Effectiveness of Interval vs. Endurance Training to Minimize Asthmatic Symptoms in Recreationally Active Adults

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The prevalence of asthma is on the rise, affecting the quality of life of those who suffer from this condition. There are several treatments for asthma, exercise being one of the most affordable, while also offering other physiologic benefits. High intensity interval training (HIIT) consists of short bouts of maximal intensity exercise, followed by short periods of recovery. Endurance training consists of continuous, steady-state aerobic exercise, usually around 70% to 80% of maximal heart rate for 30 to 60 minutes in duration. Improvements in asthmatic symptoms have been seen utilizing both training protocols; however, most of the participants in these studies have been children. The purpose of this study was to determine if exercise will improve asthmatic symptoms of recreationally active adults, and to determine if there is a difference in interval and endurance training protocols in terms of asthmatic symptoms. It was hypothesized that exercise will improve asthmatic symptoms; however, due to lack of recruitment, the second aim of this study was not addressed. One
recreationally active adult, 26 years of age, with no other chronic diseases, was recruited through the use of flyers. The participant was informed of the risks and benefits before partaking in any training protocol. Due to the fact that only one participant was recruited and time constraints to conduct a crossover design study (as was originally intended), the participant was randomly assigned to a six-week endurance protocol. Biometric and pulmonary measurements were taken before and after the protocol. It may appear that there was a slight decrease in pulmonary functions following the six-week endurance protocol; however, the measurements are likely within normal variation. Because this was a case study, no statistical analyses could be performed to determine statistical significance.
CHAPTER 1: LITERATURE REVIEW

Introduction

Asthma is a chronic lung disease resulting in the narrowing of airways, causing shortness of breath, wheezing, and coughing. In individuals with asthma, the airways become inflamed, the muscles contract, and the airways partially close. In addition, mucus is produced, which makes breathing difficult. Most individuals with asthma have certain triggers, like pollen, pollution, chemicals, or dust, and try to avoid them to reduce asthmatic symptoms. Asthma is not curable, only controllable, and cannot be contracted from another person with asthma. It is typically caused by genetics, allergies, and respiratory infections.

Asthma severity is typically measured by pulmonary function tests using a spirometer, a device to measure the air that flows into and out of the lungs. Three of the measurements used are forced expiratory volume in one second (FEV\(_1\)), forced vital capacity (FVC), and the FEV\(_1\)/FVC ratio. Forced expiratory volume in one second measures the amount of air that can be expelled from the lungs in one second following a full inhalation. Normal ranges are typically between 80% to 120% of the predicted value, which is based on sex, age, and body weight. Forced vital capacity is the amount of air, in liters, which can be
forcibly exhaled following a complete inhalation. Forced expiratory volume in one second/FVC is the ratio of FEV₁ to FVC, and should be about 75% to 80% in healthy individuals. In those with asthma or other chronic lung disease, the ratio will have a reduced value because of bronchoconstriction. In some cases though, the ratio may appear normal because of both a reduced FEV₁ and a reduced FVC.

The prevalence of asthma has been on the rise for the past 10 years, increasing by about 15% in 2009. Asthma symptoms can decrease work productivity and everyday quality of life through symptoms such as coughing, wheezing, and shortness of breath, resulting in missed work or avoidance of certain activities. Not only does asthma affect a person’s quality of life, it also can be expensive, costing the United States about $56 billion each year, including medications and hospitalizations. Because of these high costs, not everyone who requires medication can afford it, and must find an alternative for controlling their symptoms or go untreated. One of these alternatives that do not require funding is physical activity.

People who suffer from asthma generally have a fear of developing symptoms or having an asthma attack and tend to avoid exercise, whether they have taken a bronchodilator or not. If this fear is reduced, those who suffer from
asthma can improve both their asthma symptoms, through an improved pulmonary function, and their overall health, as seen in children. Exercise training has been shown to reduce inflammation and improve awareness of asthma symptoms, resulting in an increased amount of daily physical activity. It also has led to decreased bronchoconstriction and discomfort following an exercise challenge, as well as decreased medication need in children. In addition, individuals who exercised had an improved perception of asthma control and quality of life. Those who exercise also have a greater chance of losing weight, which may reduce asthma symptoms further, by decreasing the weight on the chest, allowing for easier breathing. Although those with asthma may be hesitant to engage in physical activity because of fear of an asthma attack, children who completed six weeks of an exercise program showed significantly less asthma attacks and engaged in more physical activity each week after the intervention than prior to the intervention. These results, observed in children, should be similar in an adult population, and show that conquering an initial fear of their disease can have great impacts on future asthmatic symptoms. Both interval training and endurance training have shown improvements in asthmatic symptoms.
Interval training and endurance training result in similar physiological adaptations that improve both acute and chronic asthmatic symptoms. However, because of the higher intensity of interval training compared to endurance training, some of these adaptations can occur more quickly when training with HIIT. Intensity regulates the acute activation of peroxisome-proliferator activated receptor γ co-activator (PGC) through nuclear translocation, which increases messenger Ribonucleic acid (mRNA) expression, corresponds to mitochondrial gene transmission and biogenesis, and increases the activation of adenosine monophosphate activated protein kinase (AMPK) which regulates the uptake of glucose and the breakdown of fatty acids for energy. Therefore, HIIT would produce a greater amount of PGC than endurance training. Peroxisome-proliferator activated receptor γ co-activator (PCG) works against inflammation, which could help those suffering from airway inflammation, reducing asthmatic symptoms. In addition, greater increases in cardiorespiratory fitness were found following HIIT compared to endurance training. High intensity interval training also improved endothelial function more than endurance training. Improved endothelial function can increase blood flow throughout the airway, reducing acute bronchoconstriction and improving bronchodilation. Endurance exercise reduces the ventilatory equivalent of oxygen and increases the efficiency of each breath. In chronic adaptation, tidal volume generally increases, and breathing
rate decreases, allowing the lungs to extract more oxygen with each breath. With these adaptations, individuals with asthma would be able to utilize more oxygen with each breath compared to before training.

High Intensity Interval Training

High intensity interval training (HIIT) consists of short bouts of maximal effort exercise separated by periods of rest. This type of exercise can result in similar pulmonary adaptations as endurance type exercise. HIIT has also been shown to decrease acute bronchoconstriction during exercise and even promote bronchodilation. In addition, HIIT has quick results, and can significantly increase maximal oxygen consumption (VO2max), a chronic adaptation, after only six sessions as seen in a study by Astorino et al. Although Astorino et al. included healthy men and women, it has implications for individuals with asthma. Due to the quick improvements in oxygen consumption, HIIT could lead to faster results, increasing adherence and decreasing overall asthmatic symptoms. Mickleborough et al. utilized a three-way crossover design with high-intensity interval warm-ups, salbutarol (a drug to relieve bronchospasms), and a combination of the previous two. Each participant completed all three experimental interventions on separate days, each followed by an exercise challenge and pulmonary function tests. The warm-up protocol consisted of
eight, 30-second treadmill sprints, with 45 seconds rest between sprints.

Mickleborough et al.\textsuperscript{15} reported increased bronchodilation with all three interventions, but there was a significantly greater bronchodilation (p<0.05) and significantly greater pulmonary function (p<0.05) with the combined salbutarol and warm-up intervention. Mickleborough et al.\textsuperscript{15} observed improved bronchodilation through the increase in FEV\textsubscript{1} following the salbutarol (+8.9 ± 6.1\%) and the salbutarol plus warm-up (+15.2 ± 4.6\%) conditions. In addition, significantly (p<0.05) reduced exercise induced bronchospasm (measured by the area under the curve plotting fall in FEV\textsubscript{1} against time post-exercise) was observed in the warm-up session (-90.2 ± 26.4) compared to the control group (-135.6 ± 32.3).\textsuperscript{15} The results suggest that the drug-induced bronchodilation has a greater effect on improved airway inflammation than the high-intensity interval training. It also indicates that salbutarol can significantly improve airway function, without interfering in exercise adaptations, which may increase physical activity adherence in those afraid of asthmatic symptoms.

The observations by Micklerough et al.\textsuperscript{15} are in contrast to those of de Bisschop et al.\textsuperscript{16}, who reported results of reduced asthma symptoms following short repeated warm-up schedules, which could be due to an increased release of inhibitory prostaglandins, reducing bronchoconstriction. The participants refrained from any asthma medication for 12 hours prior to each participation
date. Each participant completed a seven-minute run test with no warm-up (EX1) and returned on a different day to complete the seven-minute run test following a repeated warm-up schedule (EX2). Decreases in peak expiratory flow were observed to be significantly less (p=0.0002) when the run test was preceded by the warm-up. The decreases in peak expiratory flow, recorded as mean (standard deviation), were -37% (14.5%) after EX1, -6.9% (10.2%) after warm-up, and -25% (18.2%) following EX2. The results reported by de Bisschop et al. suggested that a short-repeated warm-up may reduce the severity of asthmatic symptoms post-exercise; however, the children were exercising at altitude while the peak flow meter was calibrated for sea level. In addition, the results may be skewed because they were training in an ideal, controlled climate for individuals with asthma, with little pollution or other triggers. In addition, the sample population consisted of children. This leads to the question of whether individuals with asthma are able to tolerate interval training in a “real world” setting for an extended timeframe, because Mickleborough et al. and de Bisschop et al. utilized only one training and testing day per condition. It should also be determined if these results will be typical for adults.

Emtner et al. conducted a longer term study and observed differences in individuals with asthma after 10 weeks of high intensity interval training (two weeks “inpatient” and eight weeks “outpatient”) in a pool setting. Participants’
FEV\textsubscript{1}, distance covered in a 12-minute walk test, and heart rate following a six-minute submaximal bike test were recorded before and after the 10-week training period. In addition, Emtner et al.\textsuperscript{17} separated the participants into two groups for analyses: those with less physical conditioning than the Swedish population (LCG) and those with similar physical conditioning to the Swedish population (OCG). Researchers observed a greater bronchodilation following the exercise sessions, and participants reported significantly less fear of maximal intensity exercise after two weeks. Following the 10-week intervention, participants had an improved FEV\textsubscript{1}, distance covered in a 12-minute walk test, and heart rate following a six-minute submaximal bike test. The OCG participants had a significantly (p<0.05) increased FEV\textsubscript{1}, % predicted, following the 10-week training period (69\% before and 81\% after intervention).\textsuperscript{17} Distance covered in the 12-minute walk test was significantly (p<0.05) greater in both the LCG and OCG participants, and the LCG participants had a significantly (p<0.05) lower heart rate after the submaximal bike test following the intervention (165 beats per minute before and 152 beats per minute after intervention).\textsuperscript{17} The results reported by Emtner et al.\textsuperscript{17} indicate that, once the fear of exercising is conquered, progress and improvements can be made, and participants will adhere to the program. In addition, the exercise tests to measure pulmonary function before and after training were completed on cycle ergometers, which
could reduce the chance of improvement through muscle memory and adaptation. A second longer-term study conducted by Sidiropoulou et al.\textsuperscript{17} compared an eight-week high intensity interval training intervention to conventional soccer endurance training of boys with asthma, 10 to 14 years of age, and saw similar results as Emtner et al.\textsuperscript{17} All participants recorded a baseline FEV\textsubscript{1} measurement, completed a six-minute submaximal run test, and recorded pulmonary function tests following the run; the run test was performed again following the eight-week training period. The boys were separated into two groups and either completed a standard submaximal soccer training program (control) or the intervention consisting of alternating periods of high and low intensity exercises, incorporating breathing exercises every three to five minutes.\textsuperscript{18} During the training session, none of the boys from the intervention group reported asthmatic symptoms during training; however, four to five boys from the control group (n = 11) reported symptoms during training. In addition, the intervention group recorded significantly (p<0.001) greater distance covered in the six-minute run test following the intervention.\textsuperscript{18} The intervention group recorded significantly (p<0.001) lower percent reductions of FEV\textsubscript{1} following the run test post-intervention compared to the control group (10.74 ± 3.9\% and 17.30 ± 4.58, respectively).\textsuperscript{18} The children not only improved respiratory function, but also improved their endurance.\textsuperscript{18} This strengthens the findings that interval
training has significant impacts on pulmonary function in individuals with asthma in a real world setting.

**Endurance Training**

Endurance training incorporates constant submaximal exercise, using large muscle groups, for an extended period of time, typically for a minimum of 20 minutes.\(^{19}\) This may be seen as a more appropriate protocol for those with asthma because the individuals would not be raising their heart rate as high during exercise and less stress should be placed on the pulmonary system with endurance training compared to high intensity interval training. In general, endurance training results in improved ventilation capacity and reduced breathlessness during exercise due to improved oxygen consumption.\(^{19}\) In addition, like high intensity interval training, endurance training improves quality of life and improves cardiopulmonary fitness.\(^{20}\) Bonsignore et al.\(^{21}\) compared an endurance training regimen without medication to the same regimen with montelukast, a medication to protect against bronchoconstriction. Fifty children were divided into two groups and either ingested a placebo or montelukast pill once per day for the duration of the 12-week intervention. Each participant completed an exercise stress test, as well as a bronchial responsiveness test, including spirometry, before and after 12 weeks of aerobic
circuit training. Bonsignore et al.\textsuperscript{21} observed similar improvements in children’s maximal workload and pulmonary functions in both the placebo and montelukast groups, however, only the montelukast group produced significantly (p<0.05) fewer moderate asthma exacerbations (those requiring an inhaled corticosteroid) compared to the training only group the previous year.\textsuperscript{21} In addition, both the placebo and montelukast groups had significantly (p<0.05) greater oxygen consumption at anaerobic threshold during the exercise stress test post-training compared to pre-training, with no significant differences between groups.\textsuperscript{21} Maximum heart rate post-training was significantly (p<0.05) greater at post-training compared to baseline for both groups.\textsuperscript{21} These results suggest that endurance type exercise is a viable option to improve asthmatic symptoms in children, but a medication may be needed in addition to physical activity for those with severe symptoms.

**High Intensity Interval Training and Endurance Training**

Improvements in asthmatic symptoms and quality of life have been observed in both interval and endurance training protocols. Counil et al.\textsuperscript{22} combined the two types of training. In their protocol, Counil et al.\textsuperscript{22} randomly assigned 16 boys with asthma to either a training or control group. Each participant completed an incremental exercise test on a cycle ergometer, as well
as pulmonary function tests before and after the six-week training period. The training protocol, completed three times each week for six weeks, combined a 45-minute endurance cycle ergometer ride with one-minute maximal effort sprints every four minutes, with full recovery after the sprints. This protocol was well tolerated by children with mild to moderate asthma. Following the six-week intervention, Counil et al.\textsuperscript{22} reported a significantly greater maximal oxygen consumption (VO\textsubscript{2max}) \textit{(p<0.05)}, maximum heart rate \textit{(p<0.01)}, ventilatory reserve \textit{(p<0.05)}, oxygen consumption at anaerobic threshold \textit{(p<0.01)}, and peak power \textit{(p<0.05)} in the boys in the training group compared to pre-intervention.\textsuperscript{22} These results suggest an improved exercise tolerance by the boys in the training group, which could lead to improved asthmatic symptoms. Varray et al.\textsuperscript{23} compared endurance training to interval training with a non-crossover design. Fourteen children with asthma were divided into either a control group or swimming group. All participants completed a maximal incremental exercise test on a cycle ergometer and had their pulmonary function tests measured at baseline, at three months, and at six months. In this non-crossover design, the swimmers first completed an endurance protocol two times each week for three months, followed by a high intensity interval training protocol completed two times each week for three months, with no time off between protocols. The control group completed no exercise. The endurance protocol consisted of three
sets of a 10-minute swim at individual ventilatory threshold. The high intensity interval training protocol consisted of two sets, separated by complete recovery, of six 25-meter sprints (swimming) at maximal speed, separated by one minute rest. Varray et al. reported a significant increase in maximal oxygen consumption (VO\textsubscript{2}max; p<0.001), ventilatory threshold (p<0.01), and maximum heart rate (p<0.05) in the swimming group following the endurance training compared to baseline. These measures did not differ between the endurance and high intensity interval training. Maximal oxygen consumption (VO\textsubscript{2}max) and maximum heart rate were significantly greater in the swimming group compared to the control group (p<0.01 and p<0.05, respectively) after the high intensity interval training. In addition, both VO\textsubscript{2}max and ventilatory threshold were significantly greater (p<0.001) in the swimming group compared to the control group following the endurance training. Varray et al. did not use a crossover design, so there is no indication if these results are from each training protocol or because the endurance exercise was performed prior to the interval exercise with no detraining period in between sessions. In addition, there were no adult participants, and there was no way to determine if the participants were actually exercising at maximal intensity during the interval training, because only time was recorded. This may skew the results of the interval training adaptations.
Conclusion

The preceding studies verify that exercise training is a viable intervention for those with asthma. However, there are adaptations seen with both high intensity interval training and endurance training. Although some individuals with asthma may be initially fearful of physical activity, the improvements in pulmonary function, muscular power, and quality of life should be a good motivation to begin physical activity. Participants in the previous research may not have been exercising at their full potential because of their fears of developing asthmatic symptoms. For this reason, recreationally active adults with asthma will be recruited as participants in the present study. In addition, many of these previously named studies involved child participants. Research is required in adults to observe any differences in training adaptations between adults and children.

The use of an asthma medication while completing the exercise has also shown significant improvements over exercise or medication alone. This enabled more participants to engage in physical activity without the worry of developing asthmatic symptoms. Most of the previous researchers, however, did not use long-term protocols, and it is difficult to determine if these exercise interventions are able to be carried out for a long period of time, to continually improve airway
function. Varray et al.23 is a start for directly comparing interval and endurance training, but additional research is needed. A crossover study design may allow researchers to determine if one training produces better adaptations than the other. In addition, some of the previously mentioned studies provided the participants with an ideal or close to ideal environment for the physical training. It was, therefore, the original purpose of the present study to compare the effectiveness of interval and endurance training to minimize asthmatic symptoms in recreationally active adults.
CHAPTER 2: SPECIFIC AIMS AND HYPOTHESES

Specific Aim 1: To determine whether exercise can improve asthmatic symptoms of recreationally active adults.

Hypothesis: Exercise will improve asthmatic symptoms of recreationally active adults.

Specific Aim 2: To compare the effectiveness of endurance and high intensity interval training on reducing asthmatic symptoms in recreationally active adults

Specific Aim Addendum: Due to the lack of participants and time constraints, only the endurance protocol was completed and no comparison between endurance and high intensity interval training was made.
CHAPTER 3: METHODOLOGY

The original design of the present study incorporated a cross-over design with a six-week endurance protocol, two weeks rest, followed by a six-week interval protocol, as represented in Figure 1 on page 24. Due to difficulty in recruiting, there was only one participant in the study, and the cross-over design was eliminated due to time constraints.

The present study was first approved by the Drexel University Institutional Review Board. Recruitment methods included the strategic placing of flyers (Appendix A) in the Philadelphia area, at asthma and allergy clinics, around the Drexel University Campus and inside the Drexel Recreation Center. Pulmonologists in the Philadelphia area were also contacted for patient recruitment. Despite all of these recruitment efforts, only one recreationally active woman with diagnosed mild to moderate controlled asthma was recruited. Recreationally active was defined as exercising a minimum of two days per week. This was chosen to ensure that the participant was comfortable with exercise, but not excessively training to ensure the exercise protocol would result in adaptations. The individual who responded to the flyer was given access to an online pre-screening survey (Appendix B) to ensure she qualified for the study. The participant was 26 years of age and had diagnosed asthma that was well controlled. Well-controlled asthma was defined as symptoms twice or
less per week, a forced expiratory volume in one second (FEV$_1$) greater than 80% of predicted value$^{25}$, and a FEV$_1$/forced vital capacity (FVC) of less than 0.70.$^{25}$ Exclusion criteria included those less than 18 or greater than 40 years of age to minimize any risks of contraindications to exercise, those with known cardiovascular disease, osteoporosis, diabetes mellitus, hypertension, obesity (body mass index > 30 kilograms/meter squared [kg/m$^2$]), and those who have sought medical treatment for uncontrolled asthma within the past 12 months. The participant who completed the study had the opportunity to review her pulmonary function tests and her results for the exercise protocol.

The participant was informed of the benefits and risks of the study prior to beginning the Institutional Review Board (IRB) approved protocol. The participant was given ample time to read an informed consent document and ask any questions regarding her participation. Once oral and written consent was given, which included the participant initialing each page of the informed consent document, and the researcher witnessed (signed) the informed consent document, the participant was asked to complete a Physical Activity Readiness Questionnaire (Appendix C) to determine if the participant should seek physician approval before beginning the study. If the participant required physician approval prior to beginning the study, the participant was required to contact her physician, and give an original letter from her physician to the
researcher. In addition, pulmonary function tests (FEV₁, FVC, and FEV₁/FVC) were measured to ensure the participant qualified for the study. The participant was asked to refrain from taking fast-acting bronchodilators for 12 hours prior to the test to ensure the results of the pulmonary test would accurately measure the degree of bronchoconstriction of the individual.¹⁵

Baseline measurements were taken, including height (centimeters [cm]), body weight (kilograms [kg]), body mass index (BMI; kg/m²), blood pressure (mm Hg), resting heart rate (beats per minute [bpm]) FEV₁, FVC, FEV₁/FVC, and a 24-hour diet recall. Body composition was measured using bioelectrical impedance analysis (BIA) with an Inbody 520 Body Composition Analyzer (Biospace, Cerritos, California) at baseline and post-intervention. The participant was asked to refrain from caffeine eight hours prior to her appointment.¹⁵ Height was measured using a stadiometer (Seca 700, Chino, California). Body weight was measured using a balance beam scale (Seca 700, Chino, California). Blood pressure was measured manually using an American Diagnostic Corporation (ADC) proscope aneroid adult sphygmomanometer (Haupauge, New York) and ADC adscope 609 stethoscope (Haupauge, New York). Three measurements were taken, one sitting, one standing, and one lying supine. All measurements were taken on the right arm. All anthropometric measurements were recorded on the appropriate data collection sheet (Appendix D). All pulmonary function
tests were measured using an Encore Metabolic Cart operating Vmax™ software (Carefusion, San Diego, California) with a spirometer. All measurements were taken three times to ensure accuracy (Appendix E). In addition, the participant completed a 24-hour diet recall using the Automated Self-administered 24-hour recall-2014 (ASA24-2014; Appendix F). The participant was asked to complete a short questionnaire each week regarding additional exercise beyond the protocol (Appendix G). Heart rate was measured at the first and last training sessions of the protocol to determine any adaptations due to training (Appendix H). The heart rate measurement was taken at rest, 10 minutes into the endurance protocol, then 10 minutes after the endurance protocol. Heart rate was only measured at the first training bout and the last endurance training bout. Had the interval training protocol been completed, heart rate would have been measured during the HIIT training (Wingate protocol), as well. Heart rate would have been measured at rest, during the third high intensity training bout of the Wingate protocol, then 10 minutes after the Wingate protocol. As per the endurance training, heart rate would only be measured at the first training bout and the last high intensity interval training bout.

The participant was randomly assigned to complete one six-week endurance exercise protocol. Two pieces of paper were folded up with “endurance” or “interval” written inside. The papers were shuffled on a table
and one was selected by a person who was not involved with the study. All biometric and pulmonary function measurements were taken before and after the six-week training protocol. The pulmonary function tests were measured two days after the final exercise session. These were taken at rest, not following exercise, to determine if exercise affects chronic asthmatic symptoms.

The interval training protocol that had planned to be used was the Wingate protocol on a mechanically braked cycle ergometer adapted from Astorino et al.\textsuperscript{14} who reported an increase in maximal oxygen consumption after only six sessions. An exercise protocol on a cycle ergometer was chosen because it requires minimal skill and exercise can be terminated easily if needed.\textsuperscript{24} If completed, each participant would have completed a warm-up pedaling for five minutes with no weight on the flywheel. Following the warm-up, the participant would have pedaled as fast as she could for about six seconds to determine her peak cadence. After two minutes of recovery, the participant would have reached her peak cadence again, and a resistance equal to 7.5% of her body weight would have been applied to the flywheel. The participant would have pedaled all out for 30 seconds, recovered for five minutes, and repeated the protocol for a total of four times during weeks one and two. The peak cadence would have been reduced by 20 revolutions per minute after each segment of the protocol to account for fatigue.\textsuperscript{14} The participant would have completed this
protocol three times each week for six weeks because the American College of Sports Medicine (ACSM) recommends at least three days of exercise each week. Each training session would have been separated by at least 48 hours to allow for recovery to reduce the risk of overtraining or injury. During weeks three and four, the participant would have completed five rounds of the Wingate protocol, and during weeks five and six, the participant would have completed six rounds of the Wingate protocol, to minimize plateaus in progress due to physiological adaptations. During the first and last training bout, heart rate would have been recorded at rest, during the third bout of exercise, and 10 minutes after the exercise was completed. If time had allowed, a crossover design study would have been completed with the two protocols. A significant reduction in maximal oxygen consumption (VO$_2$max) and working capacity have been observed after two weeks of sedentary behavior; therefore, two weeks would have been used to separate the two exercise protocols to allow time for the participant to detrain.

The endurance training protocol required the participant to complete a continuous exercise on a mechanically braked cycle ergometer at 74% to 84% estimated maximum heart rate (Karvonen method [220 - age in years]) three times each week for six weeks, based on the ACSM endurance recommendations for individuals with fair to average physical fitness. For the first two weeks, the participant performed 30 minutes of continuous exercise each session, the
minimum recommended by ACSM for individuals with fair to average fitness levels\textsuperscript{24}, weeks three and four consisted of 40 minutes of continuous exercise, and weeks five and six consisted of 50 minutes of continuous exercise each session. The 10-minute increases in physical activity each week were based on the ACSM recommendation to increase physical activity by five to 10 minutes every 1 to 2 weeks.\textsuperscript{24} In addition, by increasing the length of exercise over the course of the six weeks for both the interval and endurance protocols, the participant was able to continue to make progress in her physiological adaptations due to exercise. The heart rate measurement was taken at rest, 10 minutes into the endurance protocol, then 10 minutes after the endurance protocol was completed. The participant was asked to maintain a consistent diet for the entirety of the study to reduce the risk that a change in diet may affect weight loss or pulmonary functions. To record any changes in diet, the participant was asked to complete a 24-hour diet recall using ASA24-2014\textsuperscript{26} before and after the six-week protocol.

The participant was able to leave the study at any time for any reason. In addition, the researcher had the opportunity to ask the participant to leave the study if she was not adherent or for other reasons (e.g., safety). The reason(s) would have been recorded if the participant no longer wished to partake in the study or was asked to leave the study.
Figure 1. Crossover study design for original protocol. (PAR-Q: Physical Activity Readiness Questionnaire)
**Statistical Analyses**

At the start and completion of the exercise protocol, height, body weight, blood pressure, FEV₁, FVC, and FEV₁/FVC were measured on the participant, as well as a 24-hour diet recall. Due to the difficulty in recruiting participants for this study and the sample size of one, descriptive statistics were used to analyze the data to determine if the exercise protocol improved asthmatic symptoms.

**Summary**

Asthma is a chronic lung disease resulting in the narrowing of airways and symptoms including coughing and wheezing.¹ There are a number of pharmaceutical treatment options with side effects; however, exercise, if effective would be the best option for treatment. Exercise is cost-effective and results in overall health benefits. Results from a number of studies indicate that exercise may have a positive effect on asthmatic symptoms while increasing maximum oxygen consumption (VO₂max) and maximum heart rate, indicating exercise adaptation. However, the majority of participants in these studies were children. In addition, many of the researchers did not mention if the participants were previously physically active. Individuals with asthma tend to have an initial fear of developing symptoms from physical activity, and may refrain from exercise. This may lead to an inaccurate determination as to whether exercise is an effective treatment for asthma. Recruiting participants who are already
physically active may help reduce the risk of participant dropout or fear of completing the exercise protocols.

Only one study, conducted by Varray et al.\textsuperscript{23} directly compared high intensity interval training to endurance training. All of the child participants completed the endurance training first, followed by the high intensity interval training protocol, with no period for detraining in between protocols. The study design by Varray et al.\textsuperscript{23} leads to questions as to whether the initial endurance training skewed the results for the high intensity interval training protocol. The aim of the present study was to directly compare high intensity interval training with endurance training on asthmatic symptoms; however, due to difficulty in recruitment, only the endurance protocol was completed. The original design of the study required participants, consisting of recreationally active adults, to complete a cross-over design of six weeks of endurance training and six weeks of high intensity interval training separated by a two-week period for detraining. A significant reduction in maximal oxygen consumption (\( VO_{2\text{max}} \)) and working capacity have been observed after two weeks of sedentary behavior\textsuperscript{24}. It was expected that the participants would have significant improvements in asthma symptoms.
CHAPTER 4: RESULTS

Although the original aim of this study was to recruit two to 10 participants for a crossover design study to compare asthmatic symptoms between an endurance protocol and interval protocol, recruitment was difficult. After recruitment efforts across the Drexel campus, local asthma and allergy clinics, and through pulmonologists in the Philadelphia area, only one participant was recruited for the study and was assigned to the endurance protocol. Only the endurance protocol was completed due to time constraints. Due to the small participation, data were analyzed using descriptive statistics only.

The participant’s descriptive data are listed in Table 1. Pulmonary function test results at Baseline and Week 6 are listed in Table 2 and Table 3, respectively. It may seem like there was a slight decrease in pulmonary functions following the endurance protocol; however, the results are likely within normal variations. Statistical analyses could not be performed on one participant. The weekly exercise of the participant, as reported by weekly surveys, is listed in Table 4. The pulmonary function data from the present study are compared to previous research in Table 5. All raw data are presented in Appendix I.
Table 1. Participant Descriptive Data at Baseline and Week 6

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (centimeters)</td>
<td>171</td>
<td>171</td>
</tr>
<tr>
<td>Body Weight (kilograms)</td>
<td>56.8</td>
<td>56.9</td>
</tr>
<tr>
<td>Body Mass Index (kg/m^2)</td>
<td>19.3</td>
<td>19.5</td>
</tr>
<tr>
<td>Percent Body Fat (%)</td>
<td>13.1</td>
<td>12.9</td>
</tr>
<tr>
<td>Blood Pressure (supine; mm Hg)</td>
<td>118/82</td>
<td>118/78</td>
</tr>
<tr>
<td>Blood Pressure (sitting; mm Hg)</td>
<td>118/76</td>
<td>112/70</td>
</tr>
<tr>
<td>Blood Pressure (standing; mm Hg)</td>
<td>124/78</td>
<td>122/76</td>
</tr>
</tbody>
</table>
Table 2. Pulmonary Function Measurements at Baseline of Endurance Protocol

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV₁ (Liters)</td>
<td>3.97</td>
<td>3.95</td>
<td>4.15</td>
<td>4.02</td>
</tr>
<tr>
<td>FVC (Liters)</td>
<td>4.67</td>
<td>4.56</td>
<td>4.98</td>
<td>4.74</td>
</tr>
<tr>
<td>FEV₁/FVC (%)</td>
<td>85</td>
<td>87</td>
<td>83</td>
<td>85</td>
</tr>
</tbody>
</table>

FEV₁: Forced Expiratory Volume in one Second; FVC: Forced Vital Capacity

Table 3. Pulmonary Function Measurements at Week 6 of Endurance Protocol

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV₁ (Liters)</td>
<td>4.05</td>
<td>3.88</td>
<td>3.91</td>
<td>3.95</td>
</tr>
<tr>
<td>FVC (Liters)</td>
<td>4.83</td>
<td>4.7</td>
<td>4.71</td>
<td>4.75</td>
</tr>
<tr>
<td>FEV₁/FVC</td>
<td>84</td>
<td>83</td>
<td>83</td>
<td>83</td>
</tr>
</tbody>
</table>

FEV₁: Forced Expiratory Volume in one Second; FVC: Forced Vital Capacity
### Table 4. Weekly Survey Results of Exercise by the Participant in Addition to Study Exercise Protocol

<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>Frequency</th>
<th>Intensity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>None</td>
<td>0</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>Week 2</td>
<td>Aerobic</td>
<td>1</td>
<td>moderate</td>
<td>1.5 hours</td>
</tr>
<tr>
<td>Week 3</td>
<td>Aerobic</td>
<td>2 to 3 times</td>
<td>moderate</td>
<td>40 to 50 minute sessions</td>
</tr>
<tr>
<td>Week 4</td>
<td>None</td>
<td>0</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>Week 5</td>
<td>None</td>
<td>0</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>Week 6</td>
<td>Aerobic</td>
<td>1</td>
<td>moderate</td>
<td>1.5 hours</td>
</tr>
</tbody>
</table>

N/A = not apply

This was a short questionnaire developed by the research (AppendixG)
<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Merlie</th>
<th>Mendes et al.\textsuperscript{30}</th>
<th>Emtner et al.\textsuperscript{17}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Endurance</td>
<td>Endurance</td>
<td>Interval</td>
</tr>
<tr>
<td></td>
<td>(6 weeks)</td>
<td>(3 months)</td>
<td>(10 weeks)</td>
</tr>
<tr>
<td>FEV\textsubscript{1} (L) Pre-Intervention</td>
<td>4.02</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>FEV\textsubscript{1} (L) Post-Intervention</td>
<td>3.95</td>
<td>2.3</td>
<td>2.5</td>
</tr>
<tr>
<td>FVC (L) Pre-Intervention</td>
<td>4.74</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>FVC (L) Post-Intervention</td>
<td>4.75</td>
<td>3.1</td>
<td></td>
</tr>
</tbody>
</table>

FEV\textsubscript{1}: Forced Expiratory Volume in one Second; FVC: Forced Vital Capacity;

L = Liters
CHAPTER 5: DISCUSSION

The original purpose of the study was to compare asthmatic symptoms after completion of an endurance training protocol and an interval training protocol. Due to low recruitment, only the endurance protocol was completed by one participant, therefore it cannot be determined if there were differences in pulmonary functions between baseline and week six of the endurance training protocol.

This is in contrast to a longer study conducted by Mancuso et al.\textsuperscript{27} in which enrolled men and women, 43 years of age (average), were encouraged to increase physical activity over a 12-month period to observe changes in asthmatic quality of life. This was measured through several validated scales. The Asthma Control Questionnaire (ACQ) focused on medications and symptoms. The ACQ scores range from zero to six, with a lower score indicating better control of asthma. The Severity of Asthma Scale (SOA) focused on long-term asthma medications and hospitalizations. Scores for the SOA range from zero to 28, with a higher number indicating more severe asthma. The final scale used was the Asthma Quality of Life Questionnaire (AQLQ), which focused on limitations due to asthma and emotional and environmental effects. Scores for the AQLQ range from zero to seven, a higher score indicating a higher quality of life. The results showed an improvement in AQLQ score at four months, which
was maintained through the 12th month (5.0±1.3 at baseline and 5.9±1.1 at four months). Furthermore, the ACQ score was improved from 1.43 at baseline to 0.84 at 12 months (P<0.0001 for within-patient change). Most of the participants engaged in walking as their physical activity, with only 45% to 55% engaging in formal exercise. This demonstrates the impact of a small amount of activity on asthmatic quality of life. There was no comparison of improved quality of life based on type or intensity of exercise, which was the original aim of the present study. The improvement of asthmatic symptoms after 12 months in the Mancuso et al. study leads to the question of whether there may have been differences in pulmonary function in the present study if the length of the exercise protocol had been greater than six weeks, and with more participants, which is a major limitation to this study.

Similar to Mancuso et al.’s study, Garcia-Aymerich et al. observed a significant difference between amount of physical activity reported and asthmatic exacerbations. More than 2,000 women with mild to moderate asthma were sent surveys over the course of 12 years to monitor reported physical activity and asthma exacerbations (at least one hospital admission, emergency department visit, or urgent office visit for asthmatic symptoms in a 12-month period). A significant (p=0.05) inverse relationship was observed between level of physical activity and amount of exacerbations. However, the results did not
indicate what type or intensity of physical activity in which the participants were engaged. Garcia-Aymerich et al.\textsuperscript{28} and Mancuso et al.\textsuperscript{27} demonstrated the importance of consistent physical activity on the control of asthmatic symptoms; however it is not clear whether there is a specific type of activity that reduces symptoms to a greater extent.

Latorre-Román et al.\textsuperscript{29} observed improved asthmatic symptoms in children who performed an exercise intervention. In a 12-week study, the researchers randomly assigned children (mean of 11.5 years of age) with controlled asthma into either a control group or an experimental group. The experimental group completed three, one-hour sessions each week incorporating various exercises, such as intervals, flexibility, running, walking, and relaxation. The sessions consisted of a 10-minute warm-up of arm and leg exercises, 40 minutes of alternating aerobic and anaerobic exercises, like running or walking at different speeds or team sports, and strength training. The session ended with a 10-minute cool-down session of stretching, balance, and coordination exercises.\textsuperscript{29} Latorre-Román et al.\textsuperscript{29} observed significant (p<0.001) differences in forced expiratory volume in one second (FEV\textsubscript{1}) between the experimental (+1.22 Liters) and control groups (-0.12 Liters) following the 12-week intervention. Quality of life was measured by the Pediatric Asthma Quality of Life
Questionnaire (PAQLQ), which indicates daily restrictions based on asthmatic symptoms; higher scores indicate fewer daily restrictions.

Latorre-Román et al.\textsuperscript{29} observed significantly (p<0.001) improved PAQLQ scores in the experimental group (+2.51) compared to the control group (-0.17) following the 12-week intervention\textsuperscript{29}. One limitation in the study by Latorre-Román et al.\textsuperscript{29} is that it is not known in what behaviors the participants were partaking outside of the intervention. This research, as well as the research conducted by Manusco et al.\textsuperscript{27} and Garcia-Aymerich et al.\textsuperscript{28}, indicates that exercise is much more beneficial for children and adults with asthma, than not exercising to avoid asthmatic symptoms. The methods of the present study were based on previous studies in children, but a longer intervention, a greater number of participants, and additional measures, like quality of life, in the present study may have enabled significant results to be observed. Regular physical activity, whether walking, running or interval training, can alleviate asthmatic symptoms and improve quality of life.

Research by Mendes et al.\textsuperscript{30} may be able to explain why exercise is able to reduce asthmatic symptoms through decreased inflammation. Adult participants with diagnosed asthma were randomly assigned to either the control or experimental group. The control group participated in an educational program...
and breathing exercises for three months, while the experimental group participated in an educational program, breathing exercises, and an exercise protocol. The educational program consisted of two, two-hour sessions each week and addressed asthma pathophysiology, medications, self-monitoring techniques, environmental triggers, and avoidance strategies. The education sessions also included a discussion with the participants about their doubts of any topic. The breathing exercises consisted of two, 30-minute sessions each week. Three sets of each exercise were performed with two minutes of exercise and one minute of rest between each breathing exercise. The yoga based breathing exercises included a fast expiratory breathing exercise, followed by passive inhalation, a full exhalation followed by a forced inspiration performed without air inhalation, and a full exhalation followed by a sequence of retractions and protrusions of the abdominal wall. Only participants in the experimental group completed the aerobic training, which consisted of two 30-minute sessions each week on a treadmill. The first two weeks were run at 60% maximal oxygen consumption (VO$_2$max) and the subsequent weeks were run at 70% VO$_2$max. Both the experimental and control group completed the educational program and breathing exercises, but only the experimental group completed the treadmill exercise. There were no significant differences in pulmonary function measures in either group following the intervention; however, the experimental
group significantly (p<0.001) improved maximal oxygen consumption (VO\textsubscript{2}\text{max}) compared to the control group. The experimental group experienced significantly (p<0.05) fewer asthmatic symptoms compared to baseline and the control group. Furthermore, there was a linear relationship between aerobic exercise and symptom-free days (p<0.003).\textsuperscript{30} Fractional exhaled nitric oxide (FeNO) is a measure of airway inflammation\textsuperscript{31} measured by Mendes et al.\textsuperscript{30} The experimental group had significantly (p=0.009) decreased inflammation, as measured by FeNO, compared to baseline and to the control group, while the control group had no change (p>0.05) in inflammation compared to baseline.\textsuperscript{30}

The results reported by Mendes et al.\textsuperscript{30} were not only similar to other researchers reporting decreases in asthmatic symptoms with exercise, but measured the inflammation of the lungs. This indicates that not only are the participants improving aerobic capacity, but the exercise is reducing the inflammation which causes the bronchoconstriction. However, this decrease in inflammation may not have been the same across all participants in previous studies, if it had been measured, because each team of researchers recruited participants with different types and severities of asthma.

Similar to the present study, McKenzie et al.\textsuperscript{32} aimed to compare pulmonary functions of participants with exercise-induced asthma following
interval and continuous exercise protocol. The participants completed a cross-over design protocol consisting of interval and continuous warm-ups and a control prior to a treadmill exercise test. The interval warm-up consisted of eight 30-second sprints on a treadmill at 100% VO$_2$max with 90 seconds rest between sprints. The continuous warm-up consisted of a 15 minute run at 60% VO$_2$max. Each participant rested for two minutes between the intervention and the exercise test. Pulmonary functions were measured at baseline, after the intervention, and after the exercise test. There was a significantly (p<0.05) lower reduction in pulmonary functions from baseline to post-exercise between the continuous warm-up and the control. There was no significant difference in pulmonary function reduction post-exercise between the interval warm-up and control and between the interval warm-up and the continuous warm-up.$^{32}$ The participants performed all three interventions; therefore they can be compared easily, with the knowledge that all groups had the same population. Many of the previously mentioned studies had different populations of varying ages, type, and intensity of asthma, which makes it difficult to directly compare the results.

The present study had only one participant who had exercise- and allergy-induced asthma. Due to the timing of the measurement of pulmonary functions, it is not surprising that changes were not observed. There were no allergens in the indoor laboratory in which the pulmonary function measurements and the
exercise protocol were completed. Furthermore, the pulmonary function measurements were taken at rest, not following exercise, to determine if exercise affects daily asthmatic symptoms. If the present study measured pulmonary functions following the exercise protocol, as McKenzie et al. did, changes may have been observed; however, the results would have represented induced asthmatic symptoms, not daily symptoms experienced regularly by the participant.

One of the strengths of the present study is that the original study incorporated a crossover design, which would have allowed a comparison of both an interval and endurance protocol on asthmatic symptoms. The design, including a two-week washout period, would have decreased the chance that results of one exercise protocol influenced the other. This would have been a novel comparison because there are few studies that compare these two types of exercise, and there are no longer term studies in adults that compare the two.

However, the present study had many limitations. The first was the fact that there was only one participant. Statistical analyses could not be performed on one participant; therefore, it could not be determined if changes occurred due to the exercise protocol, or if they were simply within the normal variations expected. Furthermore, there was a slight decrease in pulmonary functions after the intervention, unlike previous research. To determine if this alteration
was due to the exercise protocol or another factor, more participants needed to be recruited for the study. Additional measures, like surveys, also needed to be utilized to determine if there were improvements in quality of life or perceived asthmatic symptoms. This would be especially useful in those who have exercise- or allergy-induced asthma, which may be difficult to measure through pulmonary function tests without an exercise test immediately preceding it.

The participant in the present study has exercise- and allergy-induced asthma, which may be a reason for the lack of change from baseline to week 6. Furthermore, the present study was recruiting recreationally active participants (2 days per week) to reduce the risk of fear of exercise. The participant in the study was actively training for running races, as indicated on the physical activity questionnaire delivered each week during the intervention. The intervention in the present study may have been ineffective because it was designed from recommendations by the American College of Sports Medicine for those with fair to average fitness levels. The participant may have been at a higher fitness level, reducing the amount of stress on the body from the exercise protocol and reducing adaptations from exercise. The present study took place in a laboratory with a single participant present. Although this is a safe and effective way to control variables, this may not be an effective way to improve physical activity overall. The air quality was controlled and the participant may
have greater asthmatic symptoms when exercising outside or in another uncontrolled environment when her asthmatic triggers are present. Furthermore, if more participants were recruited for the study, a group setting may have been more effective at creating a fun environment with camaraderie among participants, which may be able to improve overall performance.

It is clear that exercise aids in the reduction of asthmatic symptoms; however, further research is needed in order to determine any differences based on intensity or type of exercise. The results of the present study are compared to results of previous research in Table 5 in the results chapter. Mendes et al.\textsuperscript{30} reported no significant differences in pulmonary functions following a three-month aerobic training intervention; however, maximal oxygen consumption (\(\text{VO}_2\text{max}\)) was significantly (\(p<0.001\)) increased from 73.5\% predicted at baseline to 88.0\% predicted post-intervention. This suggests that the exercise intervention was beneficial in improving lung function, despite the lack of changes in pulmonary functions. Emtner et al.\textsuperscript{17}, on the other hand, reported a significant (\(p<0.05\)) improvement of FEV\(_1\) following a 10-week interval training intervention. The time that pulmonary function tests were taken was not stated. This timing, whether immediately after exercise or several days later, may play a role in observed changes. Furthermore, there is limited research in adults, which makes it difficult to directly compare results of studies. Nonetheless, although no
statistical analyses could not be conducted in the present study, due to the recruitment of only one participant, previous research with more participants demonstrated the various results in pulmonary function tests.

The present study was based on previous research with child participants that showed differences in pulmonary function measurements following a six-week, or shorter, exercise protocol. Adults may not be able to improve lung functions in that short of a time frame because of the decrease in lung function as adults increase age. For this reason, it may be beneficial to speak with several pulmonologists prior to designing an exercise intervention. They may have been able to provide feedback on exercise protocols, to provide methods used to measure asthmatic symptoms, and to assist in recruitment.

The present study could have incorporated a longer intervention that could have produced measureable results. Furthermore, a group setting could have helped with recruitment. Another option would have been to collect data through the use of surveys. This would have enabled data collection from a much wider area across the nation or world, with little commitment from the participants. However, these types of data are not as accurate as supervised exercise.

In conclusion, differences in pulmonary function measures could not be determined following a six-week endurance protocol because only one
participant was recruited, and the slight changes seen were likely due to normal variations; however, no statistical analyses could be performed. Previous research indicates that exercise may have anti-inflammatory effects and may help improve asthmatic symptoms. These studies are conducted with a wide range of participants with varying age, type and severity of asthma, type and intensity of exercise, and length of protocol. Furthermore, different measures, like pulmonary function measurements and asthma quality of life questionnaires, are used to evaluate severity of asthma and the extent to which exercise improves symptoms. The present study only measured pulmonary function measures at rest before and after the six-week exercise protocol to determine any differences in daily asthmatic symptoms. There may have been no differences in pulmonary functions in the present study because the one participant had allergy- and exercise-induced asthma. All measurements were conducted in a lab, free of allergens, and no exercise was performed on the day of the pulmonary function tests. Further research is needed to determine if there is a difference in asthmatic symptoms and quality of life based on type or intensity of training, and if one training type is more advantageous based on age or type and severity of asthma.
REFERENCES


10. Wanner A, Mendes EA. Airway Endothelial Dysfunction in Asthma and Chronic Obstructive Pulmonary Disease: A Challenge for Future


Appendix A

_Drexel University_
Recruiting Volunteers for a Research Study

**Research Title**
Effectiveness of Interval vs. Endurance Training to Minimize Asthmatic Symptoms in Recreationally Active Adults

**Research Objectives**
The purpose of this study is to measure the effectiveness of exercise on alleviating asthmatic symptoms. This 14-week study involves completion of two exercise protocols, interval and endurance, three times each week for six weeks each.

**Information for Research Subjects Eligibility**
You can participate in this study if you are 18-40 years of age, recreationally active at least two days per week, and diagnosed with well-controlled asthma or exercise-induced asthma. If you meet the above criteria, please contact us using the contact information below.

**Location of the research and person to contact for further information**
This research is approved by the Institutional review board.
If you are interested in participating in this study, please contact
Margaret Merlie
610-745-1964
drexelasthma@gmail.com
Research will be conducted at 1601 Cherry St, Room 325A

This research is conducted by a researcher who is a member of Drexel University.
Appendix B

Prescreening Survey

You have been given access to this pre-screening survey because you have shown interest in taking part in a research study about asthmatic symptoms and exercise. If you qualify to participate in this study, it entails a 14-week commitment, during which time you will be asked to partake in two types of exercise protocols (interval training and endurance training). Each protocol involves 3 sessions each week for 6 weeks. Body composition and pulmonary function tests will be completed before and after each protocol. Each exercise session will be scheduled at your convenience and will take place in the Drexel University Nutrition Sciences Laboratory at 1601 Cherry Street, Philadelphia, PA.

1. What is your age (in years)?
2. What is your sex?
3. How many times each week do you exercise and for how long each session?
4. What type of exercise? What intensity?
5. Have you been diagnosed with asthma?
6. What triggers your asthma?
7. Are you currently on any medications? If so, please list.
8. Have you ever been diagnosed with any of the following:
   a. Cardiovascular disease
   b. High blood pressure
   c. Diabetes Mellitus
   d. Obesity
   e. Osteoporosis
   f. Other (please list):
9. When was the last time you experienced an asthma attack that required you to seek medical treatment?
Appendix C

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

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

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?</td>
<td>□ □</td>
</tr>
<tr>
<td>2. Do you feel pain in your chest when you do physical activity?</td>
<td>□ □</td>
</tr>
<tr>
<td>3. In the past month, have you had chest pain when you were not doing physical activity?</td>
<td>□ □</td>
</tr>
<tr>
<td>4. Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td>□ □</td>
</tr>
<tr>
<td>5. Do you have a bone or joint problem (e.g., back, knee or hip) that could be made worse by a change in your physical activity?</td>
<td>□ □</td>
</tr>
<tr>
<td>6. Is your doctor currently prescribing drugs (e.g., water pills) for your blood pressure or heart condition?</td>
<td>□ □</td>
</tr>
<tr>
<td>7. Do you know of any other reason why you should not do physical activity?</td>
<td>□ □</td>
</tr>
</tbody>
</table>

If you answered YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kind of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live activity. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/84, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- If you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

I have read, understood and completed this questionnaire. Any questions I had were answered to my fullest satisfaction.

NAME:

SIGNATURE OF PATIENT

SIGNATURE OF GUARDIAN (for participants under the age of 18 years)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.
Appendix D

Anthropometric Data Collection Sheet

Date:________________________         Time:_______________
Protocol:________________________   Week:_______________
Participant #: _________________

Height (cm):           1. _______    2._______   3.________
Body Weight (kg): 1. _______    2. _______  3. ________
Body Mass Index (kg/m²): __________

Blood Pressure (mm/Hg):
              Supine: _______
              Sitting: _______
              Standing: ______

Percent Body Fat:
              BIA:   _______
              DXA (Week 1 Only): _______

Bone Mineral Density (Week 1 Only): _______
Appendix E

Pulmonary Function Data Collection Sheet

Date: ________________  Time: ___________________

Participant #: ________________

Intervention: _________  Week: ________________

FEV₁: 1. ____  2. _______3. _______

FVC: 1. ____  2. _______3. _______

FEV₁/FVC: 1. ______2. ______3. _______
Appendix F

The Automated Self-administered 24 hour Recall (ASA24) is an online application that leads respondents through a 24-hour recall, filling in gaps, and forgotten foods. Once the respondent finishes, the responses are available for viewing by the researcher. Below is an excerpt of what is seen by the researcher. Additional information can be found at the website: http://appliedresearch.cancer.gov/asa24/.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Description</th>
<th>Data Type</th>
<th>Length</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>USERNAME</td>
<td>Study abbreviation plus researcher-provided ID</td>
<td>Character</td>
<td>30</td>
<td>Assigned per project</td>
</tr>
<tr>
<td>USERID</td>
<td>Unique system ID</td>
<td>Character</td>
<td>38</td>
<td>System assigned GUID such as (40C290AB-4C78-423F-956C-8A86 B5E77B39)</td>
</tr>
<tr>
<td>RECALLNO</td>
<td>Recall number</td>
<td>Numeric</td>
<td>2</td>
<td>1—99</td>
</tr>
<tr>
<td>RECALLATTEMPT</td>
<td>Sequence number for attempt within recall</td>
<td>Numeric</td>
<td>2</td>
<td>1—99</td>
</tr>
<tr>
<td>RECALLSTATUS</td>
<td>The final status of this recall</td>
<td>Numeric</td>
<td>1</td>
<td>1=Food Details Complete, Supplement Details complete; 2=Food Details Complete, No Supplements Reported; 3=Food Details Complete, Supplement Details Breakoff; 4=Food Details Complete, Supplement Details Not Started; 5=Food Details Complete, Supplement Details Not Applicable; 6=Food Details Breakoff</td>
</tr>
<tr>
<td>INTAKESTARTDATETIME</td>
<td>Date and time of the start of the 24-hour period for which the intake is being reported</td>
<td>Date</td>
<td>22</td>
<td>MM/DD/YYYY hh:mm AM/PM</td>
</tr>
<tr>
<td>INTAKEENDDATETIME</td>
<td>Date and time of the end of the 24-hour period for which the intake is being reported</td>
<td>Numeric</td>
<td>22</td>
<td>MM/DD/YYYY hh:mm AM/PM</td>
</tr>
<tr>
<td>REPORTINDATE</td>
<td>The date that the last data were reported within the reporting period. Reporting period is the time within which respondents are allowed to report their intake.</td>
<td>Date</td>
<td>8</td>
<td>mmdyyyyy</td>
</tr>
<tr>
<td>LANG</td>
<td>Language used for recall</td>
<td>Numeric</td>
<td>1</td>
<td>1=English 2=Spanish</td>
</tr>
<tr>
<td>AMTUSUAL</td>
<td>Respondent’s assessment of amount of food consumed on intake day</td>
<td>Numeric</td>
<td>1</td>
<td>1=Much more than usual 2=Usual 3=Much less than usual 8=Don’t know</td>
</tr>
<tr>
<td>SALTTYPE</td>
<td>Type of salt added to foods at the table</td>
<td>Numeric</td>
<td>1</td>
<td>1=Ordinary, sea, seasoned, or other flavored salt 2=Lite salt 3=Salt substitute 4=None 5=Other 8=Don’t know 9=Not applicable</td>
</tr>
<tr>
<td>Field Name</td>
<td>Description</td>
<td>Data Type</td>
<td>Length</td>
<td>Codes</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>--------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SALTREQ</td>
<td>How often salt is added to foods at the table</td>
<td>Numeric</td>
<td>1</td>
<td>1 = Rarely, 2 = Occasionally, 3 = Very often, 4 = Other, 8 = Don't know, 9 = Not applicable</td>
</tr>
<tr>
<td>SALTUSED</td>
<td>How often regular or seasoned salt is added to foods during preparation</td>
<td>Numeric</td>
<td>1</td>
<td>1 = Never, 2 = Rarely, 3 = Occasionally, 4 = Very often, 5 = Other, 8 = Don't know, 9 = Not applicable</td>
</tr>
<tr>
<td>OCC_NO</td>
<td>System assigned sequence number for this eating occasion; eating occasions (meals) are sorted chronologically based on the times reported by respondent. By default, supplements are assigned the final sequence number in the intake.</td>
<td>Numeric</td>
<td>2</td>
<td>1–99</td>
</tr>
<tr>
<td>OCC_TIME</td>
<td>Time of eating occasion; supplements are assigned a default time of midnight on the intake day.</td>
<td>Date</td>
<td>19</td>
<td>MM/DD/YYYY hh:mm AM/PM</td>
</tr>
<tr>
<td>OCC_NAME</td>
<td>Name of eating occasion</td>
<td>Numeric</td>
<td>1</td>
<td>1 = Breakfast, 2 = Brunch, 3 = Lunch, 4 = Dinner, 5 = Supper, 6 = Snack, 7 = Just a Drink, 8 = Supplements</td>
</tr>
<tr>
<td>EATWITH</td>
<td>Who was with the respondent for the meal</td>
<td>Numeric</td>
<td>1</td>
<td>1 = Eat alone, 2 = Family Member(s), 3 = Other(s), 4 = Family Member(s) and Other(s), 8 = Don't know Blank = Not applicable</td>
</tr>
<tr>
<td>WATCHTV/USECOMPUTER</td>
<td>Respondent's TV and computer use during the meal</td>
<td>Numeric</td>
<td>1</td>
<td>1 = Watching TV, 2 = Using a computer, 3 = Watching TV and using a computer, 4 = Neither of these Blank = Not applicable</td>
</tr>
</tbody>
</table>
Appendix G

Weekly Questionnaire

Date:______________  Protocol:_______________________

Did you continue normal exercise in addition to the exercise protocol this week?

    If so, what type?

    How long?

    How often?

    At what general intensity?
Appendix H

Heart Rate Data Collection

Date:_________________   Protocol:___________________

Participant #: __________________________________________________

Heart rate at rest (bpm):________________________________________

Heart rate during exercise test (bpm):______    Time taken:_________

Heart Rate 10 minutes after exercise completion (bpm):_____________
### Appendix I

**Raw Data: Baseline Measurements**

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>FEV₁ trial 1</th>
<th>FEV trial 2</th>
<th>FEV trial 3</th>
<th>FVC trial 1</th>
<th>FVC trial 2</th>
<th>FEV₁/FVC trial 1</th>
<th>FEV₁/FVC trial 2</th>
<th>FEV₁/FVC trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>3.97</td>
<td>3.95</td>
<td>4.15</td>
<td>4.67</td>
<td>4.56</td>
<td>4.98</td>
<td>85</td>
<td>87</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Height (cm)</th>
<th>Height (cm)</th>
<th>Height (cm)</th>
<th>Weight (kgs)</th>
<th>Weight (kgs)</th>
<th>Weight (kgs)</th>
<th>BMI</th>
<th>% Fat (BIA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>171</td>
<td>170.8</td>
<td>171.4</td>
<td>56.8</td>
<td>56.8</td>
<td>56.8</td>
<td>19.3</td>
<td>13.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Heart Rate (HR) Rest</th>
<th>HR 10min into bout</th>
<th>HR 10min after bout</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>75</td>
<td>150</td>
<td>78</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Blood Pressure supine; mm Hg</th>
<th>Blood Pressure sitting; mm Hg</th>
<th>Blood Pressure standing; mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>118/82</td>
<td>118/76</td>
<td>124/78</td>
</tr>
</tbody>
</table>

**Raw Data: Week 6 Measurements**

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>FEV₁ trial 1</th>
<th>FEV trial 2</th>
<th>FEV trial 3</th>
<th>FVC trial 1</th>
<th>FVC trial 2</th>
<th>FEV₁/FVC trial 1</th>
<th>FEV₁/FVC trial 2</th>
<th>FEV₁/FVC trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>4.05</td>
<td>3.88</td>
<td>3.91</td>
<td>4.83</td>
<td>4.7</td>
<td>4.71</td>
<td>84</td>
<td>83</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Height (cm)</th>
<th>Height (cm)</th>
<th>Height (cm)</th>
<th>Weight (kgs)</th>
<th>Weight (kgs)</th>
<th>Weight (kgs)</th>
<th>BMI</th>
<th>% Fat (BIA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>171</td>
<td>170.5</td>
<td>171</td>
<td>57</td>
<td>56.8</td>
<td>56.8</td>
<td>19.5</td>
<td>12.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Heart Rate (HR) Rest</th>
<th>HR 10min into bout</th>
<th>HR 10min after bout</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>80</td>
<td>150</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Blood Pressure supine; mm Hg</th>
<th>Blood Pressure sitting; mm Hg</th>
<th>Blood Pressure standing; mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTEND0001</td>
<td>118/78</td>
<td>112/70</td>
<td>122/76</td>
</tr>
</tbody>
</table>

Forced expiratory volume in one second (FEV₁) and forced expiratory volume (FVC) measured in Liters; body mass index (BMI) measured in kg/m²; heart rate measured in beats per minute.