THE EFFECT OF EXPIRATORY MUSCLE RESISTANCE

TRAINING ON COLLEGIATE ROWERS

by

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ABSTRACT

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Expiration during exercise requires the active contraction of trunk muscles (Fuller, Sullivan & Fregosi, 1996). After prolonged exercise it has been demonstrated that expiratory muscles become fatigued (Suzuki, Suzuki, & Okubo, 1991) which can be deleterious to performance (Hill, Jacoby & Farber, 1991). Sapienza, Davenport, and Martin (2002) reported increased expiratory muscle strength following an expiratory muscle resistance training program (EMRT). Though no data has been collected on the effects of EMRT on athletes, Volianitis, McConnell, Koutedakis, McNaughton, Backx, & Jones (2001) indicated that an inspiratory muscle resistance training program (IMRT) increased inspiratory strength and rowing performance. The present study looked at the effects of a 5-week EMRT program on members of the Humboldt State University Men's Rowing team (n = 14). Post-test data revealed no significant changes in expiratory muscle strength or 2000m ergometer rowing time between the groups, but the experimental group did experience significant gains in strength between the pre- and post-tests. Overall results were inconsistent from previous studies, most notably the lack of change in rowing performance. Expiratory muscle strength data were similar to earlier studies using no control group. Various aspects of the study, including the fact that the subjects were highly trained competitors at the height of their season, raise questions about the effects and implementation of EMRT.

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Chapter One

Introduction

Though expiration at rest is a passive movement that requires no muscle contraction, heavy breathing during exercise is active, requiring the recruitment of rectus abdominus, transversus abdominus, internal intercostals, internal abdominal obliques and external abdominal obliques (Fuller, Sullivan & Fregosi, 1996; Ramonatxo, Mercier, Cohenedy & Prefaut, 1991; Powers & Howley, 2004). In two separate studies, Fuller et al. and Suzuki, Suzuki and Okubo (1991) demonstrated decreased EMG activity of these muscles following exercise and hyperventilation, respectively, signaling expiratory muscle fatigue. Hill, Jacoby and Farber (1991) and Loke, Mahler and Virgulto (1982) demonstrated decreased expiratory muscle strength following a triathlon and marathon, respectively. Furthermore, it has been demonstrated that increased ventilatory effort is accompanied by a decrease in exercise performance (Mador & Acevedo, 1991; B. Martin, Heintzelman & Chen, 1982; Ker & Schultz, 1996).

To reduce the effect respiratory fatigue has on performance, it has been theorized that the expiratory muscles can be trained to resist fatigue. Leith and Bradley (1976) demonstrated that after a 5-week program of hyperventilatory respiratory training, subjects increased their expiratory strength and maximum ventilatory volume (MVV). Spengler, Roos, Laube and Boutellier (1999) demonstrated increased cycling endurance time after 4 weeks of hyperventilatory respiratory endurance training. After a longer training period of 15 weeks, Stuessi, Spengler, Knopfli-Lenzin, Markov and Boutellier (2001) demonstrated increased time to exhaustion on a cycle ergometer.

Though respiratory training is not a usual component of rowing coaches' training programs, there is evidence that this may improve rowing performance. Volianitis, McConnell, Koutedakis, McNaughton, Backx, & Jones (2001) reported that 30 s after a 6 min all-out rowing effort, inspiratory muscle strength decreased significantly, but following an 11-week inspiratory training period, this decrease was attenuated and maximal inspiratory mouth pressure (MIP), an index of inspiratory strength, was increased. At the present time, no study has been found that has examined the effects of specific EMRT on rowing or athletic performance. In a sporting event in which expiratory muscle fatigue may decrease performance, an investigation of the effect of EMRT on performance would reveal the validity of incorporating such training into a coach's program.

Statement of Problem

In collegiate level rowing, there is a possibility that fatigue of expiratory muscles can affect performance. Though typical rowing training is oriented toward increasing the endurance capabilities of the locomotor muscles, very little knowledge exists regarding the effect of EMRT on the expiratory muscles. To develop training methods that enhance expiratory muscle strength and 2000m rowing performance, more data needs to be collected examining the specific effects of EMRT.

Review of Literature

Mechanics of expiration. During expiration at rest, or quiet breathing, air is expelled from the lungs via transpulmonary pressure. After inspiration, elastic recoil occurs as the elastin and collagen fibers within the lung tissues return to original length after being stretched during inspiration. In addition, surface tension of the fluid within the alveoli creates roughly two-thirds of elastic recoil. This surface tension causes the alveoli to reduce to the smallest diameter possible, decreasing the alveolar volume and increasing the alveolar pressure; thereby forcing air out of the lungs. This process is passive, meaning no muscles are contracted to decrease the volume of the pleural cavity (Stamenovic, 1990). During exercise, however, expiration becomes active, requiring the contraction of the abdominal and rib cage muscles (Fuller et al., 1996; Ramonatxo et al., 1991; Sheel, 2002). The contraction of these muscles decreases the volume of the thoracic cavity by pushing the diaphragm upward and the ribs inward, increasing intrapulmonary pressure (Powers & Howley, 2004). The force these muscles produce increases respiratory pressure and is a measure of respiratory muscle strength (American Thoracic Society/ European Respiratory Society [ATS/ERS], 2002).

Maximal expiratory pressure (MEP) has been experimentally determined to be an index of respiratory muscle strength (Black & Hyatt, 1969; ATS/ERS, 2002). This pressure, measured at the mouth, reflects the pressure generated by the respiratory muscles coupled with the pressure generated by elastic recoil (ATS/ERS). Since MEP includes elastic recoil, which is not a product of muscle contraction, a true value for the pressure generated by the expiratory muscles would be the pressure generated by elastic recoil subtracted from MEP. However, the value for the pressure generated by elastic recoil differs among subjects according to lung volume and is therefore very difficult to determine. For this reason, standard clinical measurements of expiratory muscle strength include the pressure generated by elastic recoil (ATS/ERS).

The protocol of obtaining maximal respiratory mouth pressures have differed over time in attempts to create a uniform method with high reliability. Black and Hyatt (1969) were among the first investigators to examine the measurement of these pressures, and created a device and protocol that have been adopted by the vast majority of studies measuring respiratory muscle strength. Maximal expiratory pressure was defined as the maximal pressure measured at the mouth during a maximal expiration against an occluded valve beginning at TLC and maintained for at least 1 s (Black & Hyatt, 1969). Since their investigation, this definition has been refined and expanded somewhat with the proliferation of further studies and technologies, while the key points have been maintained. Some more advanced instruments allow investigators to take the actual reading of the pressure sustained for 1 s (maximal static expiratory mouth pressure) while other investigators use the peak measurement obtained during the 1 s (peak expiratory mouth pressure). While the peak measurement is not believed to be as reproducible (ATS/ERS, 2002), the two measurements have been used interchangeably in the literature.

Fatigue of the respiratory muscles. Loke et al. (1982) reported decreases in both respiratory strength and endurance among experienced runners following a marathon. Suzuki et al. (1991) demonstrated decreased power of the rectus abdominus muscles during respiratory loaded breathing. Suzuki et al. also demonstrated significant decreases in MEP and MIP values after expiratory loading. A later study confirmed a decrease in power for the rectus abdominus muscles but also demonstrated a decrease in the power of the external obliques following a maximal cycle ergometer effort (Fuller et al., 1996). Ker and Schultz (1996) reported an inspiratory muscle endurance fatigue that lasted for 3 days after an ultra-marathon among experienced runners. Two other studies demonstrated a trend of decreased respiratory muscle strength after completion of a triathlon and marathon (Hill et al., 1991; Chevrolet, Tschopp, Blanc, Rochat & Junod, 1993). Following an endurance triathlon, Hill and colleagues reported trends of decreased forced expiratory volume for 1s (FEV_1), forced expiratory flow rates at 50% of forced vital capacity ($FEF_{50\%}$) and during the middle half of FVC ($FEF_{25-75\%}$). Chevrolet et al. also demonstrated a trend of decreased expiratory muscle strength following a marathon. Though not all of the subjects experienced expiratory muscle fatigue, 8 of 15 marathoners and 5 of 12 half-marathoners experienced such fatigue as signaled by a decrease in MEP after the races. To explain this, Chevrolet et al. suggested that people have different responses to the increased expiratory use of abdominal muscles during exercise and heavy breathing. Such fatigue of the expiratory muscles indicates that expiration may be a limiting factor for exercise performance.

Effect of respiratory muscle fatigue on athletic performance. Researchers have demonstrated that when the expiratory muscles become fatigued, exercise is limited (B. Martin et al., 1982; Mador & Acevedo, 1991). After prolonged hyperpnea, B. Martin et al. determined that short-term (4-10 min) maximal running performance decreased for active recreational runners. Subjects also demonstrated lower peak V_E, peak HR, and peak V_{O2} compared to a control group. Mador and Acevedo demonstrated decreases in cycle ergometer exercise duration, peak V_E, peak V_{O2}, peak V_{CO2}, and peak HR following induced fatigue of the inspiratory muscles.

Respiratory muscle fatigue in rowing. Respiratory muscle fatigue has also been discovered in rowing specific exercise. Volianitis, McConnell, Koutedakis, McNaughton et al. (2001) demonstrated a decrease in MIP following a 6 min all-out rowing effort. After a 4-week inspiratory muscle training period, this fatigue decreased significantly.

The investigators theorized that the mechanics of rowing play a larger role in respiratory fatigue due to "additional demands on the respiratory muscles, which stabilize the thorax during the stroke, as well as bringing about breathing related excursions of the thorax." In a separate study, Volianitis, McConnell, Koutedakis & Jones (2001) determined the effects of an inspiratory warm-up period before rowing exercise, and demonstrated that 6 min all-out ergometer rowing performance was improved after the respiratory warm-up. These two studies demonstrate rowing-specific inspiratory muscle fatigue and are the only studies that have focused on respiratory fatigue in rowing. The paucity of information in this area requires further testing to determine whether or not expiratory training can improve rowing performance. The purpose of the present study is to determine the effects of expiratory training on rowing performance.

Hyperventilatory training. Leith and Bradley (1976) demonstrated increased strength and endurance after a 5-week training period of inspiratory and expiratory breathing among healthy adults. Two separate training groups (strength and endurance) performed different hyperventilatory maneuvers 5 days per week. Boutellier & Piwko (1992) also demonstrated increased breathing endurance as well as an increase in cycling endurance after a 4-week hyperventilatory training program. Cooper, Coates, Wardrobe-Wong, and Reed (1999) demonstrated an increase in MEP after a 4-week, 5 days per week, expiratory and inspiratory training regimen for healthy subjects. Spengler et al. (1999) demonstrated increases in time to exhaustion (TE) and respiratory endurance following a 2-week respiratory training regimen for active, healthy subjects. Stuessi et al. (2001) demonstrated increases of TE and respiratory endurance for sedentary subjects following 4 weeks of training similar to Spengler et al.

Threshold training. Though many of the devices used in the hyperventilatory training regimens provide a resistance to respiration, causing a load that can be increased or decreased, they do not provide flow-independent resistance. These devices allow the generation of an increase in mouth pressure but are unreliable and generally only create resistances equal to 50% MEP (Sapienza, Davenport & Martin, 2002; Smeltzer, Lavietes & Cook, 1996). Furthermore, due to the design of the devices, pressure is a function of flow, which decreases as the training breath progresses. This, in turn, causes a decrease in effort as the breath progresses (Sapienza et al.). To create flow-independent resistance, threshold devices have been developed using spring-loaded valves which can be adjusted to specific resistance levels. To overcome the resistance of the valve produced by the spring, the subject must create a mouth pressure greater than the pressure generated by the spring. This pressure must be maintained throughout the training breath to keep the valve open, therefore providing a consistent resistance that must be overcome and sustained throughout the entire duration of the effort (A. D. Martin, Davenport, Franceschi & Harman, 2002; Sapienza et al.).

Threshold devices are precise instruments that are generally simple to operate. The training resistance level is easy to adjust, using a screw mechanism to increase or decrease the pressure of the spring pushing against the valve. This resistance can be measured and calibrated to ensure a specific, reliable and quantifiable load. Threshold devices are also hand-held, making them practical for uninitiated subjects to operate. Many commercial spring-loaded threshold devices have been developed and sold over the past 20 years and subsequently have been tested by numerous investigators with varied applications. In this review, EMRT and IMRT will refer to programs involving threshold devices that provide flow-independent resistance as described above.

Many studies have focused on medical applications of threshold devices. Drs. P. W. Davenport and A. D. Martin developed an inspiratory threshold device for use with medical patients suffering from a variety of respiratory diseases and disabilities. Six studies demonstrated increases in MEP/MIP following EMRT/IMRT (A. D. Martin et al., 2002; Ruddy, Davenport, Baylor, Lehman, Baker & Sapienza, 2004; Baker, Sapienza, Martin, Davenport, Hoffman-Ruddy & Woodson, 2002; Huang, Martin & Davenport, 2003; Kellerman, Martin & Davenport, 2000; Sapienza et al., 2002). The device created by Dr. Davenport and Dr. Martin is the instrument used in the present study.

A number of other threshold devices have been created by other individuals and marketed commercially. The Threshold™ device has been used to increase MEP in medical patients (Smeltzer et al., 1996; Weiner, Magadle, Beckerman, Weiner & Berar-Yanay, 2003a; Weiner, Magadle, Beckerman, Weiner & Berar-Yanay, 2003b) and to increase MIP in trained track endurance athletes (Inbar, Weiner, Azgad, Rotstein & Weinstein, 2000). Caine and McConnell (2000) developed an inspiratory threshold trainer (Powerbreathe™) which demonstrated increased MIP and rowing performance (Volianitis, McConnell, Koutedakis, McNaughton et al., 2001) and increased MIP cycling performance (Romer, McConnell & Jones, 2002; Sonetti, Wetter, Pegelow & Dempsey, 2001). Other threshold devices have been used to elicit increases in MEP/MIP in singers (Nam, Lim, Ahn & Choi, 2004) and athletes (Amonette & Dupler, 2001; Williams, Wongsathikun, Boon & Acevedo, 2002).

Effects of specific expiratory muscle resistance training. Sapienza et al. (2002) demonstrated a 47.5% increase in MEP after only 2 weeks of EMRT 5 days per week with a threshold device set at 75% MEP among high school band students. Weiner et al. (2003a, 2003b) demonstrated increased MEP and 6-min walk time among patients with chronic obstructive pulmonary disease (COPD) following 3 months of EMRT. Smeltzer et al. (1996) reported increased MEP for patients with multiple sclerosis following a 3 month EMRT program.

Effects of respiratory muscle resistance training on athletes. Triathletes demonstrated a trend of increased MEP and significant increased sub-maximal exercise time after 4 weeks of ERMT and IMRT (Amonette & Dupler, 2001). Romer et al. (2002) demonstrated significant decreases in 20- and 40-km cycling time trial time after 6 weeks of IMRT. Though an increase in MIP was demonstrated following a 4-week IMRT program, no significant increase in endurance run time was observed in the study by Williams et al. (2002). Inbar et al. (2000) demonstrated increased MIP but no change for markers of exercise capacity including V_{O2max}, V_E, or arterial O_2 saturation after 10 weeks of IMRT.

Two studies examined the effects of EMRT/IMRT with a threshold device on rowers. As mentioned earlier, Volianitis, McConnell, Koutedakis, McNaughton et al., (2001) demonstrated that IMRT resulted in both increased rowing performance and MIP among competitive rowers. Ruddy et al. (2004) examined the effects of inspiratory muscle resistance training on one 15-year-old rower with exercise-induced paradoxical vocal-fold dysfunction. After a 6-week training period, the subject demonstrated an increase in MIP of 93%. The present study was designed to follow a similar training regimen, though exercising the expiratory muscles only- inspiratory breaths remained unloaded. While past studies have demonstrated that onset of fatigue can be prolonged by training both inspiratory and expiratory muscles or inspiratory muscles only, no study has been located which demonstrates the effects of specific EMRT

Rowing mechanics. The rowing movement consists of four major phases, catch, drive, finish and recovery. The catch phase is the movement created just as the blade of the oar breaks the surface of the water. During the catch phase, the trunk is flexed forward with the arms extended forward and the legs flexed at the hip, knee and ankle joints. The drive phase is the portion of the stroke in which the blade is under the water and force is applied to the water via the oar to propel the boat forward. During the drive phase the trunk extends and the legs push the body backwards. The finish phase is the last moment of drive when the trunk extends, with arms pulled toward the stomach and legs extended. Just after the finish phase is the recovery phase, which is the portion of the movement in which the oar is moved over the water, with the blade parallel to the surface, back to the position of the catch phase. During this phase, the trunk is again flexed forward back into the position of the catch. These changes in trunk position can affect breathing patterns.

Entrainment. The coupling of locomotor activity to ventilation, or entrainment, has been postulated to exist in elite rowers and may effect respiration (Siegmund, Edwards, Moore, Tiessen, Sanderson & McKenzie, 1999). Siegmund et al. determined that experienced rowers are entrained to breathe twice during each stroke and tend to expire during the beginning of the drive phase and at the beginning of the recovery phase, and to inspire at the end of the drive and recovery phases. This entrainment pattern shows that the rowers were taking advantage of the changes in abdominal and thoracic cavity volumes. When the expiratory volume was greatest (during the early drive phase) the rowers had a tendency to expire; when the inspiratory volume was greatest (during the late recovery phase) the rowers tended to breathe in. In some subjects, secondary breaths were taken which also occurred during periods in which ventilatory volumes were most conducive (expiration at mid- to late recovery and inspiration at early drive). The majority of the subjects exhibited this breathing ratio of 2:1. Cunningham, Goode and Critz (1974) observed breath-to-stroke ratios of 1:1 during submaximal activity and ratios of 2:1 at maximal activity levels to exhaustion. Mahler, Shuhart, Brew, and Stukel (1991) discovered that for elite female rowers, entrainment was one breath per stroke with a small sample size ($n = 2$). The conflicting information in this area demonstrates a need for more investigation. Regardless of the breath to stroke ratio, entrainment has been demonstrated to occur during 2000m rowing performance, suggesting that locomotor movement does effect respiration.

Mahler et al. (1991) observed that the rectus abdominal muscles are in extension and the chest wall is stabilized during the drive phase, impeding active expiration. Consistent breathing patterns and timing among individuals, however, was not observed. Cunningham et al. (1974) observed that ventilation was decreased for rowers when compared to cyclists and believed this was due to the nature of the cramped position of the rower during the drive phase, which constricts the abdominal muscles and pushes the viscera upward, affecting the diaphragm during inspiration as well. This is in agreement with the observation that the rowers had lower V_E/V_{O2} ratios, suggesting greater O_2 extraction, which was believed to be an adaptation to counter the decreased ventilation.

Seigmund et al. (1999) demonstrated that expiratory volume was lowest at or just after the catch phase.

2000m rowing performance. Mahler, Andrea and Andresen (1984) demonstrated that, for top-level American male rowers in season, 6-minute all-out rowing was not significantly different from an incremental test to measure physiological values. The study reported no significant difference for HR, V_E, V_{CO2}, or rating of perceived exertion (RPE). The 2000m distance is the standard race distance and is used to assess and predict performance during training. For this reason the present study will use the 2000m test to examine the effects of expiratory muscle training.

Expiratory muscle resistance training protocol. Training of the expiratory muscles is generally prescribed for a period of 4-5 weeks, 5-6 days per week, 20-30 minutes per session (Baker et al., 2002; Boutellier et al., 1992; Cooper et al. 1999; Huang et al., 2003; Kellerman et al., 2000; Spengler et al. 1999; and Stuessi et al. 2001). The training procedure of the device used in the present study (P. W. Davenport, PhD, personal communication, 2003) suggests a resistance of 75% of the subject's maximal expiratory pressure (see Appendix A). This resistance setting was used in investigations by Dr. Davenport and various colleagues with results demonstrating increased mouth pressures (Baker et al., 2002; Huang et al., 2003; Kellerman et al., 2000; and Sapienza et al., 2002).

Purpose of study

The purpose of the present study was to determine if EMRT would affect MEP and 2000m rowing performance.

Hypothesis

Expiratory muscle resistance training, using a spring-loaded threshold expiratory trainer, will increase MEP and a decrease 2000m rowing time.

Operational Definitions

2000m rowing performance: Evaluated as the amount of time (s) in which the subjects can complete 2000m.

Maximum expiratory pressure (MEP): The peak pressure measured at the mouth after inhaling to TLC and expiring forcefully and maximally for 1 s into the pressure calibrator. Units measured in cmH_2O using the Fluke 717 30G pressure calibrator.

Experience Level: Official standing on the team- those athletes with less than 1 year of experience on the team were classified as 'novice,' while those with at least 1 year of experience were termed 'varsity.' All participants in this study classified as 'novice' had no rowing experience or training prior to the 2004-2005 academic year.

Expiratory muscle threshold training device: The device consists of a one-way spring-loaded valve with a screw mechanism to control the variable resistance provided by the spring. A mouth piece at one end allows the subject to exhale into the device, attempting to create enough pressure to force the valve open. If the pressure needed to force the valve open is not maintained, the spring will force the valve closed, ending the training breath.

Assumptions

The following assumptions were made in this study:

1. The subjects understood and performed the training breaths according to the methods previously stated, and with an honest effort.

2. The Fluke 71730G pressure calibrator is a valid and reliable instrument for measuring pressure.

3. MEP is an index of maximal expiratory muscle strength.

Limitations

The study may have the following limitations:

1. The subjects may not have performed the training breaths with an honest effort.

2. The subjects were full-time undergraduate students, with associated responsibilities and coursework that may affect their performance, anxiety levels and training over the 5-week schedule.

Delimitations

The study may have had the following delimitations:

1. The study involved competitive rowers only.

2. The study was limited to the HSU campus.

3. This study involved only male athletes.

Significance of the Study

This study applies the theory that training expiratory muscles can increase expiratory strength and endurance to a specific sport setting. This study applies directly to men's rowing and the specific training technique that can be easily reproduced with the proper equipment. At present, EMRT is not commonly employed by coaches in the sports setting. As the availability of respiratory devices increase, athletes will be able to perform training breaths more readily and this area of conditioning can be utilized to enhance performance more readily. In a world of sport in which fractions of a second may decide the winner, every training advantage is of utmost importance, especially training that is relatively simple and undemanding. This is an emerging area of training that requires more in-depth exploration before it can be utilized properly.

Chapter Two

Methodology

Subjects. The subjects (n = 16) in this study were male collegiate rowers competing for the Humboldt State University club team. Human subjects approval was obtained before any testing took place. Participants kept a training diary to record their daily expiratory training and a training log was filled out after each session by the investigator. In addition to anthropometric data, baseline MEP, 2000m rowing ergometer, FVC and FEV_1 tests were performed before the training regimen was initiated. Of the initial 16 participants, 2 were eliminated from the statistical analysis. One subject missed the last week of training and failed to complete a final ergometer test and the other was injured and unable to complete the ergometer tests. This left a total of 14 subjects; 7 in each group.

Instrumentation. The expiratory training device used in the study consisted of a mouthpiece housed with a one-way adjustable valve used to increase the tension of the spring that resists the expiratory flow of the subject. Five days prior to the first training session, an initialization session was held during the team's practice time. At this time, the training protocol written by the developer of the device was adopted and handed out to each participant (see Appendix A). The investigator demonstrated proper use of the device, after which the subjects were given a 10 min period to independently familiarize themselves with the device. Following this period, the resistance of the devices were increased minimally (≤20 cmH_2O) and subjects were instructed to exhale, using proper technique. The subjects were then monitored to ensure proper technique and coached as to any corrections that needed to be made

Pre-test measurements. On the Wednesday before the initiation of EMRT, subjects performed a 2000m rowing ergometer time trial. The subjects performed the baseline pulmonary function and mouth pressure tests the following day. At this time, proper technique was demonstrated for each of the measurements and subjects were given 2-3 practice attempts before measurements were taken. A 5-minute rest was allowed between the initialization and first MEP measurement, after which a 2-minute rest was given between attempts. The FEV_1 and FVC measurements followed, after a similar demonstration period.

Measurement of maximal expiratory pressure. To determine the resistance setting of the trainer and to track any changes in MEP, maximum expiratory strength was measured each Monday using a Fluke 71730G pressure calibrator. MEP was measured until three values that fell within 20% were obtained, with a maximum of five breaths to avoid over-stressing the expiratory muscles and to ensure that obtained values would not suffer as a result of fatigue (ATS/ERS, 2002). As mentioned previously, it has been stated in the literature that the peak expiratory mouth pressure measurement used in this study is not as reproducible as the other main method of obtaining maximal mouth pressure (ATS/ERS). To test the reliability of the present method, an ANOVA with a Cronbach's alpha intraclass reliability test was used to analyze pre-test values. The test demonstrated a high positive correlation (R_1 = .982), confirming that the instrument was highly reliable. During the course of the study, there were no problems obtaining three reliable values without exceeding the maximum of five breaths.

The protocol for measuring MEP used in this study was adopted from the EMRT study performed by Sapienza et al. (2002). Since a relationship has been shown between lung volume and MEP, subjects were instructed to take a maximal inhalation prior to each expiratory maneuver to achieve TLC, the optimal lung volume for obtaining an accurate MEP (Black & Hyatt, 1969; ATS/ERS, 2002). The mouthpiece consisted of a section of tubing attached to a plastic fitting that was hooked-up to the pressure calibrator. To avoid the use of buccal muscles, a 2 mm hole was drilled into the tube. Subjects did not wear nose clips, but were instructed to pinch their nostrils closed if they were unable to avoid exhaling through their nostrils (ATS/ERS). They were also instructed to keep a tight seal between their lips and the mouthpiece, and again to use their hands to pinch their lips down to the tube if necessary to avoid leaks (Black & Hyatt). In this position, the hands could also be used to keep the cheeks from pouching out. If an air leak between the lips and mouthpiece was observed or if the cheeks were used, the subject was instructed to repeat the maneuver after a 2 min rest. Subjects were also instructed to try and maintain their maximal expiratory effort for ~2 s to achieve a more reliable reading (Black & Hyatt; ATS/ERS). The pressure calibrator was zeroed and calibrated to atmospheric pressure before each measurement (ATS/ERS). To avoid subject bias, the digital readout on the pressure gauge was covered and readings were not disclosed to the participants.

Expiratory muscle resistance training protocol. As mentioned earlier, the protocol (see Appendix A) in this study was adapted from Dr. Davenport, the developer of the device (personal communication, 2003). The first training session took place during the team's regularly scheduled practice time. The subjects were monitored and coached during training breaths to assure compliance with proper technique as well as training protocol. Training took place 5 days a week (Monday through Friday), once per day at 75% MEP in a closed setting. During training breaths, the subject placed his mouth over the opening of the trainer, using his hands if necessary, to create a tight seal. The subject then expired into the device forcefully five times consecutively, taking a deep inspiration to TLC before each training breath. Subjects were instructed to expire into the trainer forcefully, while maintaining the longest possible breath, with the goal being to keep the valve open as long as possible. The duration of each actual expiration depended on how long the subject was able to maintain enough force to keep the valve open. A rest period of 2 min was used between sets of five breaths, and a total of five sets made up one training session, which lasted roughly 9-10 min.

Each subject was given his own training device and mouthpiece for the pressure calibrator. Training devices and mouthpieces were numbered for identification purposes. Each device was cleaned before each use with a 10:1 bleach solution and stored in a locked cabinet. When the team traveled on weekends to a competition and left Thursday or Friday, the devices were given to the coach to hand out to the athletes to complete the training breaths as a group on the road. On the one occasion in which the team was gone for two consecutive training days, the devices were kept in numbered, sealed sandwich bags to avoid contamination after the first day of use.

Measurement of rowing performance. Rowing performance was measured as time, in seconds, to finish a 2000m piece on a rowing ergometer (Concept2, Vermont, USA). All time trials were held at the same time of day (6:30 am) each Wednesday, with the exception of the post-test, which was held on a Monday. Due to time conflicts, some subjects missed the time trials between the pre- and post-tests, eliminating those trials from statistical analysis.

Post-test measurements. The post-test measurements were conducted on the Monday following the final EMRT session. The 2000m rowing ergometer time trial was held at 6:30 am, after which subjects performed final MEP, FVC, and FEV_1 maneuvers in the lab later in the morning. All conditions were kept the same as for the pre-test noted above.

Adherence. As mentioned earlier, subjects kept training diaries and attendance was noted by the investigator for each training session. A subject was eliminated from the data analysis if he missed more than three training sessions.

Study design. This study used both a control (n =7) and training (n = 7) group. For 2 days, the groups familiarized themselves with the power trainers and performed the initial MEP tests. The 2000m ergometer rowing test was performed the Wednesday before the first day of EMRT. After performing initial MEP and 2000m ergometer tests to determine baseline values, subjects were randomly assigned to one of the groups, after which the groups were tested to ensure normality of the two groups. The training period lasted for 5 weeks and subjects trained once daily on weekdays. On the Monday following the final training session, post-tests were performed to determine final MEP and 2000m rowing erg values.

In addition to the regular in-season rowing training program, the EMRT group participated in the expiratory training program at 75% MEP, while the placebo group participated in a sham expiratory training program in which they performed the same training protocol but at only 15% MEP resistance (Volianitis, McConnell, Koutedakis, McNaughton et al., 2001; Amonette & Dupler, 2001; Romer et al., 2002). The subjects were informed that they were testing a device which has been known to increase expiratory muscle strength. Since the placebo group was training at such a low resistance setting (15% MEP), to avoid sensitization and potential bias, they were told that they were training for “endurance,” while the experimental group was training for “strength” (Volianits et al., 2001). To further avoid sensitization, when possible, subjects were separated during training according to their grouping. All training sessions took place in the lab, under controlled settings, as a part of their daily practice. Daily rowing practice consisted of 6:00 am ergometer workouts in the gym and 5:00 pm water workouts in Humboldt Bay. As per the decision of the head coach, after 2 weeks of the study the morning ergometer workouts were cut back to Wednesdays only, to give the athletes more rest to prepare for the two major competitions at the end of the season (the last of which coincided with the last week of the study).

Statistical Analysis

Differences in anthropometric data were compared using multiple ANOVAs with Bonferroni adjustments along with a Chi-square test for the nonparametric data. Multiple ANOVAs with Bonferroni adjustments were also used to determine if differences between groups existed for expiratory muscle strength, 2000m rowing time, FVC, FEV_1, height, and weight. ANOVAs with Bonferroni adjustments to the alpha level were used for analysis because a MANOVA was not deemed appropriate due to the small subjects-to-dependent-variable ratio (Vincent, 1999; Wagoner, 1994). To test for within-groups differences for the MEP data, a Repeated Measures ANOVA was conducted. The level of significance for all factors was set at $p < .05$.

Chapter Three

Results

To assess the effects of EMRT on MEP and rowing performance, pre- and post-tests were conducted, including 2000m erg time trials, MEP maneuvers, and spirometric data. To determine if differences existed between the groups following EMRT, Analyses of Variance were conducted, using Bonferroni adjustments to avoid family-wise error. A Repeated Measures ANOVA was used to determine if differences occurred within groups over time for MEP and 2000m erg time trial time. An alpha level of .05 was used for all statistical tests. All statistical procedures met the required assumptions and were performed using OpenStat4 Version 8, Revision 6 (Dr. William G. Miller, 2005). Of the original 16 subjects, a total of 14 subjects completed the required tests and training to be used in the statistical analysis.

Table 1

Spirometric Pre- and Post-test Measurements (n = 7)

	Pre-test		Post-test	
Variable	Placebo	EMRT	Placebo	EMRT
FVC (L)	4.3 ± 1.0	4.5 ± 1.9	4.0 ± 0.8	5.0 ± 1.7
FEV_1 (L/s)	3.7 ± 0.7	3.6 ± 1.4	3.7 ± 1.0	4.3 ± 1.2

Data are expressed as mean ± SD.

Baseline measurements. Groups were similar for anthropometric data (mean age = 21.8 yrs, mean height = 186.25 cm, and mean weight = 84.00 kg). Baseline FEV_1 and FVC measurements, listed in Table 1, were also not significantly different. Additionally, the results of a chi-square test reveled that no significant differences existed between the two groups for experience level ($\chi^2 = 0.286$; $p < .05$). As expected, the results showed no significant difference between the two groups for the 2000m Erg time and MEP pre-tests (see Table 2).

Table 2

Pre- and Post-test MEP and 2000m Erg Data (n = 7)

	Pre-test		Post-test	
Variable	Placebo	EMRT	Placebo	EMRT
MEP (cmH_2O)	166.6 ± 47.9	158.2 ± 40.8	203.6 ± 36.2	209.6 ± 33.9
2000m Erg (s)	414.0 ± 17.2	411.7 ± 15.7	418.4 ± 17.2	414.8 ± 21.7

Data represented as mean ± SD.

Effects of expiratory muscle resistance training on pulmonary function. As expected, results of ANOVA demonstrated no significant differences between groups for FEV_1 or FVC following the 5-week EMRT program (see Table 1).

Effects of expiratory muscle resistance training on expiratory muscle strength. At the end of the 5-week EMRT program, results of a between groups ANOVA revealed that MEP of the experimental group was not statistically greater than the control (see Table 2). Comparing pre- and post-test measurements within groups, however, the Repeated Measures ANOVA showed significant increases in MEP for the EMRT group only (see Figure 1). The amount of overall change in MEP for the EMRT group was 32%, while 22% for the placebo group. The overall test results, however, show that the 5-week training program did not affect expiratory muscle strength compared to placebo.

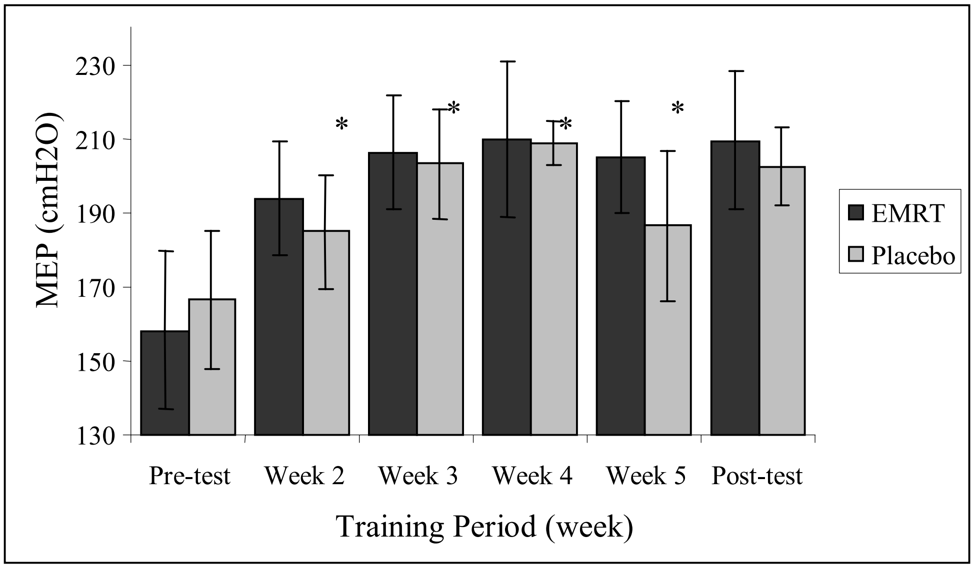

Figure 1. Changes in MEP compared to pre-test; t-bars represent SE; *Significant from pre-test; $p < .05$ (due to missing data in week 2 for EMRT and week 4 for Placebo, the cases could not be used for statistical analysis).

Effects of expiratory muscle resistance training on rowing performance. Rowing ergometer time trial performance was not shown to be changed after the 5-week intervention either between or within groups (see Table 2). Interestingly, a trend of a very slight increase in time trial completion time was shown for both placebo and EMRT groups (+4.6 s and +3.1 s, respectively).

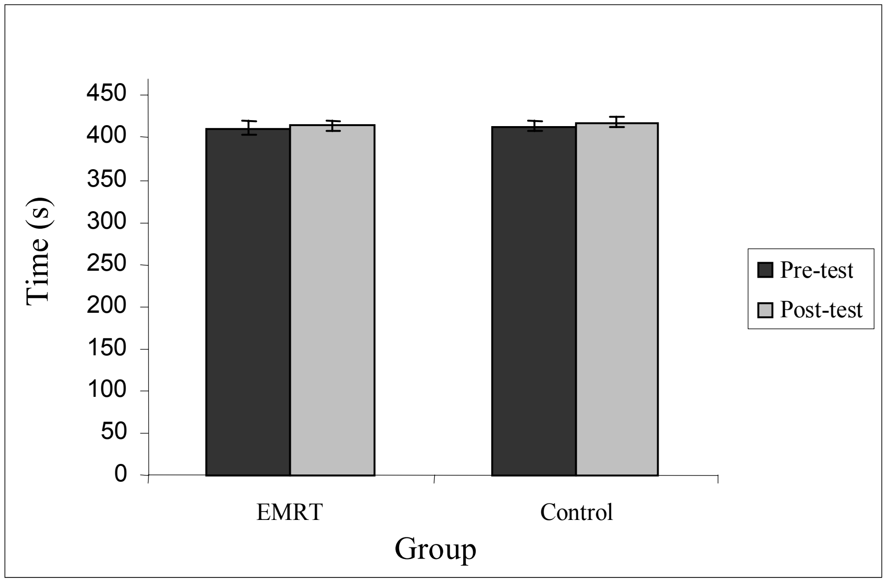

Figure 2. Pre- and Post-test means for 2000m erg time trials between placebo and EMRT; t-bars represent SE.

Chapter Four

Discussion

Effects of expiratory muscle resistance training. In this 5-week study of EMRT, no statistically significant changes in MEP or 2000m ergometer time were demonstrated between the control and experimental groups. Interestingly, however, both groups showed within groups increases in MEP values after the 5-week training period, with the results of the EMRT group reaching statistical significance (see Figure 1). Many of the previous studies examining the effects of EMRT/IMRT on respiratory muscle strength which have demonstrated increases in MEP/MIP values did not include control groups (Huang et al., 2003; Kellerman et al., 2000; A. D. Martin et al., 2002; Ruddy et al., 2004; Williams et al., 2002; Baker et al., 2002; Nam et al., 2004). Many hyperventilatory training interventions reporting increases in MEP/MIP also did not use control groups (Leith & Bradley, 1976; Boutellier et al., 1992; Kohl, Koller, Brandenberger, Cardenas & Boutellier, 1997; Spengler et al., 1999). These studies examined pre- to post-test changes within the experimental group to detect the effects of the intervention, assuming any change in MEP/MIP values would be due to the intervention.

Using the data from the present study, comparing the pre- and post-test results within the experimental group rather than between the two groups, similar conclusions to those reported in the studies using no control would be the result. Disregarding the results of the control group, the EMRT program would appear to have been effective in improving expiratory muscle strength as seen in the significant increase in MEP within the experimental group (see Figure 1). Furthermore, the control group, though showing a trend of improvement in MEP after the sham training, did not demonstrate statistically significant increases. However, the increase in the MEP of the control group was substantially higher than those values reported in studies using similar sham training, raising numerous questions (Volianitis, McConnell, Koutedakis, McNaughton et al., 2001; Weiner et al., 2003a; Weiner et al., 2003b; Scherer, Spengler, Owassapian, Imhof & Boutellier, 2000; Amonette & Dupler, 2001; Smeltzer et al., 1996).

Adherence. In many cases, subjects were unable to attend the prearranged team rowing practice due to schedule conflicts, and were allowed to come to the lab to complete their training breaths later in the morning. Furthermore, during 2 weeks of the training period, 2 participants were suspended from the team and completed the training breaths on their own. The team also traveled to three meets, missing a total of four training sessions. In all of these cases, training breaths were completed independently and confirmed verbally with the investigator at the following meeting time. Some subjects missed 1-3 sessions, while 1 subject missed significantly more days and was therefore excluded from the data analysis. Only two training diaries were returned at the end of the study, negating the usefulness of these instruments for data analysis purposes. The diaries were believed to be helpful reminders during the periods of absence for competitions, as some of the subjects mentioned using their diaries to keep track of their independent training during the study. Two subjects experienced significant illnesses during the training period. One subject had bronchitis, missing one training session and showing decreased MEP values for the following week, but returning to levels above previous for the last two measurements. The other subject had a fever and consequently missed two consecutive training sessions (along with one MEP test). The subject's MEP values did not reflect a loss of expiratory strength surrounding his illness; MEP values actually increased each week during the study.

Methodology of sham training. The control group showed an increase in MEP of 22%, which, though not significant, is an issue that requires further examination to determine the cause for such a large increase. One possible explanation for this increase is that the setting of the device was too high and provided a minimal, though nonetheless marked, load for the expiratory muscles which adapted accordingly, increasing the expiratory muscle force. Respiratory muscles have been theorized to respond to resistance training the same as other skeletal muscle tissue, though no direct investigation has been made of the expiratory muscles specifically (Sheel, 2002). At the conclusion of a relatively short training period such as this, the expiratory muscles of the subjects in this study would most likely adapt neurally- coordinating the firing of Golgi tendon organs and muscle spindles to enhance tension development, rather than structurally (Sale, 1988; Sapienza et al., 2002; Powers & Howley, 2004).

Device limitations. Though the sham protocol used for the placebo group had been implemented previously with no significant increases in MEP/MIP (Volianitis, McConnell, Koutedakis, McNaughton et al., 2001; Amonette & Dupler, 2001; Romer et al., 2002), the present study was limited by the variability of the device. Unfortunately, the minimum setting of the device was ~25 cmH_2O, a value higher than the sham setting of 4 placebo subjects at the beginning of the training period. This higher load for many of the subjects very possibly could have produced gains in MEP that would taint the control group, increasing the possibility of a Type II error. Future research should use a device with a lower resistance setting or somehow manipulate the device to not produce a resistance above 15% MEP, the resistance setting reported by Volianitis, McConnell, Koutedakis, McNaughton et al. to not elicit changes in MEP, because in the present study slightly higher resistances produced substantial increases, though not significant. This greater increase could have produced a Type II error, inflating the control group mean MEP to values that would prevent the presence of statistical differences between the groups. However, in the present study, it was feared that placebo subjects would easily detect a sham device and introduce sensitization and bias. Furthermore, it was not anticipated that MEP values would be so low among some of the subjects- past research has reported mean MEP values for 'normal' males in this age group ranging from 216.0 to 238.4 cmH_2O; values quite different from the range of 96.7 to 235.2 cmH_2O in the present study (ATS/ERS, 2002).

The device used in the present study also had limitations for the EMRT group. Since the device was originally designed for the inspiratory muscle training of medical patients with respiratory limitations, it has a maximum resistance setting of ~150 cmH_2O; an insufficient load to meet the training needs of 5 of the EMRT subjects before the conclusion of the study. Though these subjects produced MEP values requiring training resistances above 185 cmH_2O, the devices could not produce such resistances. The inability to produce an increase in load for the majority of the EMRT subjects could have produced an effect that resulted in a plateau of MEP performance. The construction of a device that can produce a wider range of resistances would be advisable for future testing of fit athletes to ensure proper training loads.

Learning effect. A second possible problem with the methodology that could have resulted in the increase in MEP seen in the placebo group could be that the initialization period was not long enough to eliminate a learning effect. If the subjects did not learn the expiratory technique and, more importantly, the MEP measurement maneuver before the study began, a learning effect could have occurred during the early phase of the study. Smeltzer et al. (1996) cited studies that had discovered significant learning effects and thus used a 4-week initialization period before beginning a 3-month training program. A trend of a very slight decrease in MEP was discovered in the control group compared to a 19.4 cmH_2O increase in the EMRT group. However, this learning effect in the present study was believed to have been largely prevented during the initialization period, due to the high degree of observation and coaching that took place the week before the study began. The initialization protocol used in the present study was similar to those used by Huang et al. (2003) and Kellerman et al. (2000), though neither study used a control group, making it difficult to detect a learning effect.

Results of unpublished studies by Davenport and collegues (personal communication, November 9, 2005) demonstrated increased MEP/MIP (10-20%) for subjects performing the weekly maximal maneuvers without participating in an EMRT or IMRT program. This suggests a large learning effect that is caused by neurological adaptations within the respiratory muscles causing the control group to be able to produce increased MEP without participating in any type of EMRT or sham training.

Pressure support. Sapienza and colleagues also addressed a very important component of EMRT with a threshold device- subglottal or support pressure. During expiration, support pressure is created due to movements within the larynx, pharynx, oral cavity, mouth and lips. Not directly affecting expiration, pressure support plays a key role in playing a musical instrument or, more pertinent to the current topic, performing training breaths with the threshold device and performing the MEP maneuver. Though Sapienza et al. (2002) did not apply support pressure to the use of the training device, they emphasized its importance in playing woodwind and brass instruments, which require the generation of pressures up to 113 cmH_2O, a pressure similar to that of the training setting of many of the subjects in the present study (who had a baseline training resistance setting range of 72.5 to 176.4 cmH_2O). Pursing the lips around the mouthpiece and using the mouth to form the basic movement used when making training breaths is key not only in ensuring a proper technique to benefit from the breaths but also in coordinating the pressure generated by the expiratory muscles into the device.

Pressure support is also important when performing maximal expiratory maneuvers into a pressure gauge. In the present study, the mouthpiece attached to the pressure gauge was designed to be similar to the mouthpiece of the training device. It could be hypothesized that neural adaptations within the expiratory muscles and the muscles associated with pressure support during the first 2-3 weeks of the training period contributed substantially to the increase in MEP values among the subjects in both groups (the learning effect mentioned above). This would explain how, after performing training breaths of minimal resistance, the control group improved their MEP by 22%.

The large MEP increase found in the control group of the present study, however, is contradictory to much of the past literature. After 4 weeks of IMRT, Volinaitis, McConnell, Koutedakis & McNaughton et al. (2001) demonstrated significant increases in MIP not only within the experimental group, but also between the experimental (which trained at 75% MIP) and the control (sham training at 15% MIP). While the experimental group mean MIP increased by 39% at the end of 4 weeks, the control only increased by

3.5%. Additionally, the majority of the increase in MIP (90 and 83% for the experimental and control groups, respectively) was achieved after the first 4 weeks (the earliest date at which the data was provided in the published study), with a much smaller increase in MIP achieved during the remaining 7 weeks of the 11-week training program. Sapienza et al. (2002) demonstrated significant increases in MEP after only 2 weeks of training. Similarly, in the present study 94 and 65% of the increases in MEP occurred during the first 2 weeks of training for the experimental and control groups, respectively. Results showing significant increases in MEP/MIP values after such short training periods further substantiate the idea that such increases are due to neural adaptations rather than hypertrophy. These results indicate a need for more information as to the exact mechanisms related to increases in MEP/MIP values, including possible differences between MIP and MEP.

Effects of expiratory muscle resistance training on rowing performance. The overall lack of effect on the 2000m ergometer rowing performances of the two groups may possibly be a product of the timing of the expiratory training program in relation to the competitive schedule of the subjects' rowing season. The EMRT program began 5 weeks before the last competition of the season, so that the final 2000m erg and MEP tests took place a couple of days after the rowing season was over. During the later stages of a training program, athletes are conditioned to the point of overload, often with very little room for error. This can be reflected in the injury and illness rates of the athletes at the end of the season. During this particular study, though no subjects were seriously injured, at least two were significantly ill for portions of the study. This could be a reflection of minor overtraining among the athletes.

Additionally, at the end of a competitive season, athletes often cease improving on their performance times, reaching a plateau. This can be due to the fact that gains in muscle strength naturally plateau after a number of weeks, and can also sometimes be the goal of the coach if the athletes are required to perform at their highest level for more than one performance over an extended period of time. The subjects in the present study had been training for the entire academic year, including the fall and winter. It is possible that the final 5 weeks of the season coincided with this plateau in rowing performance. The very small increase in performance for even the control group in the study was not in agreement with Volianitis, McConnell, Koutedakis, McNaughton et al. (2001), who demonstrated significant decreases in time to complete a 5000m ergometer time trial after 4 weeks of training within both the experimental and control groups, with significantly higher decreases for the experimental group. The published study did not indicate if the subjects were in season, but did state that they were highly trained. Sonetti et al. (2001) also used trained athletes and a placebo group, finding that the placebo slightly decreased their 8 km cycling time trial time while the experimental group significantly decreased their time by 1.8%. Contrasting these reports, Holm et al. (2004) demonstrated a significant 5% decrease in cycling time trial time for the experimental group and a very slight increase in time trial time for the control/placebo group after 4 weeks of hyperpnea training. In this study, 4 subjects performed sham exercises at lower intensities than the experimental group, while 6 subjects did no respiratory training. Unfortunately, data for both groups was combined and from the published study it is not possible to determine the effects of the sham training on the placebo group alone. Other studies using fit athletes either did not use control groups, did not directly measure athletic performance or did not discover significant improvements in athletic performance. The total number of respiratory training studies focusing on fit athletes is quite small and those using threshold devices are even fewer. This lack of information requires more experimentation and repetition to discover the effects of EMRT/IMRT on highly trained athletes.

Effects of expiratory muscle resistance training on pulmonary function. The results in this study mirror the results of former studies in that EMRT does not influence basic pulmonary function as indicated by spirometric measures, specifically FVC and FEV_1 (Kellerman et al., 2000; Inbar et al., 2000; Williams et al., 2002; Weiner et al., 2003a; Weiner et al., 2003b; Nam et al., 2004). To date, no mechanism associated with EMRT has been theorized to enhance these pulmonary functions.

Conclusion

Respiratory muscle training to increase respiratory strength with the aim of relieving respiratory fatigue is a relatively new area of research in medicine and sports science. Studies testing the effects of hyperpnea or hyperventilation have been conducted since the 70s, beginning with the work of Leith and Bradley (1976), who demonstrated increases in breathing endurance after a 5-week program of ventilation to exhaustion. Many more studies followed, using different methods of hyperventilation with a variety of devices used to resist respiratory flow. More recently, however, threshold devices have been created and improved upon, allowing a subject to train the respiratory muscles within a shorter amount of time using a convenient, nearly flow-independent hand-held device that can be adjusted easily for load increases. Threshold devices allow for convenient workouts which, as demonstrated by Dr. P. W. Davenport, Dr. A. D. Martin and colleagues, have allowed medical patients with respiratory disorders to wean off of ventilators and relieve symptoms of disorders such as COPD and vocal fold paralysis. The success of these instruments in increasing respiratory muscle strength has led to studies involving musicians and athletes. Though still somewhat early in development, many threshold devices have been made commercially available and marketed as tools to increase respiratory strength.

A lack of information regarding specific EMRT has left a hole in the information gathered regarding training devices and protocols. Numerous studies have looked at specific IMRT both in normal subjects, athletes and medical patients (Volianitis, McConnell, Koutedakis, McNaughton et al., 2001; Baker et al., 2002; Huang et al., 2003; Inbar et al., 2000; Kellerman et al., 2000; A. D. Martin et al., 2002; Ruddy et al., 2004; Smeltzer et al., 1996; Williams et al., 2002). Far fewer studies have looked at both IMRT and EMRT (Nam et al., 2004; Amonette & Dupler, 2001; Weiner et al., 2003a), and only three have looked at specific EMRT with a threshold device, neither with trained athletes (Sapienza et al., 2002; Weiner et al., 2003b; Smeltzer et al., 1996). The EMRT studies, however, all demonstrated significant increases in expiratory muscle strength.

The focus of the present study was to apply the use of the threshold device created by Dr. Davenport and colleagues to collegiate level athletes, specifically rowers who compete in endurance events and experience changes in thoracic volume as a consequence of their rowing action. Following 5 weeks of EMRT, results revealed that the program failed to improve in-season rowing performance, but evidence suggests that the treatment may have had an effect on MEP. The lack of a large body of research dealing with specific EMRT leaves many questions about the implementation of the training and the mechanisms involved in increasing expiratory muscle strength. It is possible that MEP is affected by inspiratory strengh, highlighting the importance of overall EMRT/IMRT above specific IMRT or specific EMRT. It is also possible that EMRT requires a substantial period of time to elicit increases in endurance performance- the only EMRT program measuring physical performance, albeit in medical patients, demonstrated increases after three months of training (Weiner et al., 2003b). Comparing these results to the results of the present study, this suggests that perhaps an increase in expiratory muscle mass, not only a neural adaptation, is required to improve physical performance. Unpublished studies conducted by P. W. Davenport and colleagues suggest that following EMRT/IMRT of durations longer than 8 weeks, hypertrophy contributes to 10-15% of the increases in MEP/MIP. This could be the amount of change needed to elicit improvements in athletic performance. More studies involving long-term EMRT with trained athletes need to be conducted to determine the effects on athletic performance.

Future research should focus on specific EMRT among fit athletes, outside of competitive season and with a duration long enough to elicit hypertrophy of the expiratory muscle tissues- at least 9 weeks (Powers & Howley, 2004). As demonstrated in the present study, the control group must be given a sham training regimen to eliminate the subject's awareness of being in the control group, yet the sham training must not provide enough resistance to cause increased expiratory muscle strength. Greater sample sizes, though difficult to obtain when working with such highly trained athletes, should also be sought after, considering that the largest sample of trained athletes to date has been only 20 (Inbar et al., 2000).

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APPENDIX A

EMRT Instruction Form (As Given to Each Subject)

The Power of 5's
Respiratory Power Trainer
5x5x5
5 Breaths/Trial, 5 Trials/Day, 5 Days/Week

The **Respiratory Power Trainer** is a training program designed to increase your respiratory muscle strength.

Training Procedure

1. Train once-a-day, 5 days per week.
2. FIRST WEEK OF TRAINING: The first step is to measure your maximum expiratory strength*.
3. For your daily expiratory muscle exercises, turn the knob of the **Respiratory Power Trainer** to a pressure that is 75% of the maximum expiratory pressure you just determined. This is the daily training pressure for the whole week.
4. The daily expiratory strength training session begins with placing the mouthpiece on the **Respiratory Power Trainer**. Take in a deep breath, place the mouthpiece in your mouth and breathe out through the **Respiratory Power Trainer**. Repeat this 4 more times. When you have completed the 5 breaths through the **Respiratory Power Trainer**, rest for 2 minutes.
5. When the 2 minutes of rest are complete, repeat the 5-breath exercise (step 4). Take another 2-minute rest period. Do not cheat on the rest period, your expiratory muscles need a chance to recover between exercise trials. Repeat 3 more times. You will perform a total of 5 sets of 5-breath exercises for the day.
6. You need to train 5 days in a row. You also need to take a break for 2 days.
7. Every Monday (or your first training day for the week), repeat step 1 and determine your maximum expiratory pressure. If your maximum expiratory pressure increased, adjust the **Respiratory Power Trainer** new pressure setting to 75% of the maximum expiratory pressure you just determined. You may reach the maximum pressure capacity of the **Respiratory Power Trainer**. You will simply train at the **Respiratory Power Trainer** maximum. It is **NOT** recommended that you increase the number of breath efforts per trial.

P. W. Davenport, PhD. (personal communication, 2003)

*The maximum expiratory strength, or maximum expiratory mouth pressure (MEP) will be measured as follows:

1. The subject, in a standing position, will take a deep inspiration and expiration. After a second deep inspiration he will place his mouth tightly around the hose attachment connected to the Fluke Pressure Calibrator and expire into the tube as forcefully and as

long as possible.

2. The subject will rest for 60 s; During this time, the subject's maximal effort, which was automatically measured (in cmH_2O) and saved by the calibrator, will be recorded and the instrument will be recalibrated.
3. At the conclusion of the rest period, the subject will repeat steps 1 and 2 at least two more times, for a total of three measurements. If the three values fall within 5 cmH_2O, then the mean of the values will be calculated and used for the subject's MEP. If the values are not that consistent, the subject will repeat steps 1 and 2 until three values falling within 5 cmH_2O are obtained, with a maximum of 7 efforts. In the event that three such values are not obtained after 7 efforts, the mean

   of the three closest values will be used to determine the maximum expiratory mouth pressure, MEP.

- The information gained from this study will contribute to a growing body of knowledge that has been expanding in recent years. Your participation will help to determine the effectiveness of the training device and exercises in a sport setting.
- The Respiratory Power Trainer is a device that has been used by several other investigators and has been shown to be safe. However:
    - Participation in this study is voluntary; any participant may discontinue the training program at any time.
    - If you are experiencing any difficulties or are having trouble conducting the breathing exercises, stop the exercises immediately, and inform Tim Miller of the problem.

Any questions or comments can be addressed by:

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