Master's Theses

5-2013

The influence of respiratory muscle training on exercise endurance

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Recommended Citation

The Influence of Respiratory Muscle Training
on Exercise Endurance

by

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Submitted in Partial Fulfillment of
The Requirements of the Master of Science in Exercise Science Degree

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ABSTRACT

Exercise endurance in multiple populations has been shown to increase after bouts of respiratory muscle training (RMT) (Bailey, Romer, Kelly, Wilkerson, Dimenna & Jones, 2010; Brown, Sharpe, Graham & Johnson, 2008; Griffiths & McConnell, 2007; Kilding, Brown & McConnell, 2007; Laoutaris et al., 2012; Markov, Spengler, Stuessi, Boutellier & Knöpfli-Lenzin, 2001; Spengler & Boutellier, 2000; Stuessi, Spengler, Knöpfli-Lenzin, Markov & Boutellier, 2001; Volianitis et al., 2000). The use of resistance via respiratory muscle strength training (RMST) has been shown to produce greater increases in endurance than with no resistance, but the method of RMST that produces the greatest increases in exercise endurance is still unknown (Illi, Held, Frank & Spengler, 2012). The purpose of this study was to determine whether inspiratory muscle training (IN) or inspiratory with expiratory muscle training (INEX) would have the most significant increase on exercise endurance, as measured by a constant-load cycling test at 70% of maximum power output. Subjects were randomly assigned to one of three groups: an inspiratory muscle training group (n=11), an inspiratory with expiratory muscle training group (n=11) and a placebo group (n=7). The non-placebo groups trained five times per week, two times per day, 3-5 hours apart. Their training consisted of forceful breathing through a RMT mask 30 times per training session. The placebo group trained five days per week, once per day, and took 60 regular breaths at tidal volume through the mask. After four weeks of training, the inspiratory with expiratory muscle training group saw an average increase of 75% between pre- and post-exercise endurance tests. The inspiratory muscle training group saw a 28% increase in endurance time and the placebo group saw a 7% increase in endurance time. These were not statistically significant. Inspiratory with expiratory muscle training may produce the greatest

increase in exercise endurance, but more research with a variable group of participants in even groups is necessary to confidently make this conclusion. Inspiratory with expiratory muscle training could have a greater benefit than inspiratory muscle training in multiple populations, including individuals with exercise-induced asthma because these individuals experience difficulty exhaling air while working at 80% or greater of their VO_{2max} (Wuestenfeld & Wolfarth, 2013). INEX would train the muscles of expiration, while IN alone would not.

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CHAPTER 1

INTRODUCTION

Respiratory muscle training (RMT) has been shown to improve the exercise endurance of healthy individuals, as well as individuals in special populations, such as those with chronic obstructive pulmonary disease (COPD) (Bailey, Romer, Kelly, Wilkerson, Dimenna & Jones, 2010; Brown, Sharpe, & Johnson, 2008; Griffiths & McConnell, 2007; Kilding, Brown & McConnell, 2007; Laoutaris et al., 2012; Markov, Spengler, Knöpfli-Lenzin, Stuessi, & Boutellier, 2001; Spengler & Boutellier, 2000; Stuessi, Spengler, Knöpfli-Lenzin, Markov & Boutellier, 2001; Volianitis et al., 2000). There are two specific types of RMT: respiratory muscle strength training, and respiratory muscle endurance training (Illi, Held, Frank & Spengler, 2012). It is still unclear which method is more effective in improving exercise endurance, but Illi et al. (2012) suggest that training both the inspiratory and expiratory muscles would show a greater increase in endurance. Multiple studies (Tong et al., 2008; Kilding, Brown, & McConnell, 2010; Leddy et al., 2007) have been conducted using different types of respiratory muscle training, but many of them have used different types of training regimens. Since any endurance athlete would benefit from increased endurance, it would be useful to determine which regimen is the most effective. The goal of this study was to determine whether inspiratory muscle training (IMT) or inspiratory and expiratory muscle training (INEX) produces a greater increase in exercise endurance.

Statement of the Problem

During exercise, it is generally accepted that ventilation does not physiologically limit endurance in healthy humans, but studies have shown that the diaphragm fatigues while

exercising at a constant intensity of 80% of VO_{2max} or greater (Johnson, Babcock, Suman & Dempsey, 1993; Enright, Unnithan, Heward, Withnall & Davies, 2006). Respiratory muscles that have been fatigued have been shown to decrease exercise endurance (Johnson et al., 1993). During exercise, respiratory muscles have been shown to be a limiting factor for endurance. This makes it difficult for many individuals to maintain exercise intensity or reach their peak exercise intensity due to the metaboreflex. Respiratory muscle training has been shown to be safe and effective for improving exercise endurance, so it is important to know which type has the most significant effect (Spengler, Roos, Laube & Boutellier, 1999; Bailey et al., 2010; Enright et al., 2006; Kilding, Brown & McConnell, 2010; McConnell & Romer, 2004).

Purpose

The purpose of this study was to determine whether inspiratory muscle training, and inspiratory with expiratory muscle training will increase exercise endurance in non-active, non-sedentary individuals, and to determine which provides a greater improvement in exercise endurance.

Hypothesis

It was hypothesized that the inspiratory muscle training (IN) group and the inspiratory and expiratory training (INEX) group would see improvement in exercise endurance, but the group that trained both inspiratory and expiratory muscles would see the most significant improvement in exercise endurance after a 4-week training intervention, as measured by increase in duration of time spent cycling at 70% of the participant's maximum power output.

Delimitations

The study was delimited to the following:

1) The length of the training period was four weeks, as this was shown to be an adequate amount of time to elicit the desired training effect.

2) Participants were non-active and novice cyclists with less than 3 months experience of cycling for fitness.

3) "Elevation Training Mask 2.0" (Model Number: ETM2, UPC: 610373343330, Training Mask LLC) was used as the respiratory training device because of its ability to be used for all groups and its commercial availability.

Limitations

The study was limited by the following:

1) The number of training devices and cycle ergometers was limited and most participants were using the same exact respiratory muscle trainers and cycle ergometers after they were cleaned.

2) Constant-load sub-maximal cycling was used as a pre- and post-test measure of exercise endurance.

3) The training intervention required participants to utilize the training apparatus two times per day, 5 days per week, which was limiting because the participants had to be present at the training and testing facility ten times per week.

4) Participants utilized a commercially available respiratory muscle training device, the "Elevation Training Mask 2.0" (Model Number: ETM2, UPC: 610373343330, Training Mask LLC), which was not customized for each individual.

5) The study was conducted independently and could not be conducted as a double-blind study.

Assumptions

The following assumptions were made for this study:

1) All participants were not highly trained athletes, and at a similar fitness level when the study began.

2) All participants were able to follow the training protocol, and able to be tested on a cycle ergometer.

3) All participants put forth the same amount of effort and desire to complete the study.

4) Constant-load sub-maximal cycling on an ergometer was a valid test of exercise endurance for all participants.

5) Subjects adhered to pre-cycling instructions (i.e., Prior to all cycle ergometer tests the participant refrained from ingesting alcohol and caffeine for 24 hours, and refrain from exercise for 24 hours).

6) All participants cycled to exhaustion during the constant-load tests.

Definition of Terms

Constant-Load Test – An endurance test at a constant intensity that is measured by duration.

Dynamic breath – Rapid breathing and with maximal effort against the training load.

END – Steady-state of each participant before they reached exhaustion and the cool-down began.

Hyperpnea – Increased depth of breathing required to meet the metabolic demand of body tissue.

Metaboreflex – The accumulation of metabolites such as lactic acid in the respiratory muscles, which activates group three and four nerve afferents that trigger an increase in sympathetic outflow from the brain, causing vasoconstriction in the exercising limbs (Illi et al., 2012).

Non-Active Individual – A person who does not fit into the American College of Sports Medicine recommendations on quantity and quality of exercise for cardiorespiratory exercise, but is not sedentary.

ACSM Recommendations on Quantity and Quality of Exercise (2012) –

- Adults should get at least 150 minutes of moderate-intensity exercise per week.
- Exercise recommendations can be met through 30-60 minutes of moderate-intensity exercise (five days per week) or 20-60 minutes of vigorous-intensity exercise (three days per week).

- One continuous session and multiple shorter sessions (of at least 10 minutes) are both acceptable to accumulate desired amount of daily exercise.

- Gradual progression of exercise time, frequency and intensity is recommended for best adherence and least injury risk.

- People unable to meet these minimums can still benefit from some activity.

Respiratory Muscle Endurance Training- Training of the respiratory muscles that is performed without an external load, but instead uses normocapnic hyperpnea, which is essentially deep hyperventilation with a normal CO_2 level in arteries (Illi et al., 2012).

Respiratory Muscle Fatigue – A reduction in the ability for the respiratory muscles, i.e., the diaphragm, to forcefully contract as a result of excessive usage, that recovers with rest.*Respiratory Muscle Strength Training* – Training of the respiratory muscles that is performed by breathing against an external inspiratory and/or expiratory load (Illi et al., 2012).

Respiratory Muscle Training (RMT) – The strengthening of the respiratory muscles via respiratory muscle strength training or respiratory muscle endurance training. *Tidal Volume* – Normal volume of air displacement when no additional effort is used for respiration.

Significance of the Study

This study helps answer a current question about which method of respiratory muscle training provides significantly better results for exercise endurance. Currently, multiple studies have been conducted using respiratory muscle training, but many of the methods and procedures differed. This study compared two methods of RMT that are suggested to be the

most likely to produce the best improvements in exercise endurance, and used a method of testing endurance that currently is suggested to be the best in showing clear results (Illi et al., 2012). Many different populations (i.e., trained, untrained, elderly, Chronic Obstructive Pulmonary Disease (COPD) patients, etc.) could potentially benefit from the use of RMT and currently, several types of RMT devices are being created, innovated and made commercially available. It may be more practical for special populations to use a RMT device rather than walk on a treadmill or use a cycle ergometer depending on their physical limitations. This type of training is practical for athletes as well, as RMT devices are not currently prohibited by the NCAA or any professional athletic organization, and the same benefits have been shown in this population. A study such as may be beneficial, in that it might suggest a preferred training method to use by determining which method produces the greatest improvement in exercise endurance.

CHAPTER 2

REVIEW OF LITERATURE

Respiratory muscle fatigue has been shown to decrease endurance in healthy subjects (Romer, McConnell & Jones 2001; Markov, Spengler, Knöpfli-Lenzin, Steussi & Boutellier, 2001; Bailey et al., 2010). Because of a difficulty in maintaining high levels of ventilation, it has been established that this can be a limiting factor in achieving a maximal aerobic capacity (VO_{2max}) (Taylor & Romer, 2008; Enright & Unnithan 2011). Another physiological limiting factor of exercise endurance can be the metaboreflex, that is, nerves located in muscle parenchyma becoming activated by metabolites (such as lactic acid) accumulating in the muscle during contraction, which activates a series of responses that causes vasoconstriction in the limbs to evoke effects on the heart to increase cardiac output. The metaboreflex elicits major blood pressure elevating responses during exercise to redistribute blood flow and blood volume (Boushel, 2010). Because of the decreased blood flow in the exercising limbs, exercise endurance suffers due to a premature fatiguing of skeletal muscle, and can result in earlier exercise termination and earlier exercise testing termination (Illi et al., 2012).

Because respiratory muscle fatigue is detrimental to endurance, it would be beneficial to lessen the effects of fatigue. Respiratory muscles are plastic, and able to be trained against resistance/stress (McConnell & Romer, 2004). The changes that occur to respiratory muscles can be compared to other skeletal muscle changes after resistance training. Strength and endurance can be increased, and can be accomplished through respiratory muscle training (Bailey et al., 2004; Leddy et al., 2007). This is just one of the changes that can occur in

these plastic muscles. It has also been established that respiratory muscle training can enhance pulmonary O_2 uptake and high-intensity exercise tolerance (Bailey et al., 2010), reduce blood lactate concentration during hyperpnea, increase lung volumes and physical work capacity in people with chronic lung disease and healthy people (Taylor & Romer, 2008; Enright & Unnithan, 2011; Steussi et al., 2001; van't Hul, Gosselink & Kwakkel, 2003; Laoutaris et al., 2012) and increase exercise endurance in both trained and untrained people (Illi et al., 2012; Bailey et al., 2010; Griffiths and McConnell, 2007; Leddy et al., 2007; Markov et al., 2004; Perret, Spengler, Egger & Boutellier, 2001).

The studies conducted using RMT have been conducted with diverse training protocols, participant selection, group development and placement, and various types of training regimens (Illi et al., 2012). According to Illi et al. (2012), after examining and analyzing the currently available RMT studies, a closer look is needed at the effects of different RMT training regimens. Currently, there are many names used to describe the two basic types of RMT, which, according to Illi et al., are: respiratory muscle strength training (RMST), and respiratory muscle endurance training (RMET). Because so many different methods of RMT have been utilized for a variety of reasons, there has been much speculation as to whether one type of RMT is better than the other, and if so, which type of RMT is significantly better for improving exercise endurance. The various studies are very broad, but are useful to athletes, non-athletes and even rehabilitation specialists. It would be useful to explore the different types of RMT to see if either of them will provide an increase in exercise endurance, and useful to analyze both of them to see which, if either, would provide the most significant increase in exercise endurance.

Respiratory Muscle Training

Accounting for around 70% of ventilation in healthy adults, the diaphragm is the most important inspiratory muscle in humans (McConnell & Romer, 2004). The scalene and parasternal intercoastals, along with the sternocleidomastoids are the other inspiratory muscles. The rectus abdominus, external and internal obliques, transverse abdominus, and triangularis sterni are the expiratory muscles. These muscles are structurally similar to the other skeletal muscle in the human body, and have physiologically similar properties. In a healthy human, the diaphragm is reported to be comprised of about 50% type I muscle fibers and 50% type II muscle fibers (Farrell, Joyner, & Caiozzo, 2012). The plasticity of these muscles has also been well studied and documented. They are capable of improvement in strength and size (McConnell & Romer, 2004). All of these muscles are used during extreme bouts of exercise, and are susceptible to fatigue (Romer et al., 2001; Markov et al., 2001; Bailey et al., 2010).

Respiratory muscle fatigue can limit exercise endurance, but it is believed that respiratory muscles can be trained and that this training can enhance exercise endurance in healthy and unhealthy subjects (Bailey et al., 2010; Brown et al., 2008; Enright, Unnithan, Heward, Withnall, & Davies, 2006; Griffiths & McConnell, 2007; Illi et al., 2012; Kilding et al., 2010; Laoutaris et al., 2012). During prolonged or extreme exercise, respiratory muscle fatigue can partially impair the function of several, or all the respiratory muscles. The impairment can last for more than three days after the bout of extreme exercise has occurred. Even working at a workload of 80% of one's maximum workload can induce this fatigue (Spengler & Boutellier, 2000).

Because the diaphragm and abdominal muscles are likely to fatigue under maintained intensive exercise conditions, respiratory muscle training can help train the inspiratory and/or expiratory muscles to delay the onset of fatigue. Respiratory muscle training would help delay the onset of fatigue by strengthening the inspiratory and/or expiratory muscles, similar to the way a strength athlete or bodybuilder would train the larger skeletal muscles to improve strength or endurance in those. The attempt at delaying respiratory muscle fatigue is done with the hopes that endurance will be increased or high levels of intensive exercise will be maintained for longer bouts of time, due to the higher strength or endurance potential of the respiratory muscles; studies have shown that respiratory muscle fatigue has been at least partially attenuated by respiratory muscle training (Leddy et al., 2007; Markov et al., 2001; Perret, Spengler, Egger & Boutellier, 2000; Romer et al., 2001; Spengler & Boutellier, 2000; Steussi et al., 2001).

RMT is essentially, volitional respiration performed against a resisted inspiratory or expiratory load. There are many different names for RMT, but there are essentially two types, which, according to Illi et al., are: respiratory muscle strength training (RMST); which includes any resisted inspiratory or expiratory type of training, and respiratory muscle endurance training (RMET). RMST is also called inspiratory muscle [strength] training [IM(S)T], inspiratory [flow] resistive loading [I(F)RL], resistive/resistance respiratory muscle training [RRMT], concurrent inspiratory and expiratory muscle training [CRMT], or expiratory muscle training [EMT]. RMET is also referred to as ventilatory muscle training [VMT], voluntary isocapnic hyperpnea [VIH] or endurance respiratory muscle training [ERMT].

RMET and inspiratory muscle training (IMT), a form of partial RMT, have been shown to have similar effects on exercise endurance (Illi et al., 2012). One explanation for this, proposed by Illi et al. in 2012, is that similar improvements might be seen because IMT trains half of the respiratory muscles well, and RMET trains all of the respiratory muscles somewhat well; results would have the same net effect with respect to improved exercise endurance. Griffiths and McConnell (2007) also examined IMT and expiratory muscle training (EMT) and its effects on rowing performance and found that EMT alone offered no significant benefit over IMT. There appear to be two variations of RMT that can potentially be the most beneficial, i.e., IMT or respiratory muscle strength training of the inspiratory and expiratory muscles (INEX) (Griffiths & McConnell, 2007; Illi et al., 2012).

Benefits and Adaptations of Respiratory Muscle Training

Respiratory muscles have been shown to be both metabolically and structurally plastic and respond to the regular contractile activity associated with chronic physical training. The respiratory muscles have an ability to adapt and grow, similar to the other skeletal muscles in the human body; it seems logical to train them. There are multiple documentations of the plasticity of the respiratory muscles (McConnell & Romer 2004). Studies that have examined the effects of different types of RMT on lung function or exercise potential, have found a variety of results (Brown et al., 2008; Bailey et al., 2010).

The metaboreflex is the gathering of lactic acid and other metabolites in the respiratory muscles, which activates a series of responses which cause vasoconstriction in one's limbs. If the metaboreflex is attenuated, by reducing the lactate concentration in the diaphragm and other lung muscles, increased endurance can be seen (Brown et al., 2008; Illi

et al., 2012). Strengthening the respiratory muscles has been hypothesized to reduce blood lactate concentration during hyperpnea (Brown et al.; Spengler et al., 1999). It has been speculated that the reduction in blood lactate concentration during hyperpnea was probably caused by an improved lactate uptake by trained respiratory muscles, or less lactate production due to a reduced overall energy demand/cost of breathing (Spengler et al., 1999). This seems plausible, in that the metabolic costs of supporting respiratory muscle function during max exercise is up to 16% of cardiac output. If the respiratory muscles are working more efficiently however, or are using less of the total cardiac output for a longer duration, then more blood will be flowing to and from the legs for a longer duration, as the locomotor muscles normally receive about 80% of the cardiac output during exercise (Farrell et al., 2012). Because there would be more blood flow, more oxygen would be getting to the large quadriceps muscles due to the continued dilation of the blood vessels in the legs, and lactic acid production could be decreased. This may be another reason for the decreased lactic acid production after RMT. There are several assumptions as to why this occurs, but it is generally agreed upon and has been shown that RMT tends to decrease blood lactate concentration during exercise hyperpnea (Brown et al., 2008; Spengler et al., 1999).

Increased endurance times (cycling, rowing, and swimming) were observed after bouts of RMT, which is often observed to increase in studies using healthy trained and untrained subjects (Bailey et al., 2010; Griffiths & McConnell, 2007; Kilding et al., 2010; Leddy et al., 2007; Markov et al., 2001; Stuessi et al., 2001; Volianitis et al., 2000) and unhealthy subjects (Laoutaris et al., 2012; Scherer, Spengler, Owassapian, Imhof & Boutellier, 2000). Increases in maximum inspiratory pressure (MIP) (Bailey et al., 2010) and maximal voluntary ventilation (MVV) (Spengler et al., 1999) were also observed.

Researchers have conjectured why endurance was increased, and they have ruled out many different reasons, including hypoxic ventilatory response, which was shown to remain unchanged (Markov et al., 1996) and reduction in airway resistance that would decrease respiratory work and might delay fatigue, which, no reduction in resistance was found (Kohl, Koller, Brandenberger, Cardenas & Boutellier, 1997). Blood lactate concentrations were ruled out, as no shift in the balance of aerobic and anaerobic metabolism was found (Spengler et al., 1999). Increased venous return while breathing hard during RMT was also ruled out, as no increase in stroke volume and no decrease in heart rate after RMT was found (Spengler et al., 1998). After considering all of these variables, Stuessi et al. (2001) suggested that improvements in (cycling) endurance must be attributed to a mechanism other than an increase in the partial pressure of oxygen in arterial blood and its oxygen saturation. Furthermore, they go on to suggest a decrease in perceived exertion or decrease in respiratory fatigue to be possible reasons for the increased endurance performance.

Brown, Sharpe, and Johnson (2008) split 22 physically active males into an IMT training group and a control group, and used incremental cycling tests before and after the six weeks of intervention to primarily determine if blood lactate concentration was attenuated by the IMT. They found that the increase in lactate concentrations during hyperpnea was reduced following the 6 week training protocol, and concluded that the inspiratory muscles were the source of at least part of this reduction and they provide a possible explanation for some of the IMT-mediated reductions in blood lactate that are often observed during whole-body exercise.

IMT alone has been shown to increase baseline MIP, reduce inspiratory muscle fatigue (shown by a sustained MIP for a longer period of time) after severe (60% of the

difference between a graded exercise test and work rate) and maximal intensity (100% VO_{2max}) exercise, decrease the VO_2 slow component during lower intensity (<60%) steady state exercise, and enhance exercise tolerance (Bailey et al., 2010). They suggested that the results of their IMT study indicate that improved VO_2 dynamics probably caused the increased exercise tolerance and that it was presumed to be a consequence of increased blood flow to the exercising limb. This suggestion may mean a decrease in the metaboreflex, because there is less of an accumulation in lactate/metabolites due to less fatigue in the respiratory muscles. In other words, if constriction of the blood vessels in the extremities is prevented for a longer amount of time due to stronger respiratory muscles that do not accumulate lactate as fast, there will be an increased blood flow to the periphery, which increases exercise tolerance.

Respiratory Muscle Training and Its Effects on Exercise Endurance

Studies have been conducted with various forms of RMT and tested in different ways. It has been shown that constant-intensity cycling times have been increased in both sedentary (50%) and trained populations (38%) after RMT (Boutellier & Piwko 1992; Boutellier et al., 1992). Bailey et al. (2010) has shown that cycle ergometer tolerance was significantly increased after a four week RMT training program. Subjects were assessed after a four-week period of either IMT or a placebo intervention (control) on exercise tolerance (among other things) during moderate-, severe-, and maximal-intensity exercise. The maximum exercise tolerances were identified for the participants through various incremental exercise tests and step tests. After the intervention, a 39% improvement in exercise tolerance was observed in the IMT group during severe-intensity exercise (765 ± 249 s PRE vs. $1,061 \pm 304$ s Post; $p<.01$). No significant increase in the control group was discovered. Stuessi et al. (2001)

tested the effects of RMET on cycle ergometer performance on 13 sedentary participants, and among their results, found that cycling endurance was significantly increased at 70% of their maximum Watt producing ability (35.6 min (*SD* 11.9) PRE vs 44 min (*SD* 17.2) Post). The differences were that the RMET protocol was for 15 weeks, and they had a total of 40 training sessions. The pre and posttests were done with a 70% constant-load test, compared to several different levels of intensity (moderate-, severe-, and maximal intensity).

Similar studies, conducted by Spengler et al. (1999) utilized 20 healthy, athletic participants performing RMET for 20 sessions of 30 minutes each, over the course of 4 weeks. The goal of their study was to test blood lactate concentration after 4 weeks, and determine if the concentration was lower after the training. They also tested other variables pre and post-test, including exercise performance and endurance. They found that average endurance cycling times increased significantly from 20.9 (*SD* 5.5) min PRE, to 26.6 (*SD* 11.8) min post RMET.

Other endurance exercises, such as rowing, have also been shown to increase after IMT or EMT training protocols have been implemented in club level rowers (Griffiths & McConnell, 2007). They tested IMT and found that rowing endurance was enhanced after the conclusion of their intervention. The IMT group showed a 2.7% improvement in mean power after training (p = .002), and also improved their overall distance completed in a six minute all out effort test by .92% (16.2 m)(p = .002).

More recently, Leddy et al. (2007) studied the effects of isocapnic hyperpnea, a form of RMET that essentially utilizes dynamic hyperventilation to train the respiratory muscles, on competitive male runners. Fifteen competitive male runners were split into two groups, a

training group and control group. The training group performed voluntary isocapnic

hyperpnea (VIH) training 30 minutes per day over four weeks. The athletes were pre-tested

with endurance and time trial runs on a treadmill before the intervention began. They found

that the training group had significant increases in their respiratory endurance (+208%) and

treadmill run time (+50%) seven days after the VIH had stopped. The participants in the

training group were asked to do a continued maintenance of their VIH training for 3 more

months, twice weekly, while continuing their other training. After the maintenance phase, the

training group maintained their 4-mile run times.

Validity and Usage of Constant-Load Testing

Performance tests tend to fall into two main categories: those which allow for a work

drop-off (multiple intensity levels) and constant-load tests (Weltman & Regan, 1982).

Constant-load testing (CLT) is essentially a form of testing a subject to exhaustion at a fixed

intensity. In a 2012 meta-analysis of the effects of RMT on exercise performance, Illi et al.

found that CLT better showed improvements in performance after RMT, while being

compared to interval testing (IT) or time trials (TT). Their analyses showed that CLT also

helped find a more significant difference between groups, and a higher overall improvement

from control-training groups.

The reliability of constant-load testing on cycle ergometers as a method for

determining endurance performance has been established for several decades. Performance

time, pedal revolutions, metabolic measures, and heart rate can all reliably be found using

CLT (Weltman & Regan, 1982). They found that 85% of VO_{2max} could consistently be

reached by minute three of CLT, and between 89-93% from minute four and on. CLT on a

cycle ergometer has not only been shown reliable, safe and valid on healthy individuals, but also on patients with COPD. It was demonstrated that, with a workload of 75% of maximal work capacity, exercise endurance could reliably and validly be assessed in COPD patients (McKeough, Alison, Speers, & Bye, 2008); the patients with COPD were also retested and the results did not differ significantly ($p=.40$) (van't Hul et al., 2003).

In CLT, the participants are generally working at 70% or more of their VO_{2max}, or of their peak power in watts (W_{max}) (Stuessi et al., 2001; Perret et al., 2000; Markov et al., 2001). In order to determine VO_{2max}, incremental exercise tests (IT) are usually performed on a treadmill, cycle ergometer or by step test. To determine (W_{max}), a cycle ergometer IT can be done. Perret et al. (2000) used an incremental cycling test to exhaustion to determine W_{max} as well as VO_{2peak}. Participants began pedaling against 100W, and the load was increased by 30W every two minutes. The participants chose their preferred pedaling cadence, and they were asked to keep it constant after that. The highest load a participant could pedal against for at least 90 seconds was considered to be their W_{max}, and the highest VO_2 recorded over 15 seconds was determined to be their $VO_{2\ peak}$ (Perret et al., 2000).

Markov et al. (2001) performed similar IT testing to determine Wmax and VO_{2peak}. Participants began at 60W (female) and 80W (male), and the wattage was increased by 20, every 2 minutes until exhaustion. The highest workload sustained for 90 seconds was defined as W_{max}, and the highest VO_2 averaged over 30 seconds was defined as VO_{2peak}.

To determine a participant's maximum exercise endurance, the results from an IT can be used to conduct a CLT. Markov et al. (2001) had participants begin a cycling endurance test at 35% W_{max}, previously determined via IT, as a warm-up, and then began a CLT at 70%

W_{max}. Exhaustion was assumed when subjects volitionally stopped the test, or when pedaling rate dropped 10% below the target self-selected cadence.

Summary

Exercise endurance has been shown to be limited by fatigued respiratory muscles (Romer et al., 2001; Markov et al., 2001; Bailey et al., 2010; Taylor & Romer, 2008; Enright & Unnithan 2011). Respiratory muscles are plastic, and thus able to be trained because they can grow and adapt to external loads and stress (McConnell & Romer, 2004). Training has several benefits, including: increased exercise endurance and decreased blood lactate concentrations during exercise (Bailey et al., 2010; Brown et al., 2008; Griffiths et al., 2007; Kilding, Brown, & McConnell, 2010; Leddy et al., 2007; Markov et al., 2001; Spengler & Boutellier, 2000; Stuessi et al., 2001; Volianitis et al., 2000). Multiple studies have been conducted using the different types of RMT (RMET and RMET) and have shown that RMT will increase exercise endurance while running, rowing, cycling and more (Illi et al., 2012).

CLT has been shown to be a valid and reliable method of testing exercise endurance and has been used in multiple studies that attempt to look at exercise endurance before and after a training intervention. Research supports the use of CLT as one of the best testing protocols that can be used while attempting to discern a difference between RMT pre- and post-tests, as it has been suggested that CLT tends to best illustrate the improvements made in exercise endurance (Stuessi et al., 2001; Perret et al., 2000; Markov et al., 2001; Weltman & Regan 1982).

Increases in exercise endurance have been seen between pre- and post-tests after four weeks or more of RMT (Leddy et al., 2007; Stuessi et al., 2001). While several different

ways to train the respiratory muscles have been shown effective, the best option to train the

respiratory muscles to enhance exercise endurance is currently up for debate. Illi et al. (2012)

speculate that the greatest increases in exercise endurance will come from IMT or INEX, but

suggest that further study of IMT against INEX training is necessary to help settle this

debate.

CHAPTER 3

METHODS

Increases in exercise endurance have been seen between pre- and post-tests after four weeks or longer of RMT training interventions (Bailey et al., 2010, Leddy et al., 2007, Stuessi et al., 2001, Markov et al., 2001). Illi et al. (2012) speculates that the greatest increases in exercise endurance come from either IN or INEX. The purpose of this study is to determine whether IN and INEX will increase exercise endurance significantly, and to determine which of the two types of RMT significantly increases endurance while being compared to a placebo (PLA) group. It was hypothesized that after a four week training intervention, there will be a significant increase in exercise duration between the pre- and post-tests of the IN and INEX group from the PLA group, and also a significant difference between the IN and INEX group.

Participants

After approval from the institutional review board (IRB) (Appendix E), 34 non-active SUNY Cortland students with limited cycling experience were recruited via e-mail (Appendix B) to participate in a 4-week, 40 session training program designed to measure the effect of RMT on exercise endurance. These participants were college-aged and although they were classified as non-active by ACSM standards, they were also non-sedentary. Limited cycling experience was defined as no cycling experience, or less than three months of fitness cycling experience. Informed consent (Appendix A) was given following clearance from an ACSM risk classification form (Appendix C), an explanation of the procedures and risks, and subjects were cleared to participate using a standard health

questionnaire (PAR-Q) (Appendix D). Subjects were randomly assigned to one of three groups: an inspiratory muscle training (IN) group, an inspiratory with expiratory training group (INEX), and a placebo group (PLA). A random group generating website (Mehta & Swedberg, 2010) was used for placement.

Before training began, subjects underwent a testing session that was carried out within the week prior to the start of the training intervention. In this first session, lung function variables were measured according to the standard procedures of the American Thoracic Society (Miller et al., 2005; Spengler et al., 1999), and a graded exercise test (GXT) was conducted to determine their maximum power output and maximum cycling Vo_2. The lung functions assessed were: peak expiratory flow rate (PEF), which is a person's maximum speed of expiration; FEV_1, which is the amount of air a person can forcefully exhale in one second; and FVC, which is the total amount of air a person can exhale.

Two participants dropped from the study for personal reasons during the final week of training, and the data from three participants were excluded because they did not follow the pre-testing protocol. Table 1 represents the final participant demographics.

Table 1. *Final Participant Demographics*

Table of Participant Demographics

	Male (n=15)			Female (n=14)		
	M	SEM	Range	M	SEM	Range
Age(years)	21.60	0.14	18-26	21.79	0.29	19-34
Height(in)	70.27	0.21	65-78	64.71	0.16	62-69
Weight(lbs)	178.13	1.67	141-225	143.79	1.10	115-171
Estimated VO_{2max} ($mL \cdot kg^1 \cdot min^1$)	46.80	0.47	32.7-57.7	35.50	0.51	23.7-49.8

Constant-load Testing

Cycling was chosen as the pre- and post-testing method because other exercise modalities require the respiratory muscles to be used for more than just respiratory tasks. In rowing, the respiratory muscles need to combine the motion of the thorax expanding and contracting with the rowing stroke movement. In running, intra-abdominal pressure increases to protect spinal function and the diaphragm is activated additionally by the movements of the upper limbs. The respiratory muscles of the trunk also serve postural tasks while running. In swimming, the work of breathing is increased due to hydrostatic pressure the thorax must expand against. These modalities that require dual function of the respiratory muscles are more likely to cause respiratory muscle fatigue, and were ruled out as options (Illi et al., 2012).

Participants were instructed to refrain from ingesting alcohol or caffeine for 24 hours prior to any of their cycle usage, and were also instructed to refrain from exercise for the same time period. The initial test was conducted prior to pre-testing. Using a Monark Ergomedic 828 E cycle ergometer, participants began pedaling against 0.5 kp (150 kg·m/min, or ~25 W), and the load was increased by 0.5 kp when a steady-state heart rate was recorded. The participants pedaled at a cadence of 50 rpm, which was reported from a digital screen on the ergometer. To help the participants keep a constant cadence, a metronome was set to 100 beats per minute (bpm). Heart rates of the participants were recorded every minute of cycling using a Polar FT1 heart rate monitor, and were digitally displayed on the FT1 and Monark Ergomedic 828 E. Participants were considered to be at a steady-state heart rate when two consecutive heart rate readings were within five bpm of each other. The work rate (in kg·m/min) of the participants was noted throughout, as this was needed to determine their

max power output. The initial test concluded and cool-down began when two stages occurred where the participant's steady-state heart rates were above 110 bpm. The cool-down was a return to 0.5 kp for two minutes.

To determine 70% of a participant's maximum power output, the maximum power output was first determined. Using the initial data that were collected, VO_2 was estimated using the ACSM cycle ergometry equation:

$$VO_2 = [1.8 \text{ (work rate)} / \text{Body Mass}] + 7$$

Once VO_2 was estimated, maximum power was estimated using the equation:

$$\text{Maximum Power Output} = [(VO2 * \text{Body Mass})/1.8] -7$$

The result was then multiplied by 70% to determine what the constant-load would be for the pre- and post-tests for each participant.

The participants returned for their pre-test within one week of their initial test. The pre-test began with two minutes of resting data collection via gas analyzer. After two minutes, the participants were instructed to pedal at their own pace at 0.5 kp to begin their warm-up. Two minutes following the self-selected warm-up, the resistance was increased to half of the participant's constant-load (or 35% of their maximum power output) for two minutes at the cadence of the CLT to be acclimated (80 rpm). At the conclusion of these six minutes, the resistance was then increased to 70% maximum power output. A handheld stopwatch (Sportline Model 220) was started as soon as the resistance was dialed to 70%. At this point, heart rate was recorded and continued to be recorded every minute. The participants continued pedaling at 80 rpm and were motivated by the lead researcher to

maintain that pace. The digital display of the Monark Ergomedic 828 E projected the rpm, and a metronome was set to 160 bpm so that the participants also had an audio cue to pedal. Whenever the cadence dropped, the participants were motivated by the lead researcher. The test concluded when the participant said he/she could no longer continue pedaling or if the cadence dropped 10% (to 72rpm). At this time the stopwatch was stopped, and the resistance was dropped to 0.5 kp so the participants could cool down and their heart rates could lower. The gas analyzer remained on until the heart rate display read 135 bpm. The amount of time on the stopwatch was recorded as their endurance time. The same method was utilized for the post-testing. Figure 1 is a graphical representation of the CLT.
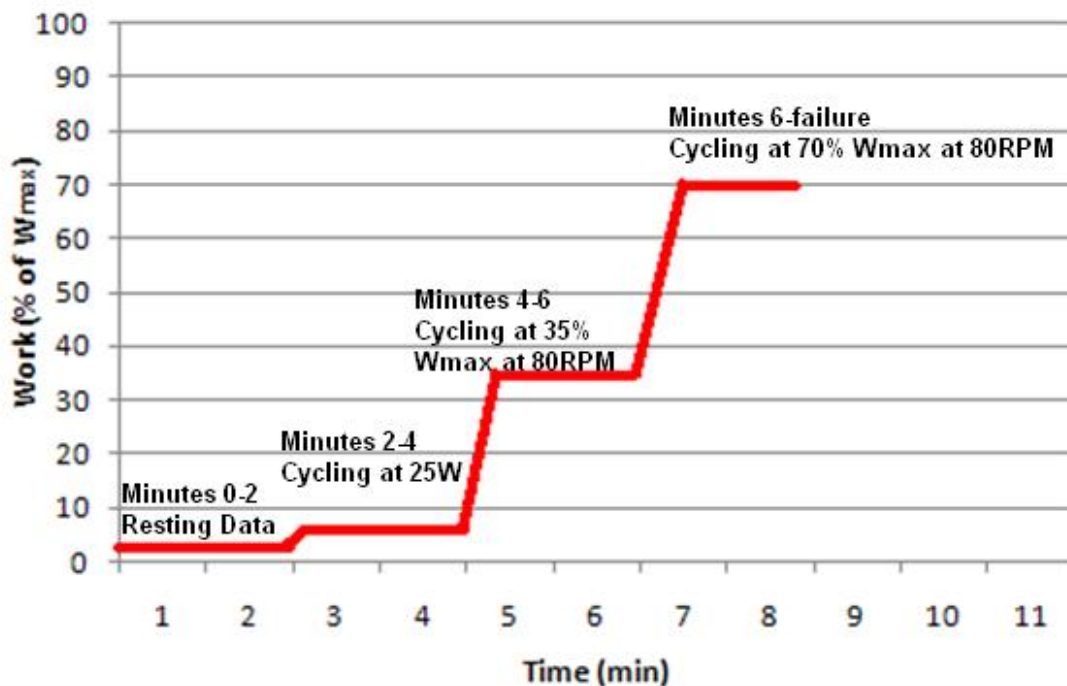

Figure 1. Graphical representation of CLT protocol

Training Sessions

The "Elevation Training Mask 2.0" is a commercially available respiratory muscle training apparatus (Training Mask LLC, Model Number: ETM2, UPC: 610373343330). It has gained popularity in the wrestling community and to date is not prohibited as a method of training for NCAA athletes. The development of the product is ongoing according to the information provided by the manufacturer's website. The device was selected for use in this study because it was easy to acquire due to its commercial availability. This mask is shown in figures 2 and 3.

All groups trained using the Elevation Training Mask 2.0. The IN group trained via forceful inhalation after regular expiration, 30 consecutive times. The INEX group trained via forceful inhalation, followed by forceful exhalation afterward. This was repeated consecutively, 30 times. Both of these training groups came twice per day, five days per week. The approximate time between each visit was 3-5 hours. The PLA group was instructed to come once per day to breathe 60 times through a mask at tidal volume (TV). All groups were instructed to take as many recovery breaths as necessary between each forced breath. The groups were all instructed to remove the mask in the unlikely event that they felt nauseated (Appendix F).

The IN group trained with two valves of inspiration, which had caps with two holes on them, and one cap of expiration with eight holes. This means that additional effort of the diaphragm was required for inspiration. The INEX group trained with two valves of inspiration that had caps with two holes on them, and one cap of expiration with four holes. This training utilized the same amount of holes for inspiration and expiration so that there

would be an equal amount of effort required for each phase of breathing. The PLA group trained with two valves of inspiration that had caps with eight holes on them, and one cap of expiration with four holes.

The IN group utilized a mask that had maximal resistance to inspiration (in-valve), and offered little or no (negligible) resistance during expiration (out-valve). The INEX group utilized the same MASK with a different configuration. The INEX group had maximal resistance occurring at both of their valves (in-valve and out-valve). The placebo group had caps with the maximum number of open holes (eight) over each one-way valve, so that there was negligible resistance during inspiration and expiration. The valves and caps are shown in figures 4 and 5, and the air flow for all groups is shown in figure 6.

Figure 2. Training mask (front) (Training Mask LLC, Model Number: ETM2, UPC: 610373343330) (Picture from www.trainingmask.com/)

Figure 3. Training mask (back) (Training Mask LLC, Model Number: ETM2, UPC: 610373343330) (Picture from www.trainingmask.com/)

Figure 4. Three one-way valves (Picture from www.trainingmask.com/)

Figure 5. Valve caps (Picture from www.trainingmask.com/)
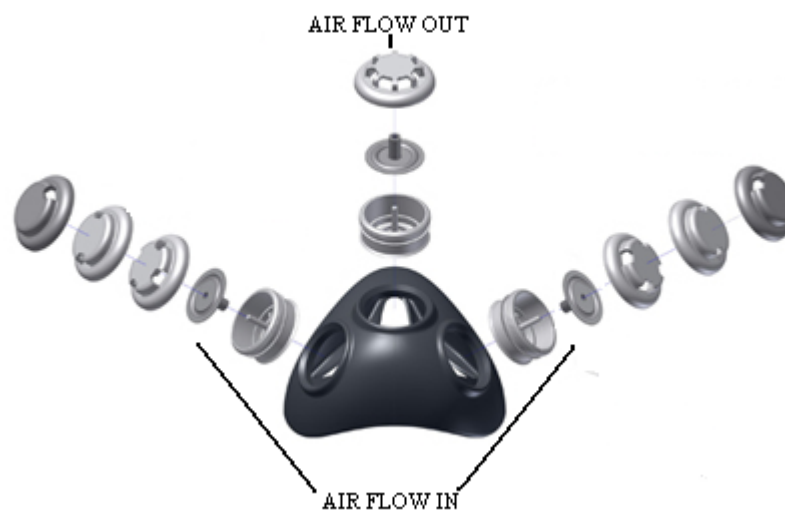
Figure 6. Air flow for all groups (Picture from www.trainingmask.com/)

A four-week training intervention was used for all groups, as this was the shortest duration utilized by others to significantly show the desired benefits (Bailey et al., 2010). Each subject was required to perform 1200 training breaths over a four-week period. The IMT and INEX groups completed 30 dynamic breaths, twice daily for a four-week period, and the placebo group completed 60 slow breaths once daily for four weeks, which has been shown to elicit negligible changes in inspiratory function (Griffiths &McConnell, 2007; Volianitis et al., 2000). These procedures have been shown to elicit the desired effects for the appropriate groups (Baily et al., 2010). Prior to each training session a script was read to individuals, depending on their group placement (see Appendix F.),

Analysis

SPSS 18 was used to run all data analyses and alpha was set at .05. A 3 (group) x 2 (test) mixed measures ANOVA was used to determine if there was a significant increase in exercise endurance in any of the groups, and to determine which group has the most significant increase. The pre- and post-test scores were compared for each of the three participant groups, and were then compared against each other to see which had the most significant increase. A Bonferroni post hoc test was utilized to compare the group effect to see which group had the most significant increase in exercise duration.

CHAPTER 4

RESULTS AND DISCUSSION

The purpose of this study was to determine whether inspiratory muscle training, and inspiratory and expiratory muscle training would increase exercise endurance in non-active, non-sedentary individuals, and to determine which provides improvement in exercise endurance compared to a control training group. It was hypothesized that the inspiratory muscle training (IN) group and the inspiratory and expiratory training (INEX) group would see improvement in exercise endurance, but the INEX group would see the most significant improvement in endurance after a 4-week training intervention, as measured by increased duration of time spent cycling at 70% of the participants maximum power output.

Results

Thirty-four SUNY Cortland students participated in the study. Two participants withdrew from the study due to personal reasons, and the remaining 32 completed the study. Prior to all cycle ergometer tests the participants were supposed to refrain from ingesting alcohol and caffeine for 24 hours, and were supposed to refrain from exercise for 24 hours. After post-testing, three participants informed the lead investigator that they had not followed the pre-testing protocol. They had all exercised the day of the post-test so their data were excluded and the following interpretation is based on the remaining 29 participants.

A mixed ANOVA was conducted to assess whether there were different exercise endurance pre- and post-test times within groups with three different RMT protocols, and between the three different groups. The following assumptions were tested: (a) independence of observations, (b) normality, and (c) sphericity. Box's test of the assumption of equality of

covariance matrices, which tests the null hypothesis that the variance-covariance matrices are the same in all three groups, was significant ($p = .001$), and therefore the assumption of homogeneity was not met. The covariance matrices were unequal. Results indicated a statistically significant interaction between pre- and post- tests, $F(1, 26) = 5.033$, $p = .034$, partial eta^2 = .162, but not overall between groups, $F(2, 26) = 1.066$, $p = .359$. The interaction showed that the INEX group significantly improved their CLT time. Group 1 (IN) showed a 28% increase in cycling time (pre-test = 300 s, SEM=20.9; post-test = 386 s, SEM = 30.6). Group 2 (INEX) showed a 75% increase in cycling time (pre-test = 212 s, SEM = 11; post-test = 371 s, SEM = 36.7). Group 3 (PLA) showed a 7% increase in cycling time (pre-test = 218 s, SEM = 16.6; post-test = 234 s, SEM = 19.3). Table 2 provides the means and standard error of the mean for average pre- and post-test times by groups, and Figure 7 graphically represents the interaction between average pre- and post-test times by groups. Inspection of the figure suggests that, while the IN and INEX groups both improved, the INEX group showing a larger improvement. Because Box's M was violated, these results must be viewed with caution.

Table 2.
Means and Standard Error of Means of the Pre- and Post-test times for RMT Groups

Group	Pre-test M (s)	Pre-test SEM (s)	Post-test M (s)	Post-test SEM (s)
IN	300.45	20.9	386.64	30.6
INEX	212.36	11.0	371.00*	36.7
Placebo	218.29	16.6	234.43	19.3

*The INEX Group's average endurance time after training was significantly greater than their pre-test time $p < .05$.
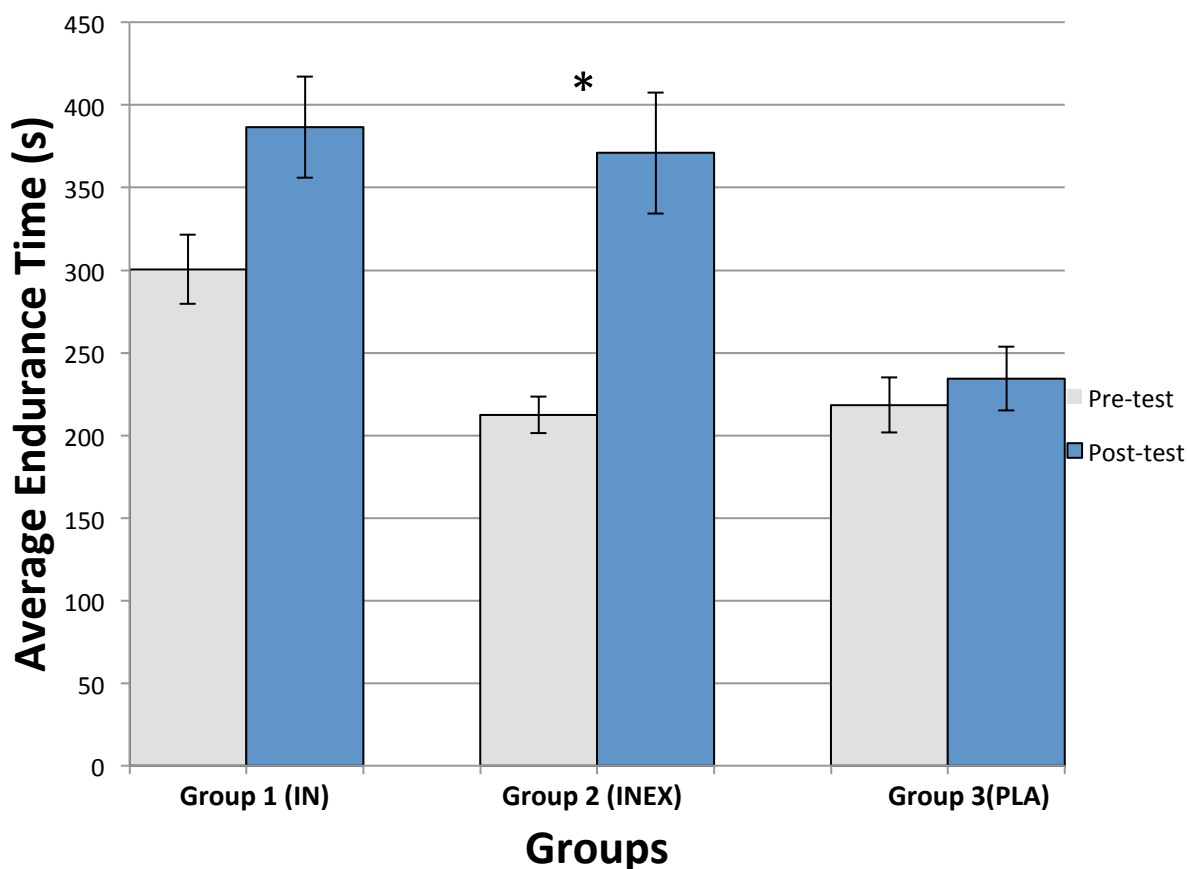
Figure 7. Column graph showing the effects of four weeks of RMT on average endurance time in seconds (s) during a constant-load cycle ergometer test at 70% of maximum power output, and the standard error of mean (SEM) for all averages.

*denotes statistically significant difference between pre- and post-tests (*p* = .034)

Along with pre- and post-test endurance time being recorded, ventilation and the oxygen cost of cycling was recorded, with heart rate (HR) taken every 60 seconds. Figure 8 is an example of one individual's pre- and post-test oxygen cost of cycling during the pre- and post-tests, plotted versus time. The participant sat on the cycle ergometer from minutes 0-2 and the gas of each expiration was analyzed. Following this rest period, the participant pedaled against a minimal load of 0.5 kp (~30 W pedaling at 60 rpm) for minutes 2-4, and from minutes 4-6 the participant pedaled against half of his working load (35% maximum

power output) at 80 rpm. The constant-load endurance test (70% maximum power output) started at minute 6 and continued until the participant achieved volitional exhaustion. Following exhaustion, the resistance was lowered to .5 kp and the participant was instructed to pedal at his own pace. This was halted when the participant's heart rate reached 135 beats per minute. Table 3 shows the average resting VO_2 and average endurance (END) VO_2 for the groups during the pre- and post-tests. These values were calculated by averaging the VO_2 during steady-state rest and steady-state exercise of the participants during peak performance. The END was the average VO_2 taken during the steady-state of each individual before they reached exhaustion and the cool-down began at the end of the cycling test.

It is unclear why the average VO_2 dropped for participants during post-testing, but an increased respiratory exchange ratio (RER = CO_2/O_2) value for all participants during the post-testing suggests that there may have been an error with the O_2 cell in the gas analyzer. O_2 cells have a certain lifespan and the cell from the analyzer used for this study seems to have been losing functionality, as seen by the drop in VO2 from pre- to post-testing (Table 3). After the conclusion of this study the gas analyzer was unable to be calibrated, which supports this conclusion.
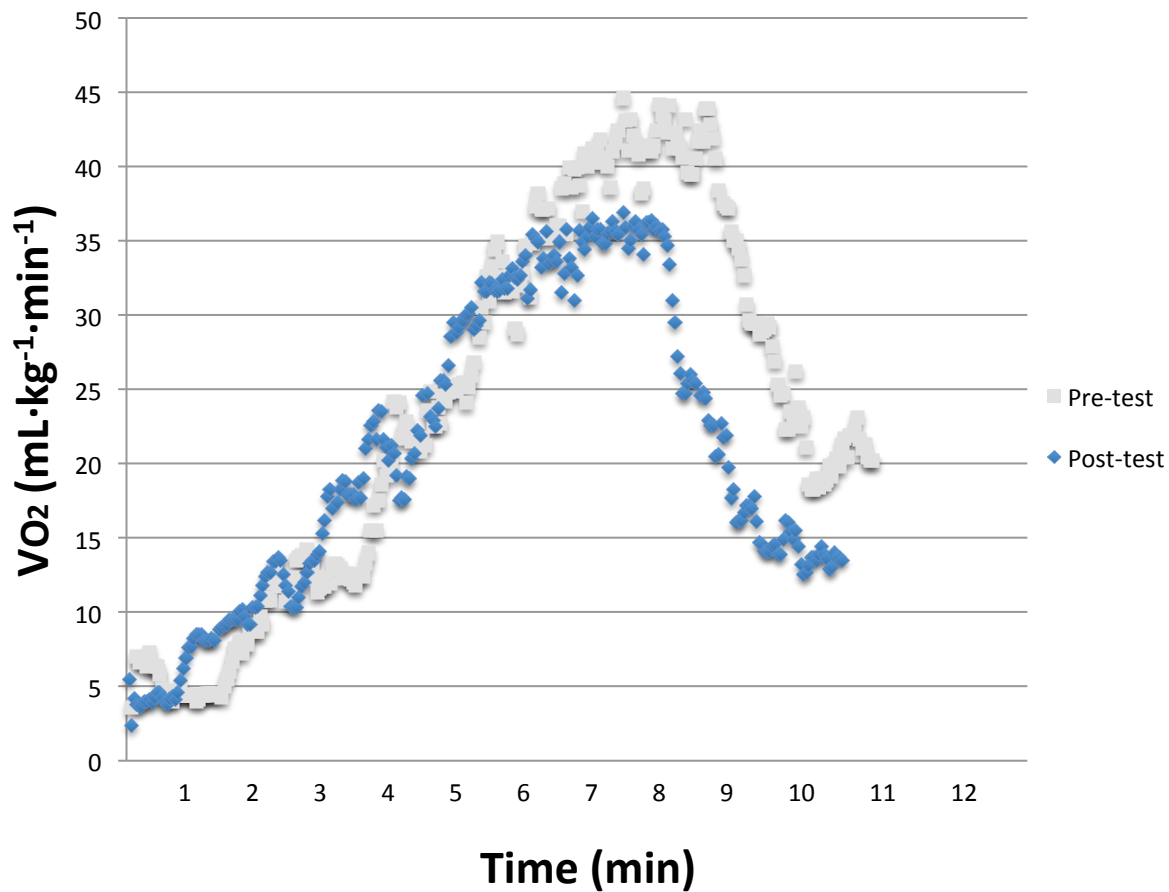
Figure 8. Scatter plot of a random participant's VO$_2$ (mL·kg^1·min^1) across each minute during pre- and post-testing.

Table 3. *Mean (mL·kg^1·min^1) of the Resting and END VO$_2$ During Pre- and Post-testing for RMT Groups*

	Pre-test Resting VO$_2$		Post-test Resting VO$_2$		Pre-test END VO$_2$		Post-test END VO$_2$	
Group	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
IN	5.20	0.47	4.64	0.42	38.27	3.48	29.42	2.67
INEX	5.07	0.46	4.85	0.44	37.79	3.44	27.80	2.53
PLA	5.14	0.73	4.74	0.68	38.03	5.43	28.61	4.09

A mixed ANOVA was conducted to assess whether there was a difference between the pre- and post-test HR averages within groups with three different RMT protocols, and between the three different groups. The following assumptions were tested and met: (a) independence of observations, (b) normality, and (c) sphericity. Results indicated no statistically significant interaction between pre- and post- tests, $F(1, 26) = 2.276$, $p = .143$, and no statistically significant interaction between groups, $F(2, 26) = 0.619$, $p = .546$. Table 4 shows the average HR during pre- and post-testing during rest and END steady-state oxygen consumption.

Table 4 *Mean (BPM) and SEM of the Resting and END HR During Pre- and Post-testing for RMT Groups*

	Pre-test		Post-test		Pre-test		Post-test	
Group	HR Rest	SEM	HR Rest	SEM	HR END	SEM	HR END	SEM
IN	70.64	1.20	70.64	0.75	175.18	1.60	171.36	1.22
INEX	70.18	0.90	71.82	0.85	173.82	1.50	173.91	0.92
PLA	68.71	1.45	70.57	1.56	173.43	3.00	173.29	3.13

The peak expiratory flow rate (PEF), is a person's maximum speed of expiration. FEV_1 is the amount of air a person can forcefully exhale in one second, while the forced vital capacity (FVC) is the total amount of air a person can exhale. These values are commonly recorded to test and monitor lung function, according to the American Thoracic Society (Miller et al., 2005). Pre- and post- training measurements were taken for all participants. The device used was the Micro Medical MicroLoop 3620, and was calibrated using a 3 L syringe. The syringe pushed a selected amount of air though the device; total volume recorded by the device was taken three times at 1 L, 2 L, and 3 L and averaged together. At each volume, the device recorded +0.04 L on average (i.e., on average, 1 L of air from the syringe was reported as 1.04 L by the device). A mixed ANOVA was conducted to assess whether there were differences between pre- and post-test PEF, FEV_1, and FVC volumes

within groups with three different RMT protocols, and between the three different groups. The following assumptions were tested and met: (a) independence of observations, (b) normality, and (c) sphericity. Results indicated: no statistically significant interaction between pre- and post- test volumes of PEF, $F(1, 21) = 2.182$, $p > .05$, and no between groups, $F(2, 21) = 2.552$, $p > .05$; a statistically significant interaction between pre- and post-test volumes of FEV_1, $F(1,26) = 11.532$, $p = .002$, partial $eta^2 = .307$, and no significant interaction between groups, $F(2,26) = .137$, $p > .05$; a statistically significant interaction between pre- and post-test volumes of FVC, $F(1,26) = 13.872$, $p = .001$, partial $eta^2 = .348$, and no significant interaction between groups, $F(2,26) = .388$, $p > .05$, partial $eta^2 = .029$. Figures 9, 10, and 11 illustrate the average ventilation pre- and post-training.

In Figure 9, group 1 (IN) showed an increase in FEV_1 (pre-test = 3.48 L, SEM=0.09; post-test = 3.69 L, SEM = 0.09). Group 2 (INEX) showed an increase in FEV_1 (pre-test = 3.66 L, SEM = 0.06; post-test = 3.82 L, SEM = 0.05). Group 3 (PLA) showed an increase in FEV_1 (pre-test = 3.78 L, SEM = 0.09; post-test = 4.06 L, SEM = 0.13). A mixed ANOVA revealed a significant interaction between pre- and post-test volumes ($p = .002$) but no significant difference between the groups ($p > .05$).

In Figure 10, Group 1 (IN) showed an increase in FVC (pre-test = 3.60 L, SEM=0.09; post-test = 3.91 L, SEM = 0.11). Group 2 (INEX) showed an increase in FVC (pre-test = 3.88 L, SEM = 0.078; post-test = 4.16 L, SEM = 0.07). Group 3 (PLA) showed an increase in FVC (pre-test = 3.92 L, SEM = 0.11; post-test = 4.3 L, SEM = 0.13). A mixed ANOVA revealed a significant interaction between pre- and post-test volumes ($p = .001$) but no significant difference between the groups ($p > .05$).

In Figure 11, Group 1 (IN) showed an increase in PEF (pre-test = 493 L/min, SEM=14.4; post-test = 514 L/min, SEM = 10.0). Group 2 (INEX) showed an increase in PEF (pre-test = 475.1 L/min, SEM = 11.7; post-test = 543 L/min, SEM = 0.07). Group 3 (PLA) showed a decrease in PEF (pre-test = 533 L/min, SEM = 14.2; post-test = 513 L/min, SEM = 14.5). A mixed ANOVA revealed no significant interaction between pre- and post-test volumes ($p > .05$) and no significant difference between the groups ($p > .05$).
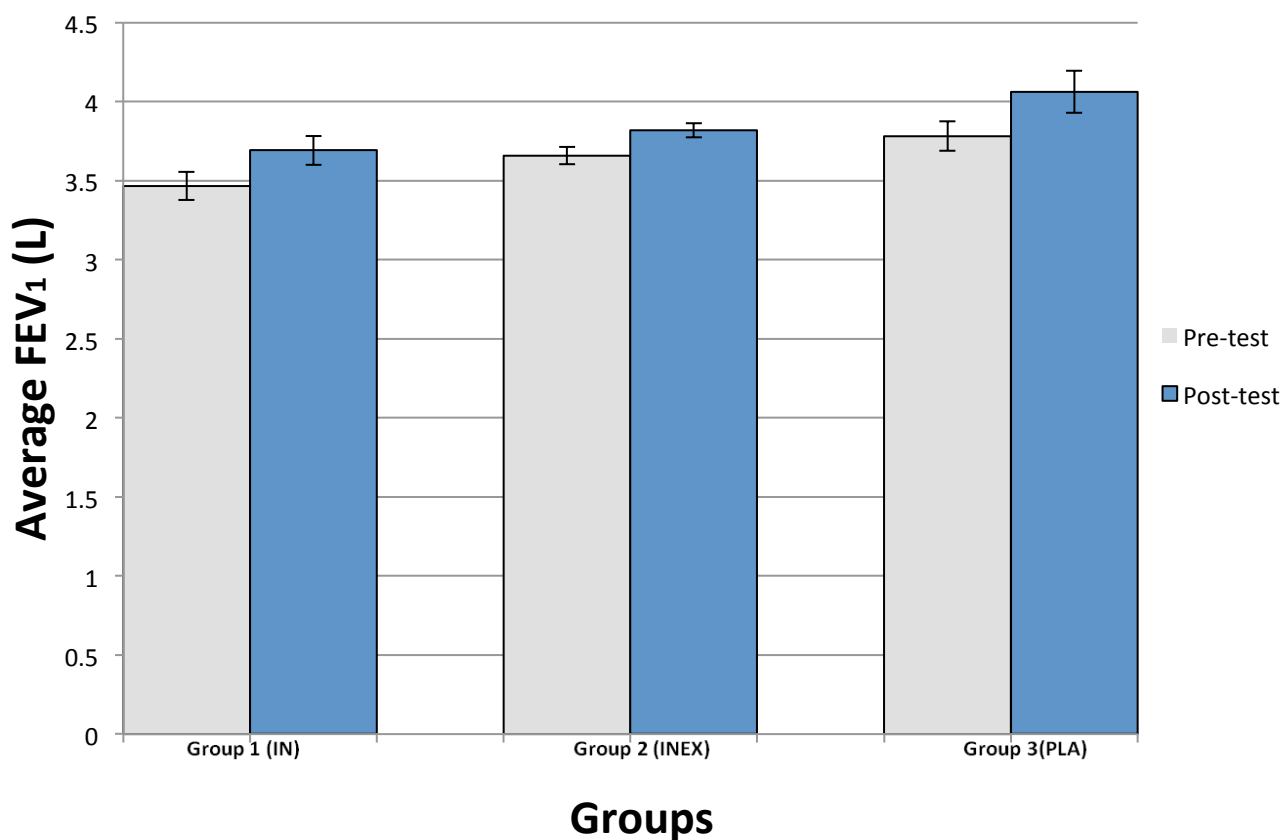
Figure 9. Column graph showing the effects of four weeks of RMT on average FEV_1 (L) before a constant-load cycle ergometer test at 70% of maximum power output, and the standard error of mean (SEM) for all averages.

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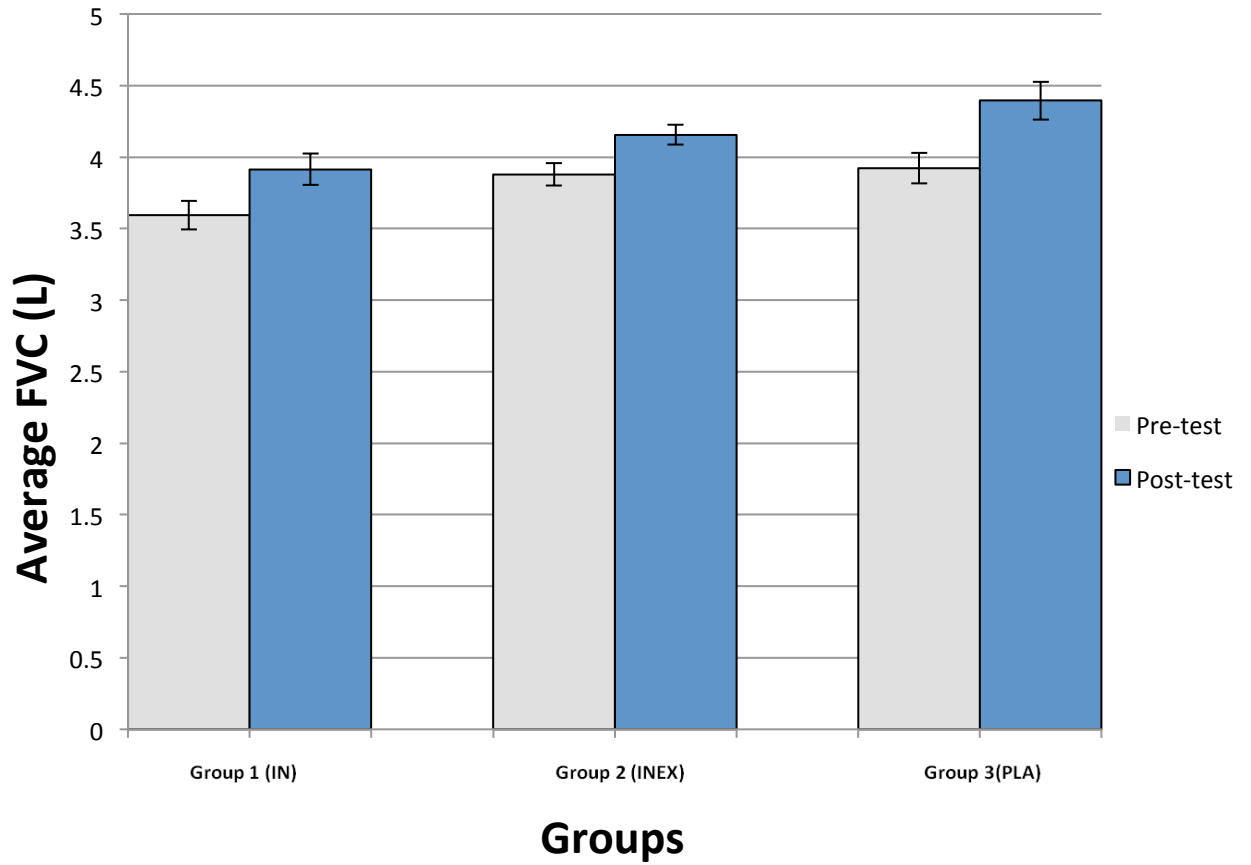
Figure 10. Column graph showing the effects of four weeks of RMT on average FVC (L) before a constant-load cycle ergometer test at 70% of maximum power output, and the standard error of mean (SEM) for all averages.

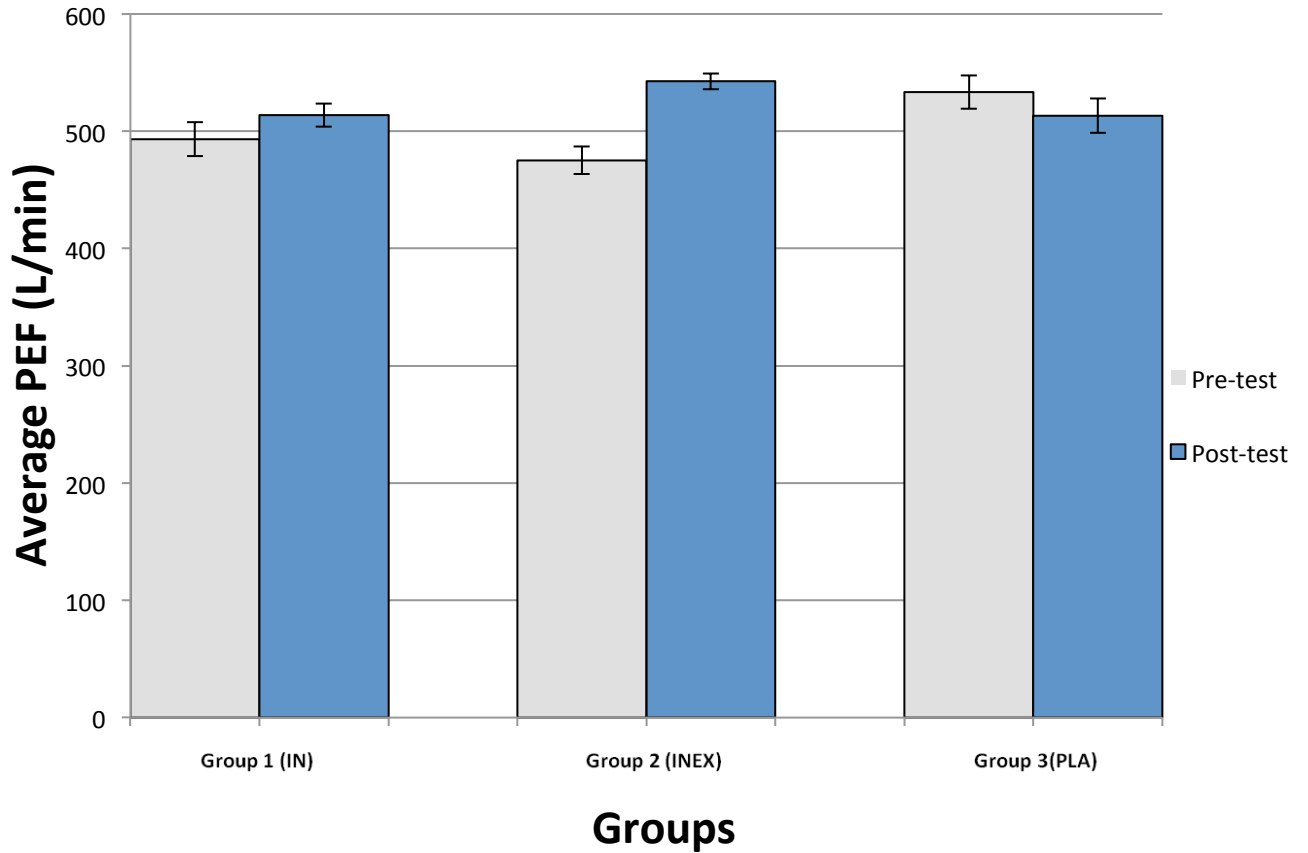*Figure 11*. Column graph showing the effects of four weeks of RMT on average PEF (L/min) before a constant-load cycle ergometer test at 70% of maximum power output, and the standard error of mean (SEM) for all averages.

The oxygen analyzer recorded the end-tidal tensions of oxygen ($PETO_2$) and carbon dioxide ($PETCO_2$) as well as oxygen consumption (VO_2) and carbon dioxide production (VCO_2). These values were obtained by sampling the end of each exhalation so that the O_2 and CO_2 measured at the end of each breath reflected alveolar O_2 and CO_2. (Wasserman, Hansen, Sue, Whipp & Casaburi, 1994). Tables 5 and 6 shows the average partial pressures of the end-tidal O_2 and CO_2 for all three groups, and the SEM.

Discussion

The result of a four-week RMT protocol on cycling time at 70% of maximum power output was a 29% increase in the IN group, a 75% increase in the INEX group, and a 7% increase in the end cycling time of the PLA group. The placebo group saw a minor increase, as they were training with a mask as well as the IN and INEX group. The difference was that the PLA group was only required to attend one training session per day, and breathed 60 times through the RMT mask at tidal volume (TV), which is the normal volume of air displacement when no additional effort is used for respiration. The large improvement of the INEX group supports the original hypothesis that the group would increase in duration of exercise endurance, but because Box's M was violated, statistically, the results are viewed as suspect. Box's M tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups. The reasons for the violation could be that the groups were uneven, or that the sample size was too small. Because of the suspect results, the second hypothesis of a statistically significant increase of the INEX group over the IN group cannot be supported, but the large percent improvement between pre- and post-test cycling time of the INEX group warrants further study of the topic.

Oxygen consumption, heart rate and ventilation were recorded in addition to cycling time, for the pre- and post-test. Non-significant FEV1, FVC and PEF increases were shown on average for the IN and INEX groups after the four-week RMT protocol, while no significant improvements in FEV1 and FVC were shown on average in the placebo group along with a decreased average PEF. No significant differences were found when comparing pre- and post-test average HR averages during resting states and END states of the cycling tests. This physiological occurrence is expected, due to the participants cycling at the same workload (70% of max power output, which was determined prior to the pre-test) during pre- and post-tests. The average partial pressure of the end-tidal O_2 and CO_2 for all three groups was also collected and examined. This is the measure of the amount of O_2 and CO_2 present in the exhaled air. No apparent differences were noted while examining the data. Lastly, there seemed to be a large drop in the average VO_2 of all participants between the pre- and post-tests. The exact reason for the drop in VO_2 is unclear, but it can be speculated that there was an error with the calibration of the O_2/CO_2 gas analyzer, as the cycle ergometer was calibrated using 1, 2, and 3 kg weights, the HR averages were similar, and the cycling time improved between all groups. O_2 cells have a certain lifespan and the cell from the analyzer used for this study seems to have been losing functionality, as seen by the drop in VO2 from pre- to post-testing (Table 3). After the conclusion of this study the gas analyzer was unable to be calibrated, which supports this conclusion.

According to Illi et al. (2012), only six studies have been published that compare the benefits of INEX and IN forms of RMT, and these studies suggest that INEX training will be superior in improving exercise endurance. The statistically significant results between pre- and post-testing and 75% improvement in exercise duration by the INEX group of this study

supports that suggestion, but due to a significant Box's M the results must be viewed as suspect. If there were the same number of participants across all groups, the likelihood of this occurrence would be reduced.

Illi et al. (2012) also suggested that changes in endurance performance would be easily detectable using a constant-load test (CLT), and this was supported. This continues to be the preferable method of testing endurance performance, rather than a regular incremental test such as a graded exercise test to VO_{2max}. An issue with CLT is that psychological factors such as motivation or boredom may play a role in determining the point of exhaustion (Jeukendrup et al. 1996). One might question whether the participants of this study were cycling to complete failure, but the physiological data presented in Table 4 illustrates a similar average heart rate between pre- and post-testing. Figure 8 also supports this, as a clear steady-state at the END is present.

In this study, the oxygen cost of cycling at a constant-load was measured, and the results show that VO_2 decreased in all groups between pre- and post-testing. This is an odd occurrence. Illi et al. (2012) reviewed of 22 studies that assessed VO_2 before and after RMT, and 20 of these articles mentioned no change in VO_2 took place, one article mentioned an increase (Leddy et al. 2007), and one article mentioned a decrease in VO_2 (Verges et al. 2008).

There were no apparent differences between average heart rate during rest and during END, while compared before and after training (see Table 4). This was not expected, as the majority of the participants seemed to initially have lowered heart rates during the post-test. Gething, Passfield and Davies (2004) reported a significant decrease in heart rate ($p = 0.02$)

after six weeks of RMT, but it was only in the maximum RMT training group that trained at 100% of maximum inspiratory pressure (MIP) three days per week. They reported no significant differences in the heart rates in their other groups. Had the participants of the IN and INEX groups been training at higher intensities (close to 100% of MIP), they might have seen significant decreases in heart rate.

Enright and Unnithan (2011) attempted to evaluate the impact of IMT (the method of training performed by the IN group) at varying intensities (80%, 60%, and 40% MIP) on FVC and several other variables. The findings were that the maximum training group, which trained at 80% MIP, was the only group to show improvement in FVC. In the current study, FVC did not noticeably increase in any group. One reason for this could be that the intensity was not high enough to produce this result, but due to the limitations of the training apparatus, it is not possible to determine the training intensities for each individual with precision. Enright et al. (2006) also showed improvements in total lung capacity and FVC in participants who were training for eight weeks at 80% of their maximal inspiratory effort.

$PETO_2$ and $PETCO_2$ are variables that were not specifically mentioned in other studies. These variables are easily recorded along with oxygen consumption, as the gas analyzer determines the pressures after every exhalation. Several participants exhibited increased end-tidal CO_2 concentrations and decreased end-tidal O_2 concentrations. This means that they were exhaling more CO_2 from the alveoli and less O_2 during the post-test, as this is what $PETO_2$ and $PETCO_2$ are measures of. Further study is necessary to determine if RMT increases oxygen utilization at the alveoli.

CHAPTER 5

SUMMARY, FINDINGS, CONCLUSIONS, IMPLICATIONS AND

RECOMMENDATIONS

Summary

The purpose of this study was to determine which method of RMT could produce the greatest increase in exercise endurance during a constant-load cycle ergometer test. Constant-load cycling time at 70% of each participant's maximum power output was recorded before and after a four-week RMT protocol of either inspiratory muscle training (IN), inspiratory with expiratory (INEX), or placebo training (PLA). Oxygen consumption, heart rate (HR), $PETO_2$ and $PETCO_2$ were recorded during the pre- and post-testing, while ventilation (FEV1, PEF and FVC) was recorded prior to each constant-load test. It was hypothesized 1) that the IN and INEX groups would see a significant increase in cycling times compared to the PLA group, and 2) that the INEX group would see a significant cycling time improvement compared to the IN group.

All groups trained using the Elevation Training Mask 2.0. The IN group trained via forceful inhalation after regular expiration, 30 consecutive times. The INEX group trained via forceful inhalation, followed by forceful exhalation afterward. This was repeated consecutively, 30 times. Both of these training groups came twice per day, five days per week. The approximate time between each visit was 3-5 hours. The PLA group was instructed to come once per day to breathe 60 times through a mask at tidal volume (TV). All groups were instructed to take as many recovery breaths as necessary between each forced breath. The groups were all instructed to remove the mask in the unlikely event that they felt

nauseated. The IN group trained with two valves of inspiration, which had caps with two holes on them, and one cap of expiration with eight holes. This means that additional effort of the diaphragm was required for inspiration. The INEX group trained with two valves of inspiration that had caps with two holes on them, and one cap of expiration with four holes. This training utilized the same amount of holes for inspiration and expiration so that there would be an equal amount of effort required for each phase of breathing. The PLA group trained with two valves of inspiration that had caps with eight holes on them, and one cap of expiration with four holes.

Statistical analysis revealed that there was a significant interaction between pre- and post-tests ($p = .034$). Further analysis revealed that this training protocol yielded significant improvements in the INEX groups constant-load cycling endurance time, but this improvement must be viewed as suspect due to a significant Box's M ($p = .001$). This significance is likely due to uneven groups, or a sample size that was too small. No other measures produced significance from pre- to post-testing.

A mixed ANOVA revealed a significant interaction between pre- and post-test volumes of FEV_1 ($p = .002$) with no significant difference between the groups ($p > .05$), and a significant interaction between pre- and post-test volumes of FVC ($p = .001$) but no significant difference between the groups ($p > .05$). No additional statistical significance was recorded.

Findings

This study found increases in exercise endurance of 28% in the IN group (pre-test = 300 s, SEM=20.9; post-test = 386 s, SEM = 30.6), 7% in the PLA group (pre-test = 218 s,

SEM = 16.6; post-test = 234 s, SEM = 19.3), and of 75% in the INEX group (pre-test = 212 s, SEM = 11; post-test = 371 s, SEM = 36.7), which was statistically significant (p = .034). Resting and END heart rates are similar between pre- and post-testing. The oxygen consumption from pre- to post-testing appears to have decreased by 30%, but the cause of this is likely an O_2 cell at the end of its lifespan. FEV_1 and post-tests are statistically different from pre-tests (p = .002), but no group differences were noted. FVC and post-tests are statistically different from pre-tests (p = .001), but no group differences were noted. No statistically significant differences were found between pre- and post-testing for PEF.

Conclusions

The results from this study support the conclusions of previous studies which showed that RMT can increase exercise endurance in healthy (non-active, non-sedentary) populations. There was a 75% increase in constant-load endurance time in the INEX group. Due to a Box's M violation, the results must be viewed with caution however. Regardless, a 75% increase in constant-load cycling time of the INEX group from pre- to post-testing compared to a 28% improvement of the IN group suggests that INEX is viable better method of improving endurance time in an average college population. Future research should be conducted with larger, even groups and with different populations.

Implications and Recommendations

The results of this study suggest that there may be an advantage to using INEX as the primary method of RMT if an increase in exercise duration is the objective. This is unfortunately statistically unsupported, but can likely be fixed in future studies by having larger groups with an equal number of participants between them. Future studies need not

utilize a PLA group, as various studies have shown that PLA and other control groups have not shown any improvements after RMT (Illi et al. 2012).

Because RMT has been shown to offer the benefit of increased exercise endurance, the best method of training the respiratory muscles is pertinent information for several different populations; specifically, sedentary populations. Utilizing RMT, a sedentary person could increase their capacity for exercise before they begin any physical training. This method of training would provide physiological improvements without the risk of any physical harm/discomfort that may come from improper or forced physical activity.

Along with sedentary populations, non-active populations can also benefit in the same way. RMT is a safe way to begin any exercise program by getting the body ready for physical activity prior to the act, as the only requirement is for an individual to sit down and forcefully breathe. RMT at higher resistance has been shown to decrease heart rate, which has been correlated to rating of perceived exertion (Gething, Passfield & Davies, 2004; Chen, Fan & Moe, 2002). Because of this physiological drop in exercising heart rate, a psychological change tends to occur which changes an individual's perception of a physical activity. This psychological advantage can also be one of the reasons constant-load cycling time increases.

All participants were asked if they felt any discomfort after, volitional exhaustion occurred, the CLT was stopped, and the cool-down began. The majority of the participants in the IN and INEX groups took this opportunity to mention that they did not feel any discomfort, and felt that they were able to continue cycling. These participants stated that the reason for exhaustion was due to fatigue of the legs, but not of the respiratory muscles.

Many of these same participants said that the post-test seemed easier than the pre-test. This qualitative information has implications for future studies. Rating of perceived exertion (RPE) is not often recorded in RMT studies, but has been done previously (Bailey et al., 2010; Fontes et al., 2010). These studies mention that RPE has been shown to decrease at higher RMT intensities. Along with the physiological variables which are often recorded, psychological analysis is possible via qualitative data recording and different types of RPE recording (i.e., session RPE recorded after each training session and minute RPE).

Wuestenfeld & Wolfarth (2012) discuss exercise-induced asthma (EIA) and its prevalence in children. They mention that EIA is found in 8-10% of healthy school-aged children and 35% of children with asthma, and that FEV_1 has been shown to drop by 8.8% while exercising at 85% of VO_{2max} and 25% while exercising at 95% of VO_{2max}. This drop in FEV_1 is due to bronchoconstriction. With constricted bronchioles, the respiratory muscles have to work harder to force out used air. Utilizing INEX, a person experiencing EIA would be able to force out used air with less distress, as the expiratory muscles would be strengthened and FEV_1 increased.

Future research that is not conducted independently can be improved by utilizing a double-blind method. In this situation, one researcher would be responsible for group randomization and training, while the other would be responsible for collecting the data during the pre- and post-testing. Using this method, the researcher who is collecting the pre- and post-test data would be less biased to see certain participants perform better on the CLT.

Currently, RMT is not prohibited in college athletics. Specific training of the respiratory muscles is not a common occurrence, however. Athletes would benefit from RMT

because the respiratory muscles are normally only trained indirectly via cardiovascular training. The Elevation Training Mask 2.0 is an available device that can be utilized for RMT. As it is one of the more affordable RMT devices, the resistance is not fully customizable for each person utilizing the device. More expensive RMT devices are more customizable, but are only useful in a lab setting. The Elevation Training Mask 2.0 is unique, in that it can be utilized in applied settings as well as lab settings. The type of RMT device used should be taken into account for future research, as well as the desired environment.

The mechanism for increased endurance time after RMT is unknown (Griffiths & McConnell, 2007; Romer et al., 2001). It has been speculated that the reasons may be: increased tidal volume, decreased proportion of the maximum force capacity required for each breath, improved efficiency of breathing due to reduced chest wall distortion, lower work of breathing and reduced metabolic and blood flow demand by the inspiratory muscles, or a decreased perception of inspiratory muscle effort (Volianitis et al., 2000; Romer et al., 2001). Additional research should be conducted on physiological variables in an attempt to determine why exercise endurance can be increased so drastically by RMT alone.

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APPENDIX A.

Informed Consent

State University of New York at Cortland
<u>Informed Consent</u>

        You have been invited to participate in a research project conducted by graduate student Justin Vanderbeck of the Kinesiology Department at SUNY Cortland. The researcher requests your informed consent to be a participant in the project described below. The purpose of the project is to examine the effect of two types of respiratory muscle training on exercise endurance. Please feel free to ask about the project, its procedures, or objectives.

        If you agree to participate, you will be asked to attend 20-40 training sessions over a 4-week span. Each session will contain 30-60 fast or slow breaths through a respiratory muscle training mask. The lead researcher will assist you in securing the mask. All subjects will also be asked to perform a graded exercise test (a test which slowly increases in difficulty) on a cycle ergometer (stationary bike) at the beginning of the study, and then will be asked to perform a constant-load endurance test at 70% of their maximum power output before the training sessions and after the training sessions to measure the effectiveness of the training protocols on enhancement of exercise endurance. The opportunity to participate in this study will be made available to approximately 45 people from SUNY Cortland.

        The risks associated with your participation in this study are minimal as they are similar to those that hospital patients use when leaving an extended hospital stay. Only the researcher will have access to your results and these will be stored on a flash drive. This flash drive and all other data will be stored in a locked cabinet in the lead researcher's office for no more than 3 years, upon which all files will be deleted. At no time will your name be associated with the data or results. Only group aggregate scores will be reported. Benefits of this study include, but are not limited to: the reduction of fatigue during exercise, increased ability for exercise duration, increased lung function, and lowered blood lactate concentration (which could also help increase the ability of exercise duration).

        You are free to withdraw consent at any time without penalty. Additionally, at any time, you may ask the researcher to destroy any other data or information collected.

        If you have any questions concerning the purpose or results of this study, you may contact Justin Vanderbeck at (631) 946-3926 or at justin.vanderbeck@cortland.edu. Other contacts include: Dr. James Hokanson, Professor of Kinesiology at (607) 753-4964 or james.hokanson@cortland.edu. For questions about research at SUNY Cortland or questions/concerns about participant rights and welfare, you may contact the IRB Chair Jena Curtis, PO Box 2000, Cortland, NY, 13045 (phone (607) 753-2511 or email Jena.Curtis@cortland.edu). In the event of an injury please contact the SUNY Cortland Health Center in room B-26 of Van Hoesen Hall at (607) 753-4811.

I (print name) **_____ have read the description of the project for which this consent is requested, understand my rights, and I hereby consent to participate in this study.**

Signature: _____   Date: _____

APPENDIX B.

Solicitation E-mail

From: Justin Vanderbeck

Subject: Recruiting students for respiratory muscle training research.

SUNY Cortland students:

I am a graduate student studying exercise science in the kinesiology department and am currently researching respiratory muscle training. I am looking for 45 students to take part in a training study that will offer the chance to receive compensation based on your participation. Some benefits of respiratory muscle training include, but are not limited to: lessened respiratory muscle fatigue during exercise, an increased capacity for exercise duration, lowered blood lactate concentrations during exercise, and increased lung function.

Your participation in the study should last for six weeks. There will be a four week training period, and a week before and after for pre- and post-testing.

If you are not on an athletic team, do not have a major health issue and are not currently primarily training for cardiorespiratory fitness, you are encouraged to take part in this study.

The training protocol during the four weeks will require you to visit the lab one or two times per day, Monday through Friday. You will only be in the lab for five to ten minutes per training session.

Along with the health benefits listed above, if you have at least 95% adherence to the training protocol and have completed pre- and post-tests, your name will be entered into a random drawing and you can receive up to $100. One person will receive $100, and two people will receive $50.

Your total involvement will last a minimum of 320 minutes over six weeks.

If you are interested in participating in this study, please e-mail me with your name, phone number, e-mail address, and the best time to reach you. You will then be contacted to set up a day for orientation to the study.

Only people directly involved with this project will have access to your information.

There will be no future mass e-mails regarding this subject, unless you have agreed to participate.

Thank you for taking the time to assist me in this research.

    Justin Vanderbeck

    1-607-753-4793

    Justin.Vanderbeck@Cortland.edu

APPENDIX C.

ACSM Risk Factor Checklist

ACSM Coronary Artery Disease Risk Factor Thresholds

Risk Factors	Defining Criteria	*Score*
Family history	MI, coronary revascularization, or sudden death in an immediate relative (male <55 years or female <65 years)	+1
Cigarette Smoking	Current smoker or those who quit within the past 6 months	+1
Hypertension	SBP ≥140 mmHg or DBP ≥90 mmHg confirmed by measurements on at least two separate occasions, or on antihypertensive medication	+1
Dyslipidemia	Total >200 mg/dL or HDL <40 mg/dL or LDL >130 mg/dL; if LDL >130 mg/dL, use LDL rather than total >200 mg/dL, or on lipid-lowering medication	+1
Impaired Fasting Glucose	Fasting blood glucose ≥ 100 mg/dL confirmed on two separate occasions	+1
Obesity	BMI >30, or waist girth >102 cm (40 in) for men and > 88 cm (35 in) for women, or waist-to-hip ratio ≥ 0.95 for men and ≥ 0.86 for women	+1
Sedentary Lifestyle	Persons not participating in a regular exercise program or accumulating 30 minutes or more of moderate physical activity on most days of the week	+1
High Serum HDL	>60 mg/dL	− 1

SCORE

Initial ACSM Risk Stratification

Low Risk (younger)
_____ Men <45 years of age AND no more than one positive risk factor
_____ Women <55 years of age AND no more than one positive risk factor
Moderate Risk (older)
_____ Men 45 or older
_____ Women 55 or older
_____ Those who meet the threshold for two or more positive risk factors
High Risk
_____ Cardiac, peripheral vascular, or cerebrovascular disease
_____ Chronic OPD, asthma, interstitial lung disease, or cystic fibrosis
_____ Diabetes mellitus type 1 or 2, thyroid disorders, renal, or liver disease
Those with one or more of the following signs or symptoms:

_____ Angina		_____ Ankle edema
_____ Shortness of breath at rest or with mild exertion		_____ Palpitations or tachycardia
_____ Dizziness or syncope		_____ Intermittent claudication
_____ Orthopnea or paroxysmal nocturnal dyspnea		_____ Known heart murmur
_____ Unusual fatigue or shortness of breath with usual activities		

ACSM Recommendations for (A) Current Medical Examination and Exercise Testing Prior to Participation and (B) Physician Supervision of Exercise Tests

	Low Risk	Moderate Risk	High Risk
A.			
Moderate Exercise (40–60% VO$_2$max)	Not Necessary	Not Necessary	Recommended
Vigorous Exercise (>60% VO$_2$max)	Not Necessary	Recommended	Recommended
B.			
Submaximal Test	Not Necessary	Not Necessary	Recommended
Maximal Test	Not Necessary	Recommended	Recommended

APPENDIX D.
Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness Questionnaire (PAR-Q)

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer YES or NO for each.

Y   N   Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

Y   N   Do you feel pain in your chest when you do physical activity?

Y   N   In the past month, have you had chest pain when you were not doing physical activity?

Y   N   Do you lose your balance because of dizziness or do you ever lose consciousness?

Y   N   Do you have a bone or joint problem that could be made worse by a change in your physical activity?

Y   N   Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

Y   N   Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more of these questions, talk to your doctor by phone or in person before you start becoming more physically active or before you have a fitness appraisal. Tell your doctor about the PAR-Q and the questions to which you answered YES.

If you answered NO to all PAR-Q questions, you can be reasonably sure that you can: start becoming more physically active – begin slowly and build up gradually.

_____   _____
Signature   Date

APPENDIX E.

IRB Approval Documentation

SUNY Cortland
Institutional Review Board

MEMORANDUM

To:	Justin Vanderbeck
	James Hokanson
From:	Irena Vincent, Primary reviewer *on behalf of*
	Institutional Review Board
Date:	3/6/2013
RE:	Institutional Review Board Approval

In accordance with SUNY Cortland's procedures for human research participant protections, the protocol referenced below has been approved for a period of one year:

Title of the study:	The influence of respiratory muscle training on exercise endurance		
Level of review:	Expedited	Protocol number:	121322
Project start date:	Upon IRB approval	Approval expiration date*:	3/5/2014

* Note: *Please include the protocol expiration date to the bottom of your consent form and recruitment materials.* For more information about continuation policies and procedures, visit
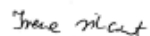www.cortland.edu/irb/Applications/continuations.html

The federal Office for Research Protections (OHRP) emphasizes that investigators play a crucial role in protecting the rights and welfare of human subjects and are responsible for carrying out sound ethical research consistent with research plans approved by an IRB. Along with meeting the specific requirements of a particular research study, investigators are responsible for ongoing requirements in the conduct of approved research that include, in summary:

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals' participation in the research, unless these requirements have been waived by the IRB;
- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to irb@cortland.edu within three days);
- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- following the principles outlined in the Belmont Report, OHRP Policies and Procedures (Title 45, Part 46, Protection of Human Subjects), the SUNY Cortland College Handbook, and SUNY Cortland's IRB Policies and Procedures Manual;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.

In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email irb@cortland.edu or by telephone at (607)753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology, visit http://www.cortland.edu/irb/members.html to obtain a current list of IRB members.

Sincerely,

Irene Vincent

Irena Vincent, Primary reviewer *on behalf of*
Institutional Review Board
SUNY Cortland

Appendix F.

Scripts Organized by Group

Placebo group:

"Please be seated and place your hands in your lap. Secure the mask to your face so that you are comfortable. If you need assistance, I will help you. You will be performing respiratory muscle training through this mask. Once the mask is secure, you will give me a thumbs-up. You will then begin taking slow, controlled breaths. You will take 60 of these breaths and then will remove the mask. If at any time you feel nauseous or dizzy, immediately remove the mask. You are free to remove this mask at any time for any reason. Do you understand the instructions as they have been read to you? Are you ready to begin?"

Inspiratory Muscle Training (IN) group:

"Please be seated and place your hands in your lap. Secure the mask to your face so that you are comfortable. If you need assistance, I will help you. You will be performing respiratory muscle training through this mask. Once the mask is secure, you will give me a thumbs-up. After breathing out normally, you will then breathe rapidly and with maximal effort inward. Make sure that you breathe out normally. You will take 30 of these breaths and then will remove the mask. If at any time you feel nauseous or dizzy, immediately remove the mask. You are free to remove this mask at any time for any reason. Do you understand the instructions as they have been read to you? Are you ready to begin?"

Inspiratory with Expiratory Muscle Training (INEX) group:

"Please be seated and place your hands in your lap. Secure the mask to your face so that you are comfortable. If you need assistance, I will help you. You will be performing respiratory muscle training through this mask. Once the mask is secure, you will give me a thumbs-up. After breathing out normally, you will then breathe rapidly and with maximal effort inward, pause for one, two, or three seconds, and again rapidly and with maximal effort outward, and pause for the same amount of time before repeating. You will take 30 of these breaths and then will remove the mask. If at any time you feel nauseous or dizzy, immediately remove the mask. You are free to remove this mask at any time for any reason. Do you understand the instructions as they have been read to you? Are you ready to begin?"