CALCULATION OF CALORIC EXPENDITURE FOR ELASTIC RESISTANCE TRAINING IN UPPER AND LOWER BODY EXERCISE

A Thesis by

Travis Joseph-McCoy Robillard

Bachelor of Arts, Hawaii Pacific University 2009

Submitted to the Department of Human Performance Studies and the faculty of the Graduate School of Wichita State University in partial fulfillment of the requirements for the degree of Master of Education

May 2013
CALCULATION OF CALORIC EXPENDITURE FOR ELASTIC RESISTANCE TRAINING IN UPPER AND LOWER BODY EXERCISE

The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Education with a major in Exercise Science

______________________________
Jeremy Patterson, Committee Chair

______________________________
Michael Rogers, Committee Member

______________________________
Kaelin Young, Committee Member

______________________________
Nicole Rogers, Committee Member
DEDICATION

This is dedicated to my parents

Thank you for the support, encouragement and love
AKNOWLEDGEMENTS

I am extremely grateful to all those who have assisted and inspired me during the pursuit of my master’s degree. Thank you to Dr. Patterson for inspiring me to pursue my doctorate, always taking the time to talk, and for helping me develop my passion for this field. Thank you to Dr. Rogers for your help with my internship, classes, and thesis development. Thank you to Dr. Young for your energy, passion, advice and assistance with this thesis. Thank you to Jonathan Fiser for your assistance in the human performance laboratory. Thank you to the Exercise Science undergraduate and graduate students who volunteered to participate in my study. Finally, thank you to all the faculty members of the Human Performance Studies Department at Wichita State University that have had a positive influence on my life the past two years.
ABSTRACT

Caloric expenditure of hundreds of activities, including conditioning exercises, occupational activities such as masonry work, self-care activities such as dressing, and lawn care activities such as mowing, have been previously reported (Ainsworth et al., 2000). However, there is little research that has been done in this specific area of MET calculation in regards to elastic resistance training. Elastic resistance training is a type of training in which one uses an elastic band to create tension during resistance/strength exercise. While there are a variety of ways to evaluate exercise intensity, METs (Metabolic Equivalence of Tasks) were used to evaluate the energy cost for elastic resistance exercises. The purpose of this study was to determine the METs and caloric expenditure per minute associated with elastic resistance exercise. 15 undergraduate and graduate exercise science students (6 male; 9 female) ages 18-25 (21.60 ±1.99 years), completed 10 repetitions of 10 upper and lower body exercises using two different strengths of Thera-bands (blue; black). METs and caloric expenditure were calculated from participants’ relative oxygen consumption. Data were analyzed and a significant difference (p<0.01) was found between upper and lower body exercise as well as between the blue and black elastic bands. Lower body exercises performed by the black Thera-band yielded significantly (p<0.01) higher energy costs (5.13kcal ±1.54; 3.85 MET±0.5) compared to pre-exercise (2.06kcal±0.67; 1.57MET±.046), black upper body (4.06kcal±1.17; 3.05 MET ±0.44), blue upper body (3.94kcal±1.24; 2.95 MET ±0.43) and blue lower body (4.69kcal±1.48; 3.51 MET ±0.49) trials. In conclusion, individuals burned more calories with greater resistance and during lower body exercise. The exercise program fit ACSM’s MET guidelines for a moderate-intensity exercise.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAPTER ONE</td>
<td></td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>2</td>
</tr>
<tr>
<td>1.1 Purpose</td>
<td>2</td>
</tr>
<tr>
<td>1.2 Significance of study</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Variables</td>
<td>3</td>
</tr>
<tr>
<td>1.3.1 Independent Variable</td>
<td>3</td>
</tr>
<tr>
<td>1.3.2 Dependent Variable</td>
<td>3</td>
</tr>
<tr>
<td>1.4 Hypothesis</td>
<td>3</td>
</tr>
<tr>
<td>1.5 Null Hypothesis</td>
<td>4</td>
</tr>
<tr>
<td>1.6 Definitions</td>
<td>4</td>
</tr>
<tr>
<td>1.7 Assumptions</td>
<td>4</td>
</tr>
<tr>
<td>1.8 Limitations</td>
<td>5</td>
</tr>
<tr>
<td>1.9 Delimitations</td>
<td>5</td>
</tr>
<tr>
<td>CHAPTER TWO</td>
<td></td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>7</td>
</tr>
<tr>
<td>2.1 Elastic Band Resistance Training</td>
<td>7</td>
</tr>
<tr>
<td>2.2 Resistance Training</td>
<td>9</td>
</tr>
<tr>
<td>2.3 Resistance Training in Special Populations</td>
<td>12</td>
</tr>
<tr>
<td>2.4 Oxygen Consumption</td>
<td>15</td>
</tr>
<tr>
<td>2.5 Metabolic Equivalents</td>
<td>17</td>
</tr>
<tr>
<td>2.6 Heart Rate</td>
<td>18</td>
</tr>
<tr>
<td>2.7 Respiratory Exchange Ratio</td>
<td>19</td>
</tr>
<tr>
<td>2.8 Rate of Perceived Exertion</td>
<td>19</td>
</tr>
<tr>
<td>CHAPTER THREE</td>
<td></td>
</tr>
<tr>
<td>METHODS</td>
<td>21</td>
</tr>
<tr>
<td>3.1 Participants</td>
<td>21</td>
</tr>
<tr>
<td>3.2 Procedures</td>
<td>21</td>
</tr>
<tr>
<td>3.2.1 Resistance band exercises</td>
<td>22</td>
</tr>
<tr>
<td>3.2.2 Setting</td>
<td>23</td>
</tr>
<tr>
<td>3.3 Date Analysis</td>
<td>23</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS CONT.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHAPTER FOUR</strong></td>
<td></td>
</tr>
<tr>
<td>RESULTS</td>
<td>24</td>
</tr>
<tr>
<td>4.1 Subject Characteristics</td>
<td>24</td>
</tr>
<tr>
<td>4.2 VO2</td>
<td>24</td>
</tr>
<tr>
<td>4.3 Caloric Expenditure</td>
<td>26</td>
</tr>
<tr>
<td>4.4 METs</td>
<td>27</td>
</tr>
<tr>
<td>4.5 Heart Rate</td>
<td>29</td>
</tr>
<tr>
<td><strong>CHAPTER FIVE</strong></td>
<td></td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>31</td>
</tr>
<tr>
<td>5.1 Overview</td>
<td>31</td>
</tr>
<tr>
<td>5.2 Practical Application</td>
<td>31</td>
</tr>
<tr>
<td>5.3 Limitations</td>
<td>31</td>
</tr>
<tr>
<td>5.4 Future Research</td>
<td>32</td>
</tr>
<tr>
<td>5.5 Conclusion</td>
<td>32</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>34</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Force Elongation Ratio for Thera-Band</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>Participant Descriptive Statistics</td>
<td>24</td>
</tr>
<tr>
<td>C</td>
<td>VO2 Descriptive Statistics</td>
<td>25</td>
</tr>
<tr>
<td>D</td>
<td>Caloric Expenditure Descriptive Statistics</td>
<td>27</td>
</tr>
<tr>
<td>E</td>
<td>METs Descriptive Statistics</td>
<td>28</td>
</tr>
<tr>
<td>F</td>
<td>Heart Rate Descriptive Statistics</td>
<td>30</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: VO2</td>
<td>26</td>
</tr>
<tr>
<td>II: Caloric Expenditure</td>
<td>27</td>
</tr>
<tr>
<td>III: METs</td>
<td>29</td>
</tr>
<tr>
<td>IV: Heart Rate</td>
<td>30</td>
</tr>
</tbody>
</table>

x
CHAPTER ONE
INTRODUCTION

Resistance type training is commonly used to increase skeletal muscle strength, mass and endurance. Resistance type training has many health benefits, such as improved strength, anaerobic capacity, body composition, bone density, flexibility, and physical function (Manley, 1997; Robergs, Gordon, Reynolds, & Walker, 2007). Resistance type training can be performed by using equipment such as machines, free weights, and elastic resistance bands. Exercise specialist in a gym or clinical settings use resistance type training for weight loss, rehabilitation, and to increase skeletal muscle strength. The American College of Sports Medicine (ACSM) is commonly used in academic journals, exercise facilities, and hospitals for strength training guidelines (Gennuso, Zalewski, Cashin, & Strath, 2012; Westcott, 2009). ACSM’s guidelines for energy costs of exercises using METs (Metabolic Equivalent of Task) are classified as: (0-3 = low); (3.1-6 = medium); (6.1-10 = high); (10 <= very high) and were used to describe energy cost (Gaydos, Pullen, Hogue, Elliott, & Franklin, 2011).

Caloric expenditure of hundreds of activities, including conditioning exercise, occupational activities such as masonry work, self-care activities such as dressing, and lawn care activities such as mowing, have been previously reported (Ainsworth et al., 2000). However, there is little research that has been done in this specific area of MET calculation in regards to elastic resistance training. Elastic resistance training is a type of training in which one uses an elastic band to create tension during resistance type exercises.
The research question for this study was: What is the caloric expenditure difference between upper and lower body exercises in response to two different types of elastic resistance bands? The answer to this question will help provide therapists, personal trainers, and other professionals who utilize resistance band regimens with guidelines for optimal use and maximum impact.

STATEMENT OF THE PROBLEM

1.1 PURPOSE

The purpose of this study was to determine the caloric expenditure of a 15-minute upper body and lower body elastic resistance training exercise program as well as analyze the physiological responses of two different strengths of elastic resistance bands (blue and black). The purpose of comparing the two bands was to determine if they yielded different physiologic responses based on their resistance strengths. Upper and lower body exercises were also compared to determine the effects of these exercises and their differences on energy cost. Pre-exercise metabolic rate and exercise metabolic rate were compared, as well as (HR) heart rate, RPE (rate of perceived exertion) and (METs) metabolic equivalents of tasks to assess if this resistance band exercise program fit into the low to moderate intensity exercise category used by American College of Sports Medicine.

1.2 SIGNIFICANCE OF STUDY

Understanding the caloric cost of performing elastic resistance band exercises will be of use to fitness professionals as well as clinical specialists who work with special
populations such as those who are diabetic, overweight or post cardiac event. This information will facilitate the development of better exercise prescriptions that utilize elastic resistance type exercise for weight loss and health interventions. Determining if there is a significant difference between two different elastic band strengths as well as upper and lower body exercises on caloric costs will guide professionals in choosing appropriate exercise prescription.

1.3 VARIABLES

1.3.1 INDEPENDENT VARIABLE

There are two independent variables in this study:

1. The elastic band (blue or black) used to complete exercises
2. Upper or lower body exercises

1.3.2 DEPENDENT VARIABLE

The dependent variables in this study are the calculated caloric expenditure, METs that are calculated from relative VO2, and heart rate.

1.4 HYPOTHESES

1. Participants’ METs of this 15-minute upper and lower body resistance band exercise program will fit into the parameters of ACSM’s moderate-intensity exercise guidelines.

2. The black elastic resistance band will yield a greater caloric expenditure, higher METs, higher heart rate and higher rate of perceived exertion when compared to the blue band.

3. Lower body exercises will yield a greater caloric expenditure, higher METs, higher heart rate and higher rate of perceived exertion when compared to upper
body exercises.

1.5 NULL HYPOTHESIS

There will be no difference in METs, caloric cost or heart rate between upper and lower body exercise or between blue and black resistance bands.

1.6 DEFINITIONS

VO2- volume of oxygen consumption (Foster, 2006).

VCO2- volume of carbon dioxide expired (Foster, 2006).

RER- (Respiratory Exchange Ratio) is the difference between carbon dioxide exhaled and oxygen inhaled (Foster, 2006).

Indirect Calorimetry- calculates the heat that a living organism produces by measuring their carbon dioxide and nitrogen wastes or from their oxygen consumption (Foster, 2006).

MET- (Metabolic Equivalents of Tasks) is a physiological measure used to describe energy costs of a particular task or exercise (Ainsworth, Irwin, Addy, Whitt, & Stolarczyk, 1999)

Resistance Type Training- Generally described as moving different weights at different velocities by means of concentric or eccentric contractions for a certain amount of repetitions and sets (Lehman, 2006).

1.7 ASSUMPTIONS

In order for the experimental design to be valid the author accepted the following assumptions:

- Participants were familiar with the use of elastic bands for resistance type training. This was assumed because all participants were undergraduate or
graduate exercise science students with experience and knowledge in this field.

- All participants were in good health with no preexisting injuries. This was assumed because all participants were verbally screened.
- All participants could follow a video led exercise program. This was assumed because all participants were undergraduate or graduate exercise science students with experience and knowledge in this field.
- All participants were able to complete a 15-minute moderate intensity exercise program. This was assumed because all participants were healthy and active 18-25 year old exercise science students.
- All equipment was working correctly. This was assumed because equipment was calibrated to manufactures standards.
- Elastic bands were correct resistance stated by Thera-Band. This was assumed because the colors and band thickness were consistent with company’s standards.

1.8 LIMITATIONS

The author recognizes the limitations to this study design and will briefly discuss them in this section:

- Bands were not brand new. This is a limitation because the bands could have lost resistance strength overtime due to usage.
- Sample size was small, there were only 15 participants
- Activity that day, caffeine, stress, current physical condition can affect pre-exercise and exercise VO2 and HR levels.

1.9 DELIMITATIONS

This study design includes the following delimitations, which may impact the
application of the results:

- Participants were 18-25 years old.
- Oxygen consumption was the form of indirect calorimetry used to measure VO2.
- All participants were in the undergraduate and graduate exercise science program at Wichita State University.
- All participants were in good health and considered active individuals.
CHAPTER TWO

REVIEW OF LITERATURE

2.1 ELASTIC BAND RESISTANCE TRAINING

There are many methods used to increase muscle strength in the general population and special populations (Chang et al., 2012; Juan C. Colado et al., 2012; Kim et al., 2012; Melchiorri & Rainoldi, 2011; Nyberg, Lindström, & Wadell, 2012; Song & Sohng, 2012). These methods must provide muscles with enough resistance to stimulate adaptation and alter contractility (Lohne-Seiler, Torstveit, & Anderssen, 2013). In order to achieve muscle adaptation, exercise or rehabilitation specialists must choose a form of resistant type training that best suits the patient’s goals, physical ability and fitness level. A popular form of resistance type training is elastic band training. Elastic resistance bands offer a simple, portable and versatile form of resistance training that can be used for a sport specific training, rehabilitation, flexibility and balance (Ellenbecker, 2003). Although there is literature available about the use of elastic bands for resistance type training, there is little known about the metabolic equivalents of this type of training and the efficacy of it’s application for exercise.

Thera-Band elastic bands are a commonly used brand for resistance type training and rehabilitation (Fahlman, McNevin, Boardley, Morgan, & Topp, 2011; Hughes, Hurd, Jones, & Sprigle, 1999; Lister et al., 2007; Patterson, Stegink Jansen, Hogan, & Nassif, 2001; Puls & Gribble, 2007; Vafadar, Côté, & Archambault, 2012) such as improving ankle instability (Smith, Docherty, Simon, Klossner, & Schrader, 2012). Thera-Band makes several different strengths of elastic bands that are
categorized by color. The color of band represents the force in pounds created by the bands’ thickness. Thera-Band elastic bands’ color coded resistance levels listed from minimum to maximum are as follows: yellow, red, green, blue, black, silver, gold (Fahlman et al., 2011). There is approximately a twenty to thirty percent increase in force between each color (Ellenbecker, 2003). The bands also develop a Force-Elongation ratio as the band is stretched, which is depicted in Table A. This table shows the percent of elongation for that color of band and the force created by the change in length when stretched. Blue and black elastic bands were chosen for their moderate force generation location in the spectrum of force in pounds.

**TABLE A: FORCE-ELONGATION IN THERA-BAND (FORCE IN POUNDS)**

<table>
<thead>
<tr>
<th>%</th>
<th>Yellow</th>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
<th>Black</th>
<th>Silver</th>
<th>Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>1.1</td>
<td>1.5</td>
<td>2</td>
<td>2.8</td>
<td>3.6</td>
<td>5</td>
<td>7.9</td>
</tr>
<tr>
<td>50</td>
<td>1.8</td>
<td>2.6</td>
<td>3.2</td>
<td>4.6</td>
<td>6.3</td>
<td>8.5</td>
<td>13.9</td>
</tr>
<tr>
<td>75</td>
<td>2.4</td>
<td>3.3</td>
<td>4.2</td>
<td>5.9</td>
<td>8.1</td>
<td>11.1</td>
<td>18.1</td>
</tr>
<tr>
<td>100</td>
<td>2.9</td>
<td>3.9</td>
<td>5</td>
<td>7.1</td>
<td>9.7</td>
<td>13.2</td>
<td>21.6</td>
</tr>
<tr>
<td>125</td>
<td>3.4</td>
<td>4.4</td>
<td>5.7</td>
<td>8.1</td>
<td>11</td>
<td>15.2</td>
<td>24.6</td>
</tr>
<tr>
<td>250</td>
<td>3.9</td>
<td>4.9</td>
<td>6.5</td>
<td>9.1</td>
<td>12.3</td>
<td>17.1</td>
<td>27.5</td>
</tr>
<tr>
<td>175</td>
<td>4.3</td>
<td>5.4</td>
<td>7.2</td>
<td>10.1</td>
<td>13.5</td>
<td>18.9</td>
<td>30.3</td>
</tr>
<tr>
<td>200</td>
<td>4.8</td>
<td>5.9</td>
<td>7.9</td>
<td>11.1</td>
<td>14.8</td>
<td>21</td>
<td>33.4</td>
</tr>
<tr>
<td>225</td>
<td>5.3</td>
<td>6.4</td>
<td>8.8</td>
<td>12.1</td>
<td>16.2</td>
<td>23</td>
<td>36.6</td>
</tr>
<tr>
<td>250</td>
<td>5.8</td>
<td>7</td>
<td>9.6</td>
<td>13.3</td>
<td>17.6</td>
<td>25.3</td>
<td>40.1</td>
</tr>
</tbody>
</table>
2.2 RESISTANCE TRAINING

ACSM recommends that healthy individuals seeking a strength training regimen do eight to ten exercises for major muscle groups, at least one set of each exercise, eight to twelve repetitions per set of exercise, exercises done to full-range of movements, pain free, at a moderate speed, and be done two to three nonconsecutive days per week (Westcott, 2009). A set is one complete exercise round of a given amount of repetitions. A repetition is the number of times a weight is lifted in a set. The amount of literature on caloric expenditure during resistance training, especially upper and lower body exercise with elastic bands is limited.

Adults who do not incorporate some type of strength training lose an average of four to six pounds of muscle tissue a decade (Westcott, 2009). The loss of muscle mass can contribute to a decline in an individual’s resting metabolic rate. Each pound of muscle is responsible for the energy expenditure of five calories per day. The decline in muscle mass overtime severely effects the amount of calories burned at rest per day, which then are stored as fat (Westcott, 2009). The amount of energy expended at rest is called resting metabolic rate (Westerterp, 2010). It has been reported that an individual’s resting energy expenditure can increase up to eight percent for three days following a high intense strength training session. Low intensity strength training programs done to volitional fatigue have also shown to produce an increased resting metabolic rate. So not only does strength training increase skeletal muscle strength, it also leads to an increased amount of calories burned at rest throughout the day (Westcott, 2009).

A recent study found that strength training helps increase and maintain lean muscle mass, which helps to increase resting metabolic rate (Westerterp, 2010). A higher
resting metabolic rate can lead to an increase in total calories burned every day. Resistance training is effective for weight management because of the increase in fat free mass that causes a higher metabolic rate and energy expenditure (Washburn et al., 2012).

Muscle tissue adaptation, also known as plasticity, occurs according to the type of exercise training performed. Resistance bands can be used for many forms of exercise such as eccentric and concentric actions. Different forms of exercise and their benefits have been studied and correlate strength gains to their type of contraction types. It is important to incorporate a mixture of each type of contraction (Clarice Sperotto et al., 2011). Strength training specific muscle groups is also beneficial to prevent injuries related to sport specific movements such as strengthening rotator cuff muscles to prevent injuries in throwing arms of baseball players (Lehman, 2006). Resistance bands are also effective when used for rehabilitation purposes such as ankle instability (Han & Ricard, 2011)

Different forms of resistance training such as high-intensity and moderate-intensity have been compared. For those individuals unable to perform high-intensity resistance training, for whatever reason, must rely on moderate to low-intensity resistance training for exercise. Lower limb blood occlusion has gained popularity because when it is paired with moderate-intensity resistance training can be just as beneficial as high-intensity resistance training alone, producing the same results. This enables those unable to lift heavier loads the ability to get the same health benefits as healthy individuals that can. Typically during blood occlusion, blood supply is partially closed off to a given limb or muscle group. This blood occlusion causes an elevation in pressure to the occluded cite which, in theory, when paired with resistance training can lead to muscle
hypertrophy (Fahs et al., 2012). With the aid of blood flow restriction therapy paired with moderate load intensity, disabled individuals can get the same benefit as a high load exercise program. Both exercise interventions exhibit similar physiological responses, supporting the theory that occlusion therapy paired with moderate intensity resistance training is an option for disabled individuals that cannot perform high intensity resistance training (Nielsen et al., 2012).

A resistance type training program, where the participant exercises to failure, will produce skeletal muscle hypertrophy despite the weight of the given load. Different loads will produce similar results as long as the exercise sets are completed to failure (Mitchell et al., 2012). Physiological responses to specific resistance exercises greatly depend on both the load and velocity, which was shown in a study that combined three different loads to four different training modes. The authors analyzed the physiological responses to the given combinations. There were many significant differences between combinations, showing that load and mode combination make a difference in ability to perform and the results of a given exercise (Buitrago, Wirtz, Yue, Kleinöder, & Mester, 2012). Slower velocities, even at low loads, when compared to fast velocities show an acute amplitude of mitochondrial and sarcoplasmic protein synthesis. This results in a higher stimulation of myofibrillar protein synthesis following resistance exercise, which lead to an increase in strength and growth of skeletal muscle (Burd et al., 2012).

There are also several adaptations to skeletal muscle that are responsible for chronic adaptations in response to high intensity, high power resistance training. A study took muscle biopsies three different times during a power clean, which is a type of Olympic power lift. They were looking for an increase in mitogen-activated protein
kinases, a mechanism partially responsible for chronic adaptations during high power training. The findings of this study were said to apply to all forms of resistance training because it found an increase of this pathway during activity, thus supporting their hypothesis of the responsibility of this pathway for muscle adaptation (Galpin, Fry, Chiu, Thomason, & Schilling, 2012).

A study done on healthy older men participated in a twenty-one week exercise program to study the effects on explosive power, dynamic balance and walk speed. Participants were separated into 3 groups consisting of a strength, an endurance, and a combined training group. The strength training only intervention group exhibited the most improvement. This study shows that resistance training can be used to improve explosive power, dynamic balance and walking speed in healthy older men (Holviala et al., 2012). When considering a combined training program involving strength and endurance training, one should consider that such a program can reduce explosive power when compared to a strength training or endurance program alone (Mikkola, Rusko, Izquierdo, Gorostiaga, & Häkkinen, 2012). This study showed a significant difference in athletes’ explosive power when they combined the two training modes. This information is useful for athletes that have a main goal of increasing their explosive power.

2.3 RESISTANCE TRAINING IN SPECIAL POPULATIONS

Resistance training is beneficial when incorporated into a weight loss program (Alberga et al., 2012). It is used to increase energy expenditure, which can be used for weight loss with obese individuals and should be used for diabetic patients as well as in
patients with coronary artery disease (Audelin et al., 2012). Resistance training can reduce abdominal fat and HbA(1c) (typically used to measure average plasma glucose concentration), as well as improve metabolic features and increase insulin sensitivity in type two diabetic patients (Bacchi et al., 2012). A resistance training exercise program can be effective in reducing the number of patients with gestational diabetes mellitus who require insulin and can improve capillary glycemic controls (de Barros, Lopes, Francisco, Sapienza, & Zugaib, 2010).

A twelve-week resistance exercise program can lead to a significant improvement in muscle strength and muscle function in pre-diabetic and type two diabetic elderly participants (Geirsdottir et al., 2012). A nine month program involving nutrition controls in pre-diabetic and type two diabetic elderly individuals found that high intensity interval training and resistance training can improve body mass, waist circumference, resting metabolic rate, and triglyceride/high-density lipoprotein cholesterol ratio (Gremeaux et al., 2012).

Post-menopausal obese women who wish to lose weight will benefit from a resistance type training program. Post-menopausal obese women who participated in a resistance training and calorie restriction program will lose significantly more body fat than a calorie restriction program alone (Cameron et al., 2013). Strength gains have been seen in women with other medical issues, such as fibromyalgia, in response to a resistance training program (Panton, 2009). Women who have osteoporosis will benefit from a resistance training program because of an increase in bone mineral density as a response to loads on skeletal muscles (Bergström et al., 2012; Burke, França, Meneses, Pereira, & Marques, 2012; Galpin et al., 2012; Gennuso et al., 2012; Gómez-Cabello,
Resistance training can be used to increase aging muscle mass and strength in older adults suffering from sarcopenia, which is the decrease in muscle tissue and quality (Candow et al., 2012). As individuals get older, they are at risk of losing muscle mass, largely due to lack of physical activity. It has been reported that after adulthood, there is a steady decline in myofibrils, which are smaller threads of protein that make up muscle fibers. Older individuals who have lost muscle mass can stimulate muscle growth, improve their metabolic health, increase strength, and increase overall muscle mass in response to a resistance training program (Candow et al., 2012; Gennuso et al., 2012; S. M. Phillips, 2007; Serra-Rexach et al., 2011). The effects of different resistance training volumes and loads on myofibrillar muscle protein synthetic responses in older and younger men showed a higher amount of muscle protein synthesis post exercise when training volumes were doubled, further suggesting the aging should increase their training volume to achieve greater muscle growth (Kumar et al., 2012).

A study involving adults over the age of 65 tested the effects of a resistance type training program on a sub-maximal walk test and leg strength. The resistance type training program found an average of a nine minute increase in the post submaximal walk test, where there were no changes in the control group. The resistance type training group also showed an increase in leg strength. There was a significant relationship between leg strength and walking endurance (Ades, 1997).

Resistance training can improve insulin sensitivity and adiposity in obese adolescent boys. Compared with a control group, a resistance training group prevented
significant weight gain, showed a significant increased insulin sensitivity and lost body fat (Lee et al., 2012). Resistance training affects male age cohorts differently. While both groups gain muscle mass in response to resistance training, younger men have shown to gain more muscle mass when compared to older groups of men after a resistance training program (Mero et al., 2013).

Busch et al., 2012 used very old adults that were post CABG, coronary artery bypass graft, and in a cardiac rehabilitation program. The individuals were randomly assigned to an intervention and a control group. The intervention group began a resistance training and balance program in addition to the cardiac rehabilitation program, where the control group was in the cardiac rehabilitation program alone with no intervention. The intervention group showed a significant improvement compared to those in the control group (Busch et al., 2012). This study however, did not provide caloric expenditure or oxygen consumption.

Many of these studies aided in the argument that using resistance training for the general population as well as special populations will produce many health benefits. However, few calculated the calorie cost of their interventions or the caloric cost of different training intensities. This information would further aid exercise specialist with data to support and monitor correct exercise prescription.

2.4 OXYGEN CONSUMPTION

Oxygen consumption can be measured by using indirect calorimetry. A popular form of indirect calorimetry is respirometry, which calculates an individual’s oxygen consumption and can be measured by a metabolic measuring cart (MMC). The MMC
measures ventilation from participants through a one-way valve mask that leads to a mixing chamber. The mixing chamber uses electronic gas analyzers to measure oxygen and carbon dioxide. The MMC has a computer that analyzes the fractions of VO2, CO2 and RER, giving the respiratory exchange ratio which enables researchers to measure the amount of gas exchange occurring in the body during a given exercise over a period of time (Foster, 2006). The participants’ oxygen exchange ratio is being used as a means to measure energy expenditure (Zeni, Hoffman, & Clifford, 1996). Using the oxygen exchange ratio is widely used and proven to be an accurate way to assess energy expenditure in response to exercise, which can be used to calculate caloric costs of activities (Caruso, Hernandez, Saito, Cho, & Nelson, 2003; Lin, 2011).

VO2 and VCO2 can be used to measure physiologic responses to resistance training (Benito et al., 2012). Oxygen and carbon dioxide exchange in ventilated patients has been used as a means of indirect calorimetry to provide physicians with a more precise way to calculate exercise prescription (De Waele et al., 2012; Lavado, Cardoso, Silva, Dela Bela, & Atallah, 2013; White, 2012). Oxygen consumption can be measured using a metabolic cart to find peak oxygen consumption and maximum oxygen consumption in athletes and special populations such as children with spina bifida (de Groot et al., 2009) was well as individuals with prosthetics (Chin, Kuroda, Akisue, Iguchi, & Kurosaka, 2012).

Robergs, Gordon, Reynolds, and Walker used indirect calorimetry during a bench press and parallel squat exercise to assess the metabolic cost. Previously trained males were assigned to one of the two groups. Tests were conducted at different intensities, in random orders, and were separated by five minutes. Steady state VO2 was the dependent
variable while the independent variables were load and distance lifted. These were used in a multiple regression analysis to predict the energy cost of resistance training at different loads. Based on the respiratory exchange ratio and caloric equivalent, VO2 was calculated into caloric expenditure. This study reported a higher calorie costs for resistance training than have previously been reported for the bench press and parallel squat and claimed the new calculation was more accurate (Robergs et al., 2007).

2.5 METABOLIC EQUIVALENTS

Metabolic equivalents are commonly used to measure an individual’s exercise capacity for exercise prescription (Ainsworth et al., 1999). According to ACSM, intensity of a given exercise using METs are classified as 0-3 = low, 3.1-6 = medium, 6.1-10 = high, and 10 <= very high (Gaydos, Pullen, Hogue, Elliott, & Franklin, 2011). METs can be calculated by means of measuring one’s gas exchange. 1 MET is considered to be equal to a relative VO2 of 3.5 ml/kg per minute (Tartaglia et al., 2000). This was the MET value used to calculate metabolic equivalents from relative VO2 in this study.

METs can be calculated to assist rehabilitation specialist in making sure that an exercise program such as a submaximal all-extremity program fits the range of METs in order to be considered a beneficial form of exercise for older/frail adults (Mendelsohn, Connelly, Overend, & Petrella, 2008). Older adults can achieve 3-6 Mets from 1 set of 15 repetitions of 8 different exercises (W. T. Phillips & Ziuraitis, 2003).

Studies have shown that the amount of body fat loss is directly associated with higher energy expenditures for men and women (Elder, 2007). It is beneficial to find out energy expenditure for specific exercises, especially when they are being used to treat
those who are overweight and have health issues to makes sure they are operating in the range appropriate for their cohort.

2.6 HEART RATE

Heart rate is commonly used to determine the body’s response to a given workload (Chang et al, 2010; Dolgoff-Kaspar, 2012; Giles, 2013; Seiler, Jøranson, Olesen, & Hetlelid, 2013). Heart rate is an accurate and noninvasive way of assessing one’s physiological response at rest or in response to exercise (Hunter, Seelhorst, & Snyder, 2003). It has been suggested that it is necessary to use an individual’s age related estimated HRmax, peak heart rate, to determine a more accurate level of fitness level (Strath et al., 2000). Heart rate can be monitored by using a polar heart monitor, which is typically placed around an individual’s chest (Dutton, 2011; McGinnis, 2004). Individual’s workload can be estimated by calculating their heart rate max using the common equation (220-age).

Heart rate monitors can be used by individuals hoping to achieve a target heart rate to by cardiac rehabilitation exercise specialist to make sure a patient does not go over a certain beat per minute (Sun et al., 2012). However, heart rate alone is not a reliable measure of workload because training state and an individual’s heart rate response can affect the HR-VO2 relationship as well as several other factors such as stimulants and other factors that can affect individuals heart rate response (Strath et al., 2000).
2.7 RESPIRATORY EXCHANGE RATIO

Respiratory Exchange Ratio is commonly used to analyze the amount of oxygen being consumed compared to the amount of carbon dioxide exhaled (Foster, 2006; Peterson et al., 2013). Measuring the amount of O2 inspired and CO2 expired can be used to estimate the respiratory quotient. The respiratory quotient can be used to determine what fuel source (fats or carbohydrates) are being metabolized for energy to complete a task. Generally RER is 0.8 at rest. When RER is 0.7 fat is being utilized primarily for the body’s fuel source, at 0.85 the body is metabolizing approximately 50% fat and 50% carbohydrates for fuel. When RER is 1.0, carbohydrates are primarily being metabolized for the body’s fuel. RER often exceeds 1.0 during maximal exercises tests and is generally the marker for achieving max during exhaustive tests such as a VO2 max test (Foster, 2006).

2.8 RATE OF PERCEIVED EXERTION

Rate of perceived exertion (Borg RPE scale) is generally used to assess a participants/patients perception of the level of intensity of an exercise (Foster, 2006). ACSM recommends the use of RPE to monitor and prescribe exercise intensity (Dishman, 1994). This is useful to exercise specialists and clinicians because it provides information from about how the patient feels in response to the exercise. RPE can and is often compared to physiologic measures. It is important to use RPE along with physiologic measures because a patient may not exhibit elevated physiologic levels but
may feel the exercise or task is very hard, and vice versa (Astorino, Roupoli, & Valdivieso, 2012; Bachasson et al., 2013; Casolino et al., 2012; Dishman, 1994; Peterson et al., 2013; Ridgel, Peacock, Fickes, & Kim, 2012; Satonaka, Suzuki, & Kawamura, 2012).
CHAPTER THREE

METHODS

3.1 PARTICIPANTS

15 participants, 6 males and 9 females, between the ages of 18-25 years of age who are undergraduate or graduate students at Wichita State University were recruited on a volunteer basis to participate in this study. All subjects were verbally screened to assess their eligibility to participate in the study. Exclusion criteria were: known pregnancy, current musculoskeletal injuries, soreness in areas of exercise, extreme fatigue, light headedness, shortness of breath, and any discomforting feelings in general.

An IRB was approved by the Wichita State University Institutional Review Board for the Protection of Human Subjects. The participants were required to read and sign the form before beginning the study. The participants were informed of all experimental procedures and risks that may be involved. Each participant was advised to wear comfortable clothes and shoes that they were capable of exercising in.

3.2 PROCEDURES

Basic information such as age, sex, height, weight, and BMI will be gathered. The participants were then shown some of the exercises they were going to be performing. Each participant was advised to wear comfortable clothes and shoes that they were capable of exercising in. After the demonstration of the exercise the participants were directed to sit quietly for five minutes to attain pre-exercise metabolic rate. During this procedure, expired air was collected and analyzed for ventilation, oxygen intake, carbon dioxide output and gas exchange ratio (RER) using a large two-way non-rebreathing mouthpiece (Hans Rudolph) leading to a mixing chamber and
metabolic cart with an oxygen analyzer, and a carbon dioxide analyzer. The gas analyzer and flow meter were calibrated according to the manufacturer’s recommendations before each test. The gas meters were calibrated against gases of known concentrations before each test. Oxygen uptake (VO₂) and carbon dioxide output (VCO₂) was determined from the measurement of oxygen and carbon dioxide concentration in the inspired and expired air. A mouthpiece was secured in place with a band around the head assuring that the participant’s breathing is easy and normal. The participant breathed through the mouthpiece so that the composition of expired air can be determined. Room air is inspired and expired air is taken via tubing from the mask to mixing chamber that measures gas composition. Nose clips were placed on the nose to prevent inspiration/expiration through the nasal cavities. After pre-exercise metabolic rate was determined, the participant was handed a blue elastic band. A video on an iPad was started; making sure the participant could see and hear exercise instructions. The participant completed all exercises led by the video. Caloric expenditure was calculated by the equation of (0.0175*METs*body weight in kilograms).

3.2.1 RESISTANCE BAND EXERCISES

Participants watched a video, made by the author, that lead them through exercises consisting of five standing elastic resistance (blue elastic band) exercises lasting five minutes (squat, hip abduction, hamstring curls, upright rows, and biceps curls), five sets of seated elastic resistance (blue elastic band) exercises lasting five minutes (chest press, chest fly, shoulder press, triceps extension, and reverse fly). Ten repetitions of each exercise were completed. After concluding the first round of exercises, the video was
restarted and the participant performed the same ten exercises with an elastic resistance band of a slightly higher resistance (i.e. black elastic band). Each exercise will consist of ten repetitions. Each upper body and lower body exercise segments lasted approximately five minutes.

3.2.2 SETTING

All testing was conducted by the author and a trained exercise science graduate student in the Human Performance Laboratory at Wichita State University.

3.3 DATA ANALYSIS

All data were entered in Excel and SPSS with each data point being checked against the original data collection form. Initial analysis yielded descriptive data for all of the variables including mean, variance, range and frequency. Assumptions of homogeneity of variance and sphericity were evaluated.

The research design was a cross over trial. This was a 2 x 3 trial (upper and lower) by condition (rest, blue, black). The two trials analyzed were upper vs. lower body resistance exercises. A within subjects repeated measures ANOVA was used to analyze data. The mean VO2, HR, METs, and caloric expenditure for upper and lower body exercises were calculated in regards to which band (blue or black) was used to complete the exercises. In the event that a significant trial by condition occurred (p < .05) for any of the dependent variables, the statistical model was decomposed by examining the main effects with separate one way repeated measures ANOVAS with Bonferoni correction factors for each trial by condition and paired samples t-tests were ran. Alpha levels were set at (p=0.05).
CHAPTER FOUR

RESULTS

4.1 SUBJECT CHARACTERISTICS

There were a total of 15 participants in this study (9 female, 6 male). Mean age for participants was 21.60 ±1.99 years old. Mean height was 169.84cm. ± 13.28. Mean weight was 75.42kg±20.32. Mean BMI for participants was 26.76±5.2.

TABLE B: PARTICIPANT DESCRIPTIVE STATISTICS

<table>
<thead>
<tr>
<th>Descriptive Statistics</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>169.84</td>
<td>13.28</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.42</td>
<td>20.32</td>
</tr>
<tr>
<td>BMI</td>
<td>26.76</td>
<td>5.20</td>
</tr>
<tr>
<td>Age (years)</td>
<td>21.60</td>
<td>1.99</td>
</tr>
</tbody>
</table>

4.2 VO2

A significant condition by trial interaction did exist for VO2. After decomposing the data, average VO2 was significantly (p<.01) higher for both upper blue (10.31 mL/kg/min±1.54) and black (10.69 mL/kg/min±1.57) band, as well as lower blue (10.69 mL/kg/min±1.57) and black (13.5 mL/kg/min±1.75) when compared to pre-exercise as
seen in Table C. There was also a significant (p<.01) difference between upper body and lower body trials for both blue and black band conditions. There was also a significant difference (p<.01) when black lower (13.5 mL/kg/min ±1.75) was compared to blue lower (12.31 mL/kg/min ±1.7), but not for blue upper (10.31 mL/kg/min ±1.53) compared to black upper (10.69 mL/kg/min ±1.57). Based on the data, the most significant trial by condition exercise performed by participants was black band lower body (13.5 mL/kg/min ±1.75) exercises, depicted in Figure I.

**TABLE C: VO2 DESCRIPTIVE STATISTICS**

<table>
<thead>
<tr>
<th>VO2 (mL/kg/min)</th>
<th>MEAN</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper/Pre-exercise</td>
<td>5.51</td>
<td>1.61</td>
</tr>
<tr>
<td>Upper/Blue</td>
<td>10.31</td>
<td>1.53</td>
</tr>
<tr>
<td>Upper/Black</td>
<td>10.69</td>
<td>1.57</td>
</tr>
<tr>
<td>Lower/Rest</td>
<td>5.50</td>
<td>1.61</td>
</tr>
<tr>
<td>Lower/Blue</td>
<td>12.31</td>
<td>1.70</td>
</tr>
<tr>
<td>Lower/Black</td>
<td>13.50</td>
<td>1.75</td>
</tr>
</tbody>
</table>
4.3 CALORIC EXPENDITURE

Data for caloric expenditure showed a significant difference (p<.01) for trial, condition, as well as trial by condition comparisons. Black lower (5.13 kcal ±1.54) and black upper (4.06 kcal ±1.17) had a significantly higher (p<.01) caloric cost over pre-exercise (2.06 kcal ±.67) and blue band lower (4.69 kcal ±1.48) and upper (3.9 kcal ±1.24) exercises as seen in Table D. The blue band lower (4.6 kcal ±1.48) and upper (3.94 kcal ±1.24) was significantly higher (p<.01) than rest but was significantly lower than black band in both upper and lower trials as seen in Figure II. There was a significant difference (p<.01) between upper and lower body exercises within blue and black band trials.
TABLE D: CALORIC EXPENDITURE

<table>
<thead>
<tr>
<th>Caloric Expenditure (kcal/min)</th>
<th>MEAN</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper/Pre-exercise</td>
<td>2.06</td>
<td>.67</td>
</tr>
<tr>
<td>Upper/Blue</td>
<td>3.94</td>
<td>1.24</td>
</tr>
<tr>
<td>Upper/Black</td>
<td>4.06</td>
<td>1.17</td>
</tr>
<tr>
<td>Lower/Rest</td>
<td>2.06</td>
<td>.67</td>
</tr>
<tr>
<td>Lower/Blue</td>
<td>4.69</td>
<td>1.48</td>
</tr>
<tr>
<td>Lower/Black</td>
<td>5.13</td>
<td>1.54</td>
</tr>
</tbody>
</table>

FIGURE II: CALORIC EXPENDITURE

4.4 METs

METs were calculated every minute from relative VO2. A significant difference (p<0.01) was found with condition and trial by condition but not trial alone. A significant
A difference (p<0.01) was found between pre-exercise and blue and black bands. Black lower (3.85 MET±0.5) had a significantly higher average MET compared to blue upper (2.95 MET ±0.43), blue lower (3.51 MET ±0.49) and black upper (3.05 MET ±0.44) as seen in Table E. By further decomposition using paired samples T-test it was found that black band METs were significantly (p<0.01) higher for lower body exercise than upper with both bands, which can be seen in Figure III. Blue bands had a higher MET calculation for lower body exercise (3.51 MET ±0.49) when compared to black lower body exercise (3.85 MET ±0.50).

TABLE E: METs DESCRIPTIVE STATISTICS

<table>
<thead>
<tr>
<th>MET/min</th>
<th>MEAN</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper/Pre-exercise</td>
<td>1.57</td>
<td>0.46</td>
</tr>
<tr>
<td>Upper/Blue</td>
<td>2.95</td>
<td>0.43</td>
</tr>
<tr>
<td>Upper/Black</td>
<td>3.05</td>
<td>0.44</td>
</tr>
<tr>
<td>Lower/Rest</td>
<td>1.57</td>
<td>0.46</td>
</tr>
<tr>
<td>Lower/Blue</td>
<td>3.51</td>
<td>0.49</td>
</tr>
<tr>
<td>Lower/Black</td>
<td>3.85</td>
<td>0.50</td>
</tr>
</tbody>
</table>
FIGURE III: METs

4.5 HEART RATE

There was a significant difference (p<0.01) for heart rate within condition and trial by condition, but not for trial alone. By decomposing and using Bonferoni pairwise comparison, there was a significant difference (p<0.01) between upper blue (96.87bpm±13.92), lower blue (102.13bpm ±13.37), upper black (100.13bpm ±14.75), lower black (100.13bpm ±29.3) and pre-exercise conditions, but not between blue and black conditions. When data from Table F was further decomposed and a paired samples T-test was used, there were significant difference (p<0.01) found between upper and lower body exercise with the blue band as well as a significant difference (p<0.05)
between upper and lower body exercise with the black band. However, there was no significant difference within band color between upper and lower body exercise, which can be seen in Figure IV.

TABLE F: HEART RATE DESCRIPTIVE STATISTICS

<table>
<thead>
<tr>
<th>Heart Rate (bpm)</th>
<th>MEAN</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper/Pre-exercise</td>
<td>84</td>
<td>14</td>
</tr>
<tr>
<td>Upper/Blue</td>
<td>97</td>
<td>14</td>
</tr>
<tr>
<td>Upper/Black</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>Lower/Rest</td>
<td>84</td>
<td>14</td>
</tr>
<tr>
<td>Lower/Blue</td>
<td>102</td>
<td>13</td>
</tr>
<tr>
<td>Lower/Black</td>
<td>100</td>
<td>29</td>
</tr>
</tbody>
</table>

FIGURE IV: HEART RATE
CHAPTER FIVE

DISCUSSION

5.1 OVERVIEW

The null hypothesis was rejected for VO2 because there was a significant difference (p<0.01) between blue and black bands as well as upper and lower body. It is assumed this difference exists because the black band is a higher resistance than the blue and lower body exercise involves a larger muscle group compared to upper. Since, METs and caloric expenditure were all based of the relative volume of oxygen consumption; they showed the same results that were observed with VO2.

5.2 PRACTICAL APPLICATION

The information on METs and caloric expenditure provided by this study will aid in the implementation of elastic band resistance training for health and rehabilitation specialist. Health and fitness specialists can prescribe exercise that is catered to their clientele’s exercise needs. The higher the intensity of band, in this study blue vs. black, the higher the caloric costs. There is an average higher caloric cost for lower body exercise when compared to upper body exercise in this cohort.

5.3 LIMITATIONS

Limitations for this study involved the following: The participants used for this study were exercise science college students between the ages of 18-25. This cohort exhibit different data than other cohorts. This study should only be applied when using this cohort. During the study, one of the blue bands broke and had to be replaced. This change in bands could have altered data by means of replacing and older blue band with a newer, possibly tighter, band strength.
Not all individuals achieved true resting levels after the 5-minute resting period prior to beginning the exercises. It was named the pre-exercise condition for this reason. This could have affected data in many ways, one being that they may have a higher resting level and would not show a significant difference when performing the lower body exercises with the blue band. This could be contributed to being nervous, caffeine intake, time of day, and how active they had been that day previous to exercising.

Some individuals yielded different levels because of certain characteristics such as being a body builder or runner. These factors would affect heart rate and VO2 compared to workload. A body builder would be more familiar with exercises while a runner would be less familiar and have a more difficult time.

5.4 FUTURE RESEARCH

The author suggests that future studies should include older adults, a larger sample size and using a wider variety of colored Thera-Bands. Further investigation should be done on the energy costs of specific exercises.

5.5 CONCLUSION

The author concludes that a 15 minute elastic band exercise with a blue or black elastic resistance band would be beneficial for those seeking a low to moderate intensity resistance training program. Results for this exercise program’s calculated METs fit ACSM’s guidelines for moderate intensity exercise (3-6 MET) for under all trial by conditions for older adults (W. T. Phillips & Ziuraitis, 2003). RPE for all participants ranged from very light to somewhat hard and was consistent with MET findings. It was concluded that a black elastic band yields a higher energy expenditure when compared to a blue elastic band. Individuals seeking more caloric costs should choose a black band
over a blue band. It was also concluded that lower body exercises generally yield a higher energy expenditure when compared to upper body exercises, but not in every individual. It is suggested that individuals follow ACSM’s strength training guidelines and use a variety of upper and lower body exercises.


