VCO₂: Carbon dioxide output

VE: Ventilation volume

VO₂: Oxygen consumption

VO_{2relative}: Relative oxygen consumption

WHO: World Health Organisation

Abstrak

Tujuan kajian ini dijalankan adalah untuk mengkaji kesan jangka pendek latihan rintangan berintensiti tinggi terhadap kadar tenaga rehat (REE) dan nisbah pertukaran pernafasan (RER) dalam kalangan wanita berlebihan berat badan dan obes dan tidak terlatih. Lapan peserta berumur lingkungan 36.9 ± 3.9 tahun telah menyertai kajian ini. Mereka dibahagikan kepada dua kumpulan iaitu kumpulan HIRT ($n=4$) dan kumpulan Kawalan. Kumpulan ($n=4$). HIRT akan membuat senaman “inclined bench press”, “lat pull down” dan “leg press”. Senaman itu mengandungi 3 set dengan 6 ulangan diikuti dengan 20 saat rehat, 2 atau 3 ulangan diikuti 20 saat rehat dan 2 atau 3 ulangan dan rehat selama 2 minit 30 saat sebelum set seterusnya. Kumpulan kawalan diarahkan untuk mengekalkan rutin harian mereka seperti biasa. Menggunakan teknik “indirect calorimetry”, gas metabolik dianalisis dalam kedua kumpulan tersebut selama 30 minit dalam keadaan rehat dengan sistem mudahalihan Cortex MetaMax3B (MM3B, Leipzig, Germany). Pengukuran ini memberi bacaan RER dan pembolehubah yang diperlukan untuk mengira REE (kcal/hari). Selain pengukuran gas metabolik pada keadaan rehat sebelum sesi senaman, gas metabolik juga diukur dalam kumpulan HIRT 24 jam selepas sesi senaman. Tiada perubahan signifikan dikesan untuk perbandingan REE pada ukuran dasar antara kumpulan. Walau bagaimanapun, kumpulan HIRT menunjukkan peningkatan pada bacaan REE daripada 1890.7 ± 520.7 kcal/hari kepada 2140.3 ± 409.0 kcal/hari ($p=0.04$), selepas 24 jam sesi senaman. Tiada perubahan signifikan dalam RER ($p=0.22$) selepas 24 jam senaman dalam kumpulan HIRT. Kesimpulannya, kajian kami mencadangkan latihan rintangan berintensiti jangka pendek berkemungkinan akan meningkatkan REE selepas 24 jam senaman dalam kalangan wanita berlebihan berat badan dan obes tanpa bergantung pada sebarang perubahan jisim otot.

Abstract

The aim of the study is to investigate the acute effects of high intensity resistance training (HIRT) on resting energy expenditure (REE) and respiratory ratio (RER) in overweight and obese, non-trained women. Eight participants with mean age of 36.9 ± 3.9 years volunteered for this research. They were divided into two groups which is HIRT group (n=4) and Control group (n=4). The HIRT group performed three exercises – inclined bench press, leg press and lat pull. The exercise consist of 3 sets with 6 reps followed by 20 sec rest, 2 or 3 reps followed by 20 sec rest and another 2 or 3 reps and rest for 2 min and 30 sec before the next exercise. The Control group maintained their usual routine. Using indirect calorimetry, metabolic gases were assessed in both HIRT and Control groups in a controlled, rested setting for 30 min using Cortex MetaMax3B portable metabolic system (MM3B, Leipzig, Germany). The measurements provided RER and variables required to calculate REE (kcal/day). Another metabolic gas assessment was conducted in the HIRT group 24 hours post-exercise. For comparison of REE at baselines between groups, there were no significant differences detected. However, HIRT group showed increased REE, from 1890.7 ± 520.7 kcal/day to 2140.3 ± 409.0 kcal/day ($p=0.04$), 24 hours post-exercise. There were no significant changes in RER ($p=0.22$) 24 hours post-exercise in HIRT group. In conclusion, our study suggests that the short HIRT session may increase REE 24 hours after exercise in overweight and obese adult women independent of any muscle mass change

CHAPTER 1: INTRODUCTION

1.1 Introduction

1.1.1 Overweight and obesity

Overweight and obese are defined as excess fat accumulation that may cause health problems (World Health Organization, 2000). The distributions of excess body fat may vary between men and women. In man, fat accumulates mainly around the waist (androids distribution) and in women, body fat tends to accumulate around the hips (gynoid distribution) (Sweeting, 2007). The areas of fat distribution are linked to higher risks of chronic disease in android distribution compared to a gynoid distribution (Sweeting, 2007). There are various method that can be used to measure body fat that have been used including cadaver analysis, computed tomography (CT), magnetic resonance (MRI), dual-energy X-Ray absorptiometry, bio-impedance analysis and body mass index (BMI) (Sweeting, 2007). However, BMI is the most widely used assessment to determine obesity, which is calculated by body mass in kilogram (kg) divided by height in square meters (m^2), $BMI = \frac{kg}{m^2}$. According to the World Health Organization (WHO), people with BMI of 25.0 to 29.9 kg/m^2 are categorised as overweight, while obesity is categorised as a BMI of 30.0 kg/m^2 and above (World Health Organization, 2000). The desirable BMI is between 18 to 24.9 kg/m^2 (World Health Organization, 2000).

1.1.2 World overweight and obesity prevalence rate

The prevalence of obesity has doubled between 1980 and 2014 (World Health Organization, 2000), worldwide mean BMI increased by 0.4 kg/m² and 0.5 kg/m² per decade for men and women, respectively (Finucane et al., 2011). In 2014, World Health Organization (WHO) estimated more than 1.9 billion adults aged 18 years and older were overweight and of these over 600 million were obese (World Health Organization, 2016). In adults aged 18 years and over, 39% were overweight and 13% were obese in 2014. Apparently, more than one in ten of the world's adult population were obese (World Health Organization, 2016). People in the United States have the highest mean of BMI among the high-income countries (Finucane et al., 2011).

1.1.3 Disease associated with obese

Overweight and obesity are commonly associated with the rates of morbidity and mortality (Kirk et al., 2012). Increases in BMI will affects the body systems and it is related to several non-communicable diseases or higher health risk states such coronary artery disease, diabetes, hypertension, dyslipidaemia, sleep apnea, cognitive dysfunction, and some malignancies such as breast, colon and prostate cancer (World Health Organization, 2016; Kirk et al., 2012). From WHO reports, overweight and obesity are the fifth leading cause of death worldwide, and 2.8 million adults die annually as a direct result of overweight and obesity (World Health Organization, 2016).

1.1.4 Obesity prevention

The increasing of overweight and obese indicates that the need of improving current intervention strategies. There are several types of interventions for obesity management have been applied, including healthy diet, regular exercise, behavioural modification, pharmacological treatment and bariatric surgery (Kirk et al., 2012).

Lifestyle program are multifactorial interventions tailored to the needs of an individual or of a group of subjects according to their risk factor status (Kirk et al., 2012). Lifestyle modification includes dietary modification and physical exercise. However, food restriction alone may not solve the problem of excess weight in the long term unless it is accompanied by regular physical activity (Miller et al., 1997). Prevention and treatment of obesity in the mid to long term lifestyle modifications can be effective in reducing blood pressure, blood lipid and blood glucose levels (Kirk et al., 2012).

1.1.5 Exercise and weight loss

There are numerous weight loss studies in the literature that involves lifestyle changes. Dietary interventions have shown to reduce 5 to 7% of initial body weight (Ditschuneit et al., 1999). However, another study showed that many of the study participants gained back the weight lost within five years of stopping the intervention programme (Mustajoki and Pekkarinen, 2001). Exercise and dietary interventions could reduce more weight and those who exercise can maintain their weight loss (Miller et al., 1997). Besides, people who exercise also tend to feel more energetic and have reduced health problems (Nawaz et al., 1999). Thus, the focus of this study would be on the use of exercise to induce weight loss in overweight and obese individuals.

1.1.6 Resistance training

As there are many studies on exercise and weight loss, an interesting exercise programme that requires further investigation is the use of high intensities and short rest duration in resistance training. High intensity resistance training (HIRT) is the type of training that has shown to effect on muscles mass and excess post-exercise oxygen consumption (EPOC) (Paoli et al., 2012a). Paoli and colleagues also mentioned that HIRT will also affect the resting energy expenditure rate and respiratory ratio better compared to traditional training (TT). The value of resting energy expenditure (REE) of the HIRT also showed an increase after 22 hours of post exercise compare to TT session. . HIRT sessions may be an effective mechanism to promote weight loss and further studies are warranted.

1.2 Problem Statement

Most resistance training studies in adults and particularly in older adults have emphasised low-intensity, short-term training programme that concentrate on strength measurement (Karabulut et al., 2011). Yet, more recent studies are reporting the changes in resting energy expenditure that accompanies resistance training programmes (Paoli et al., 2012b). However, most studies were conducted in trained population (Karabulut et al., 2011). Moreover, studies on the effects of resistance training in women are less studied especially in those who are overweight and obese. Studies in women are needed as men and women may have different physiological adaptations to exercise based on the simple fact that body composition of muscle to fat is different between genders (Osterberg and Melby, 2000). Thus, this study is designed to investigate the short-term effects of HIRT on metabolic adaptations in overweight and obese non-trained women.

1.3 Purpose of Study

The purpose of the study was to measure and record the resting energy expenditure and respiratory exchange ratio for high intensity resistance training in overweight and obese untrained women.

1.4 Objectives

1.4.1 General objective:

To investigate the acute effects of high intensity resistance training (HIRT) on resting energy expenditure (REE) and respiratory exchange ratio (RER) in overweight and obese non-trained women.

1.4.2 Specific objectives:

- 1) To objectively measure the REE and RER of a HIRT session in overweight and obese non-trained women.
- 2) To investigate the baseline differences of REE in intervention and control groups.
- 3) To determine the 24-hour changes in REE and RER after a HIRT session in overweight and obese non-trained women.

1.5 Research Questions and Hypotheses

Question 1: Are there differences of REE between intervention and control group at baseline?

Null hypothesis: There are no significant differences of REE between intervention and control group at baseline.

Alternative hypothesis: There is a significant difference of REE between intervention and control group at baseline.

Question 2: What is the 24-hour change in REE after a HIRT session in overweight and obese non-trained women?

Null hypothesis: There is no change in REE 24-hour after a HIRT session in overweight and obese non-trained women.

Alternative hypothesis: There is a significant change in REE and RER 24-hour after a HIRT session in overweight and obese non-trained women.

Question 3: What is the 24-hour change in RER after a HIRT session in overweight and obese non-trained women?

Null hypothesis: There is no change in RER 24-hour after a HIRT session in overweight and obese non-trained women.

Alternative hypothesis: There is a significant change in RR 24-hour after a HIRT session in overweight and obese non-trained women.

1.6 Significance of Study

Resting metabolic rate will directly influence caloric balance which may assist on the ability to lose excess weight or maintain a healthy weight. The Centers for Disease Control and Prevention (2011) suggested that the incidence of obesity is increasing (Centers for Disease Control and Prevention, 2015) and methods to loose or maintain a healthy weight is crucial. A study by Osterberg and Melby (2000) indicated that acute resistance exercise related to a prolonged increase in metabolic rate and caloric expenditure (Osterberg and Melby, 2000). This study, and many others like it Osterberg and Melby, (2000), suggests that resistance training can support a caloric deficit compared to those people who do not currently engage in resistance training. This research is important to understand the possible contributions of HIRT on REE in overweight and obese non-trained women. It is also vital to understand the metabolic changes during HIRT that will be objectively measured in women while conducting HIRT. This will further inform if HIRT may be an effective mechanism in a weight loss strategy through increased REE.

CHAPTER 2: LITERATURE REVIEW

2.1 Overweight and obesity prevalence rate in Malaysia

The prevalence of overweight and obesity in men has increased in Malaysia, from with a 20.1% in 1996 to 29.7% by 2006 (Abu Bakar et al., 2015). Obesity prevalence was found to be higher among adult females; with 7.6% in 1996 that increased to 17.4% in 2006 and overweight prevalence increased from 56.3% in 1996 to 61.2% in 2006 (Mohamud et al., 2011). In the 2015 National Health Morbidity Survey, about 30% or 5.6 million of Malaysian adults aged 18 years and above were overweight, while 17.7% or 3.3 million Malaysians were obese (Abu Bakar et al., 2015).

2.2 Weight loss strategies

Physical activity (PA) is suggested as one of the important component of any weight management program which may include the energy restriction, pharmacological and surgical interventions (Donnelly et al., 2009a). Physical activity in the context of weight management aims for reduce weight and the prevention of regain after weight loss (Jakicic and Davis, 2011). These positive impacts are achieved fully or partially in all types of exercise, such as the unstructured regular lifestyles and the structured exercises including aerobic exercise and (AE) and resistance exercise (RE) (Donnelly et al., 2009a).

2.3 Total energy expenditure (TEE)

Total energy expenditure (TEE) is the measure of the total amount of calories in an individual expend throughout the course of the day. TEE is express as kcal//day and includes calories expended due to resting metabolic rate (RMR), thermogenesis and physical activity (Levine, 2005). About 10% of TEE were used for food digestion and absorption and is known as the thermic effect of food energy expenditure (Levine, 2005). TEE in a person can change by conducting activity that involving large muscle movements (Aristizabal et al., 2015). The body will require muscles to use adenosine triphosphate (ATP), which is the form of energy that allows the muscle contraction to occur (Cannon and Marino, 2010). Caloric expenditure is needed to produce ATP (Cannon and Marino, 2010). During exercise, energy expenditure is raised by lengthening the duration of exercise and with increased intensity of exercise (Levine, 2005). Another component of energy expenditure is resting metabolic rate (RMR). RMR is the amount of energy that individual produce at complete rest and it is normally measured immediately after individual wake up in the morning. RMR is measured when the person get enough restful sleep, free from stress and have been fasting for at least 12 hours a night before the measurements (Hopkins, 2003).

2.4 REE and methods of measurement

Resting energy expenditure (REE) or resting metabolic rate (RMR) is the total number of calories that the person needed during a day to maintain their body functions and homeostasis (Mcmurray et al., 2014). The process involved in maintaining the REE include energy cost of cardiovascular resting and pulmonary functions, energy cost of the central nervous system, thyroid activity, the sympathetic nervous system and additional biochemical reactions that are constantly occurring within the body (Mcmurray et al., 2014). REE is the most largest contributor to the total energy expenditure which involving 60-75% of total energy expenditure (Poehlman and Melby, 1998).

During the measurement of resting energy expenditure, the person should have at least eight hours of sleep at the previous night, postprandial for 12 hours, have not exercise for at least 12 hours, and not in a stressful mind condition (Mcmurray et al., 2014). There are three methods to determine the resting energy expenditure rate. They are known as direct calorimetry, indirect calorimetry and non-calorimetric (Levine, 2005). Poehlman and Melby (1998) mention that the most common method that used is indirect calorimetry, which will estimates the energy production by measuring oxygen consumption (VO_2) and carbon dioxide production (VCO_2) (Poehlman and Melby, 1998). They also clarified that the metabolic chart are the most commonly used to collect and analyse these gases, the typical measurements from indirect calorimetry show that the values usually range from 0.7 to 1.6 kcal/min (Poehlman and Melby, 1998). Direct calorimetry is the most difficult but precise way to determine the resting energy expenditure since the measurement is extremely expensive and require a full-time technician. Levine (2005) stated that direct calorimetry measure the heat produced and heat loss from the body.

This method of measurements require a human calorimeter, a large respiration chamber, in which the person essentially spend several hours or days in the chamber while air is drawn from the chamber and flow rate is analysed for oxygen and carbon dioxide concentrations (Poehlman and Melby, 1998). Non-calorimetric methods involve predicting energy expenditure by extrapolating physiological measurements and observation such as heart rate, electromyography, pulmonary ventilation and thermal imaging (Levine, 2005).

2.5 Factors that influence REE

There are many factors influenced the REE including age, gender, body composition and genetic factors (Frisard et al., 2007). Frisard (2007) mentioned that energy expenditure rate will decrease 2-3% per decade of life in response to the decrease of fat-free mass in association with aging. A study conducted by Frisard et al. (2007) investigated the effect of age factors on REE. The study population consist of 170 people from Louisiana Healthy Aging Study. They were divided into three different age groups, which is 20-34 years, 60-74 years and 90 years and older. Indirect calorimetry was used to measure resting energy expenditure. The result showed that the REE was significantly different between three age groups. Adults aged 20-34; the REE was 1587 ± 50 kcal/day, 1465 ± 37 kcal/day for those in the 60-74 years old age group and 1165 ± 20 kcal/day for those aged 90 years and above. REE will continually decrease as age increases (Frisard et al., 2007). People who are older, which is age 70 and above, will generally had 20-25% lower than young adult resting energy expenditure (Mcmurray et al., 2014).

Another study was designed to investigate the relationship of REE with one's geographical location conducted by Aleman-Mateo and colleagues (2006), which also measured TEE and physical activity levels. This study was conducted in rural region of Cuba, Chile and Mexico involving 40 subjects aged 60 years and older. The study reported that the resting energy expenditure was higher in men compared with women. However, there was no difference between countries regarding REE. This study suggests that REE was not influence by the country one resides (Alemán-Mateo et al., 2006)..

Meanwhile a study conducted by Visser et al. (1995) investigated the relationship between ages, REE, diet-induced thermogenesis. The study population involve people aged 33-63 years old and 20-33 years. The REE was measured using indirect calorimetry with an open-circuit ventilated-hood system. The results found that young women's REE was 4.08 ± 0.33 kJ/min and 3.33 ± 0.39 kJ/min in elderly women, while young men's REE was 0.29 ± 0.53 kJ/min and 3.98 ± 0.46 kJ/min in elderly men. This study suggests that there is negative linear relationship between age and resting energy expenditure rate (Visser, and Deurenberg, 1995).

Body composition is one of the most influential components of REE. Fat-free mass consists of metabolically active muscles and organs (Miller Brown, 2009). An increase in muscle mas is associated with an increase in resting energy expenditure rate (Kwon et al., 2010). People with higher BMI, which is considered as overweight and obese, have lower resting metabolic rate compared with the person with a normal BMI. This is due to lower muscle mass that is a highly active tissue compared with adipose tissue (Miller Brown, 2009).

The most prominent influence of muscle mass is evident when comparing the REE between men and women. Men have higher resting energy expenditure rate due to higher volume of fat free mass (Poehlman and Melby, 1998). Thus, men of the same height and weight as women will naturally have a higher REE (Hunter et al., 2003). This is due to their higher proportion of muscle mass in their body. Due to the muscle mass, resistance exercise may result in different outcomes for women who tend to have lower muscle mass compared with men (Stiegler and Cunliffe, 2006).

From a study by Osterberg and Melby (2000), resistance training increased metabolic rate of young women (Osterberg and Melby, 2000). According Osterberg and Melby (2000), metabolic rate in women remained greater for an extended period following resistance exercise. Their study involved seven untrained and healthy women aged 22 to 35 years old. The researchers measured pre-exercise resting oxygen consumption before conducting 100 min of resistance exercises. Post-exercise oxygen consumption was measured 3 hours after exercise. They reported that the rate of oxygen consumption increased after 3 hours post-exercise and the REE was significantly higher after 16 hours of exercise compared with the REE (1419 kcal) in the morning prior to exercise. Meanwhile, the respiratory exchange measurements were used to determine the rate of fat oxidation during REE measurements. The study also reported the mean respiratory exchange ratio (RER) increased by 62% in after two days of post exercise. This data show that resting fat oxidation were influenced both energy expenditure and substrate oxidation.

Another component that may influence REE and is also related to gender specific is the menstrual cycle. There are differences in physiological response related to the menstrual cycle. REE generally begin to rise 7-10 days before menstruation (Osterberg and Melby, 2000).

The researchers examined the exercise treatment during the specific phase of the period cycle. They studied the participants under controlled conditions during the same phase of the menstrual cycle that will occur in the next one month. Due to difficulties of conducting the study over two menstrual cycles, a single pre-exercise VO_2 values was used to establish the baseline rather than using separate non-exercise control days. REE measurements were performed after 24 hours, which during that time, any changes in energy expenditure and substrate oxidation rate induced by the menstrual phase was minimal.

2.6 Exercise and resting energy expenditure rate

In general, physical activity and exercise are the most commonly interchangeable when there are differences in both terms. Exercise is an activity that is planned, structured and come from repetitive physical activity that is conducted in order to improve one or more components of physical fitness (Donnelly et al., 2009b). Physical activity is the any body movement that require energy, for example, mopping the floor, shopping and construction work. Regardless, both exercise and physical activity influences REE. A study conducted by Miller et al. (2012) investigated the relationship between REE and cardiorespiratory fitness levels in 64 obese people. All participants have been referred to Missouri hospital for bariatric surgery. Selected participant may have diabetes, having BMI greater or equal to 35 kg/m^2 , and if the participants were non-diabetic and free of other comorbidities, they were recruited based on their BMI, which is greater than 40 kg/m^2 . Participants with pulmonary disease were not included in the study as their ability altered the performance of a cardiopulmonary exercise test. From the study, the results showed that the group who had higher body mass and BMI had lower REE and lower cardiorespiratory fitness, measured by a peak oxygen uptake compared to those with lower BMI values (Miller et al., 2012). This study suggests that exercise will not only improve cardiorespiratory fitness but also will increase resting energy expenditure rates.

In another study, Aristizabal and colleagues (2015), studied the effect of resistance training and dietary supplementation on REE measured by indirect calorimetry. In their longitudinal, clinical intervention study of approximately nine months, 61 untrained participants, aged between 18 to 35 years old were divided into three groups that was whey group, soy group and carbohydrates group. All participants performed a whole body progressive non-linear, periodised resistance training program 3 days/week until participants obtained 96 workouts. The program was divided into three , 12 mesocycle per weeks and including heavy weight (3 to 6 repetitions, 2-3 min rest period, high intensity), medium weight (8-10 repetitions, 1-2 min rest period, moderate intensity), light weight (12-15 repetitions, 60-90 sec rest period, light intensity) and power (whole body exercises, 30-45% of the estimated 1RM, 3 min rest period) days. The results indicated that there were increases of REE from pre-training to post-training, which is from 1653 ± 302 to 1726 ± 291 kcal/day without significant differences between the groups. This study indicates that 9 months of resistance training will significantly increase REE (approximately 5% on average) but there was wide variability between individuals, which can be partially accounted for by changes in fat free mass and thyroid hormones (TH) (Aristizabal et al., 2015).

A study conducted by Potteiger and colleges (2008) investigated the effects of a 16-month moderate intensity exercise training resistance on REE in overweight young adults. There were 74 participants, aged 17-35 years with BMI between 25 and 34.5 kg/m² in this study. The participants were assigned to either in control group or into exercise group in which they walked on a treadmill at 60-75% of heart rate reserve 3-5 days per week for 20-45 minutes each session. They found that the REE increase from pre- to the post-training in women from 1583 ± 221 kcal/day to $1,692 \pm 230$ kcal/day and in men, $1,995 \pm 184$ to $2,025 \pm 209$ kcal/day.

Apparently, REE in this age group can be increased through regular exercise training (Potteiger et al., 2008). As previous studies may suggest, physical activity and exercises related to REE however information on the acute effects between exercise sessions, especially in HIRT programmes are still lacking

2.7 High intensity resistance training (HIRT)

High intensity resistance training (HIRT) is an exercise that could be achieved by lifting 80% or greater of one's repetition maximum (1RM) (Bonganha et al., 2011). A long session of HIRT can result in a prolonged recovery period, contributing to substantial post-exercise energy expenditure above resting values (Poehlman and Melby, 1998). HIRT is a resistance training conducted under high load, high volume or long duration of exercise (Strasser and Schobersberger, 2011). Strasser and Schobersberger (2011) suggested that when regularly performed, resistance exercises of sufficient intensity can stimulate skeletal muscle to synthesize new muscle protein (hypertrophy). They also mentioned that an effective amount of resistance training can promote muscle growth. They believed that 1 or 2 sets of 8 to 12 repetitions per set with intensity up to 60% of 1RM may improve health through increased skeletal muscle mass. The implementation of regular HIRT session with dietary intake restriction may lead to effective weight loss (Ditschuneit et al., 1999). Questions on the applicability, efficiency and safety of a HIRT programme in overweight and obese women have yet to be ascertained.

2.8 HIRT and REE

A study by Paoli and colleagues compared the metabolic changes induced by HIRT and traditional resistance training in a group of trained young men aged between 24 to 32 years. The study was a cross-over design with a wash-out period of 1 week. The amount of VO_2 increased by 23% after 22 hours post-HIRT compared to traditional RE that saw a smaller but also significant increase of 5% (Paoli et al., 2012a). The researchers stated that HIRT can increase the maximal blood lactate level which will subsequently increase the post-exercise energy expenditure. The greater level of lactate is produced during the recovery phase in HIRT represents major metabolic stress derived from HIRT and may reflect the utilisation of lactate as fuel in aerobic pathway (Paoli et al., 2012a). This metabolic adaptation to HIRT requires further investigation, especially when it can be helpful in weight loss programmes.

Poehlman and Melby (Poehlman and Melby, (1998) reported increases in fat oxidation during recovery period after resistance training. This seems to be a compensatory and sparing mechanism for glycogen. Hence, RER was significantly lower after the 22 hours after HIRT that reflects an increase in lipolytic metabolism (Poehlman and Melby, 1998). The RER is the way to identify the origin of energy substrate: when RER is close to 0.7 it means that the major energy source is lipid while, if the ratio is near to 1, the energy source is carbohydrate (Poehlman and Melby, 1998). In this aspect, the result showed a significant decrease of RER (from 0.827 ± 0.006 to 0.798 ± 0.010) at 22 hours after HIRT (Paoli et al., 2012a). For the TT, RER was 0.822 and 0.798 at baseline and post-22hr after HIRT, respectively. Paoli and colleagues (2012) suggested that HIRT may improve lipid metabolism at rest (Paoli et al., 2012b). This would be highly beneficial especially in individuals with excessive adiposity as presented in those who are overweight and obese (Paoli et al., 2012b).

Meanwhile, study conducted by Beckham and Earnest (2000) determined the caloric expenditure was associated with free weight circuit training at light and moderate resistance in apparently healthy adult. The participant was 18 female with age between 18-45 and 12 male ages between 19-41 years old volunteered to participate in the study. All the participants were participated in both low intensity and moderate intensity condition first, and then completed the other condition 48 hours later to ensure adequate recovery (Beckham, 1999). The light resistance was a 1.4 kg bar for both males and females. The moderate resistance condition used a 5.9kg load for females and 10.5 kg for males as a result of greater strength capacity. When the female participant completed the light resistance condition, their resting energy expenditure was 3.62 ± 0.45 kcal/min compared to the moderate resistance condition which was 4.04 ± 0.45 kcal/min. While in males, the light resistance condition elicit a 4.99 ± 0.83 kcal/min expenditure and 6.21 ± 1.01 kcal/min expenditure in moderate resistance (Beckham, 1999).

2.9 Measurements of Resting Metabolic Rate

A common method to estimate RMR is by using equations derived from large studies. (Harris and Benedict, 1918) studied the Harris-Benedict equations (HBE) which was derived from indirect calorimetric data obtained in 239 normal participants (Harris and Benedict, 1918). Using these data and additional data published (Harris and Benedict, 1918) that were obtained from participants spanning a wider age range of 18 to 45 years. They measured the relationship between REE and age, sex, and predicted body cell mass (BCM). The HBE estimated REE of a normal subject with an REE was directly related to the size of the BCM and is independent of age and sex (Roza, 1984). The variables of height, weight, age, and sex in the HBE reflect the relationship between body weight and the BCM. Indirect calorimetry and body composition

measurements were performed in both normally nourished and malnourished patients (n=74) to assess the accuracy of the HBE (M. Roza, 1984). Malnutrition was associated with an increase in resting oxygen consumption (VO_2) that becomes apparent when VO_2 is expressed as a function of the BCM (M. Roza, 1984).

The HBE equation for men is:

$$\text{RMR} = 88.362 + (13.397 \times \text{weight in kg}) + (4.799 \times \text{height in cm}) - (5.677 \times \text{age in years})$$

The HBE Equation for women is:

$$\text{RMR} = 447.593 + (9.247 \times \text{weight in kg}) + (3.098 \times \text{height in cm}) - (4.330 \times \text{age in years})$$

Measurement of REE however can also be done using a gas analysis system that assess the amount of oxygen consumed and output of carbon dioxide in a rested state. The indirect calorimetry method of determining REE has less restrictive conditions and can be easily obtained. The condition such as the time of day to measure the REE must be restricted in the morning. For HBE, an alternative method is to use predictive equations that can provide a rough estimate of the basal or resting metabolic rate. The main reason of conducting the experimental study to calculate the RMR is because the various predictive equations for determining the resting metabolic rates may significantly under or overestimate the total calories needed to maintain the current weight of an individual when combined with stress or activity factors that are selected by the individuals (Roza, 1984).

CHAPTER 3: METHODOLOGY

3.1 Sample size calculation

Sample size was calculated using PS Power and Sample Size Calculation software by Duport and Plummer (1990), version 3.0. Based on the statistically significant difference reported (Paoli et al., 2012a), which was a mean difference (μ) of 98 kcal in REE, with a standard deviation (σ) is 128 kcal, the sample size was calculated to have 80% power and a type-1 error of 5%. To conduct a between group analysis, the sample size required was 6 participants per group. Taking into account a drop-out rate of 20% due to the frequent study visits in a short time (three times in three consecutive days), a total of 7 participants per group will be recruited.

3.2 Study design

This is an experimental study with an intervention and control group designed to assess the effect of HIRT on REE in overweight and obese non-trained women. The primary outcomes of this research were to determine the acute effect of HIRT on REE and RER in overweight and obese non-trained women.

The study was conducted in Nik Fitness Centre, located in Pengkalan Chepa, Kelantan and in Exercise and Sports Science Lab Universiti Sains Malaysia in the period of February 2017 to March 2017. The study was approved by Universiti Sains Malaysia Research Human Ethics Committee (USM/JEPeM/16090333, Appendix 1).

Eligible participant were randomised via Microsoft Excel random computerised selection process to one of the two groups which is control group and intervention group. Intervention group will follow HIRT protocols while the control group were asked to maintain their usual routines.

3.3 Study participants

Potential participants were recruited through staff email, posters on university noticeboard and social media. All potential participants who expressed interest in the study were subjected to a telephone screening interview by one of the study coordinator. During the telephone interview, a brief overview of the study was given to the potential participant and the importance of consistent commitment was stressed.

Potential suitable participants included women who are overweight and obese (BMI 25 to 40kg/m²) aged between 30 to 50 years had no history of serious diseases such as cardiovascular disease, hypertension and diabetes, and who were currently not undergoing any weight loss programme.

Participant who was excluded for the enrolment included those who have any serious musculoskeletal injury or condition that are contradicted to the exercise. Those who were under medications, smokers or taking any supplement or on medications that may affect the REE were excluded in the study. In addition, pregnant women and those were on special diet and weight loss programme also excluded.

3.4 Personal demographic and anthropometry measurements

On arrival at Nik Fitness Centre (NFC gymnasium) for baseline testing, participants was briefed about the study design and protocols. Any questions were answered and informed consent (Appendix 2) was obtained.

Demographic form questionnaire (Appendix 3) and Physical Activity Readiness Questionnaire (PAR-Q) (Appendix 4) was assigned to the participants. Each participant filled in their personal details and their medical history. Participants also provided their most recent menstrual cycle date.

Anthropometric measurements (height and weight) were taken as shown in Figure 3.1. Height was measured in centimetres using a portable stadiometer (Seca 769, Germany). The stadiometer were placed on a vertical surface, e.g. a wall, as part of the protocol required to measure height. The interclass correlation coefficients for test-retest reliability and typical error of measurement of height was 0.99 and 0.2% respectively (Dick et al., 1975). The body mass is measured using a digital weighing scale (Tanita, Japan). Body mass is measured in kilogrammes (kg). The interclass correlation coefficient for test-retest reliability and typical error of measurement of body mass is 0.99 and 0.8% respectively (Dick et al., 1975). The BMI was then calculated by dividing the body weight (in kg) by height (in m). Overweight was defined as a BMI ≥ 25 -30 kg/m² and obesity as BMI of > 30 kg/m² (World Health Organization, 2000).

Once all initial baselines were completed, participants were assigned to the intervention group (HIRT protocols) and control group. The control group were asked to fast overnight and come back again the next day to take their REE measurements.

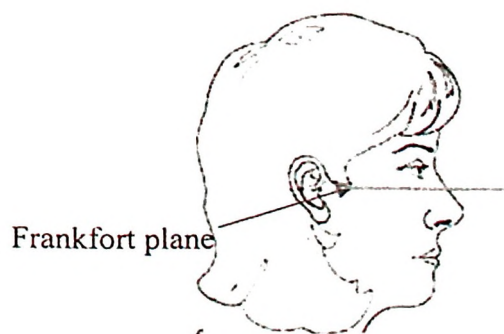


Figure 3.1: Frankfort plane for height measurements

3.5 Muscle strength test

Prior to conducting any exercise test or intervention, participants were asked to fill out the Physical Activity Readiness Questionnaire (PAR-Q) to screen for possible contraindications for exercise.

As HIRT participants were not familiar with resistance exercises, familiarisation session and muscle strength testing 7 days prior to starting the metabolic measurements. During the familiarisation, the participants conducted 6 Repetition Maximum (RM) strength test. The function of the familiarisation week is to reduce the risk of injury and to be able to control the momentum of the mass (Burt et al., 2007).

The 6 RM test is suitable to test maximal strength among the participants. The data obtained were used to determine appropriate starting level for resistance training (Paoli et al., 2012a) in HIRT session. During each workout, participants performed a warm-up that consisted of 10 to 12 repetitions with a weight that they could normally lift. The load of resistance were then increased gradually to the point of concentric failure to determine the 1RM load for the training. By using trial and error, 80% to 85% from the load of 1RM were used to resolve the 6 repetitions.

To reduce the risk of injury and to control the momentum of the mass, a slow and controlled lifting cadence of 4-0-4 principles was maintained for all repetitions with 4 seconds to descend to the bottom position and 4 seconds to ascend to the beginning position, without pausing at the bottom. To ensure that participants were consistent in following the repetition cadence, all sets will be timed using a hand-held stopwatch during the familiarisation period.