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Cardiovascular Fitness and Muscle Strength in Asthmatic Children

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Abstract

Objective: The aim of this retrospective study is to evaluate the cardiovascular fitness and muscle strength performance of children with asthma versus without.

Methods: Participants include patients who were involved in the 2012 NHANES National Youth Fitness Survey (NNYFS) as published by the Centers for Disease Control and Prevention. The average cardiovascular fitness and muscle strength scores will be appreciated by analyzing the averages of time spent on treadmill, maximal heart rate, heart rate at end of exam, recovery time, maximal endurance time, cardiovascular fitness report, upper body strength and lower body strength using two-tailed T-tests between patients with asthma versus without.

Results: Children with asthma have a statistically lower total time spent on treadmill and maximal endurance time ($p = 0.006$, $p = 0.006$, respectively). Children with asthma do not have statistically different maximal heart rate, heart rate at end of exam, recovery time, cardiovascular fitness, upper body strength, or lower body strength compared to children without asthma.

Discussion/Conclusion: History of asthma should not be considered a direct, baseline cause of decreased cardiovascular fitness or muscle strength performance in children. The anxiety of breathlessness in an asthma attack or lack of proper medical management may encourage asthmatics to have a sedentary lifestyle without engaging in regular physical activity. Our findings support the growing research that encourages the individuals with asthma to pursue a healthy, active lifestyle alongside proper medical management in order to achieve optimal cardiovascular and musculoskeletal health.

Key Words: asthma, childhood asthma, cardiovascular fitness, muscle strength

Introduction

Asthma is a chronic inflammatory airway disease affecting both children and adults with noteworthy social impact and economic burden. Well-known triggers for asthmatic events are differentiated between allergic and nonallergic triggers: allergic triggers include airborne or food allergens; whereas nonallergic triggers include respiratory viral infections, cold air, smoking, exercise, etc.[1,2] Despite the various inciting factors, asthma recognizably presents as an acute onset of wheezing, dyspnea, cough, and chest tightness and may prove fatal if not treated promptly.

It is well established that asthma has a higher incidence and prevalence in children. According to the CDC's national data of 2018, childhood asthma affects 7.5% of population aged less than 18 years old with 53.8% having experienced at least one asthma attack during the year.[3] The childhood diagnosis of asthma may either regress or persist into adulthood, thereby impacting a child's maximally attained lung function as an adult. On the other hand, asthma has higher morbidity and mortality in the adult population, which directly impacts lung function with increased risk of developing respiratory infection, obstruction, or chronic comorbidities.[1] One study identified the global prevalence of asthma as 16.4%, affecting 300 million people worldwide and responsible for 0.4 million deaths in 2017.[4] From the international standpoint, asthma is an epidemic with a disproportionately higher burden in lower to middle income countries. Despite significant progress in healthcare and medical research, asthma is estimated to affect 400 million people by 2025.[1]

Exercise-induced asthma is an important and frequent cause of asthmatic attacks in children. Often, asthmatic children avoid exertional physical activities to order to avoid episodes of bronchoconstriction and dyspnea.[5,6] A habitually reduced level of physical activity and aerobic training leads to chronic deconditioning, paradoxically worsening the respiratory function of children with asthma. One study evaluated asthmatic children with and without steroid treatment, finding that over 20% of the cohort had a cardiovascular fitness level lower than the 5th percentile of healthy children.[7] An overwhelming number of studies have evaluated asthmatic children with incremental aerobic exercise and concluded the poorer cardiovascular function and aerobic fitness was unrelated to bronchial hyperactivity or airflow obstruction, but rather, had more to do with a sedentary lifestyle.[8–12] A large systematic review identified a clear improvement of cardiopulmonary fitness in their asthmatic patients after controlled physical training.[13] Although older studies have evaluated cardiovascular fitness in asthmatic children using maximum oxygen consumption during exercise tests and maximum heart rate achieved in exercise tests, there are gaps in more recent data comparing baseline cardiovascular fitness between asthmatic children and nonasthmatic children on a larger scale.

Cardiovascular and pulmonary strength are common topics of discussion for the childhood asthmatic population; however, peripheral skeletal muscle function has not been as frequently studied in literature. One study evaluated peripheral muscle strength and endurance in children with asthma and identified a preserved maximal upper and lower muscle strength in children with mild and severe asthma compared to children without asthma; although muscle endurance was decreased in the severe asthmatic group.[14] Another study also recognized a significant difference in skeletal muscle endurance but not muscle strength, as identified by a greater lower limb fatigue in their asthmatic study group.[15] In order to highlight the importance for muscle strength training and prevent habitual physical deconditioning in young asthmatics, further research is needed to differentiate and quantify the upper and lower skeletal muscle strength in children with asthma versus without.

With an already declining trend of physical activity levels in children, significant consideration should be made on the effects of asthma on exercise capability, cardiovascular fitness, and peripheral muscle strength. Understanding the baseline differences in cardiovascular health and peripheral muscle strength using a larger scale population of children will help identify the needed areas of improvement for childhood asthmatic education. The aim of this retrospective study is to evaluate the cardiovascular fitness parameters from a treadmill test, upper body muscle strength from a modified pull-up, and lower body muscle strength from isolated knee extensions in children with asthma versus without.

Hypothesis/Specific Aims/Research Questions

How do cardiovascular fitness levels and muscle strength of children with asthma compare to those without asthma?

1. Is there statistical difference in the total time spent on the treadmill exam between children with asthma and those without?
2. Is there statistical difference in the maximum heart rate on the treadmill exam between children with asthma and those without?
3. Is there statistical difference in the average heart rate at the end of the treadmill exam between children with asthma and those without?
4. Is there statistical difference in the average recovery time at the end of the treadmill exam between children with asthma and those without?
5. Is there statistical difference in the maximal endurance time of the treadmill exam between children with asthma and those without?

6. Is there statistical difference in the cardiovascular fitness level on treadmill exam between children with asthma and those without?
7. Is there statistical difference in the average upper body strength between children with asthma and those without?
8. Is there statistical difference in the average lower body strength between children with asthma and those without?

Methods

Context/Protocol

Participants and data were obtained from NHANES National Youth Fitness Survey (NNYFS) in 2012 as published by the Centers for Disease Control and Prevention. NNYFS involved a home interview and physical fitness examination in a mobile examination center. These fitness exams included standardized measurements of cardiovascular fitness by walking and running on a treadmill and upper and lower body muscle strength.

The cardiovascular fitness of participants between the ages of 12 and 15 were evaluated using the NHANES 2004-2006 protocol for aerobic capacity. The participants underwent a treadmill test assigned to them according to their respective gender, age, BMI, and self-reported physical activity.[16] Heart rates were recorded throughout each treadmill test and were used to calculate VO2max using Fitnessgram® criterion-referenced standards.[17] A treadmill test included a 2-minute warm up, two 3-minute exercise periods, and a 2-minute recovery period with the goal of reaching the participant's 75% of predicted maximum heart rate.[16] The predicted maximal heart rate per minute was calculated by 220 minus their age at interview. Relevant data obtained for this study include the following: total time spent on treadmill (minutes), maximum heart rate, heart rate at end of exam, total time to recovery at end of exam, maximal endurance time, and CV fitness level using the estimated VO2 max. A total of 682 participants completed the cardiovascular fitness exam with 451 participants yielding an estimated VO2 max.[18,19]

The upper body muscle strength of participants between ages 5 and 15 were evaluated by a modified pull-up using a modified pull-up bar. The participants were instructed to lie flat on their back and the modified pull-up bar was set 1-2 inches above their outstretched arm length with a nylon strap hanging 8 inches down the center of the bar. While maintaining a straight body posture, the participants pulled their bodies up until their chest touched the nylon strap with only their heels remaining touching the mat. The total number of modified pull-ups until exhaustion was recorded (exhaustion was defined as a pause for 2+ seconds, inability to maintain a straight body posture, or by request). A total of 1310 participants completed the modified pull-up exams.[20]

The lower body muscle strength of participants between the ages 6 and 15 were evaluated by knee extension force using a digital hand-held dynamometer and an exam chair. Participants were seated in the exam chair with their chest, waist, and thighs strapped to limit excessive movement. The participant was tested three times per isolated leg with the maximal knee extension force recorded in pounds. A total of 1310 participants completed the three knee extension attempts per isolated leg.[21] The average leg strength per isolated leg were summed together to give the participant's combined leg strength value.

Inclusion criteria: Patients included were those who:

- ages 12 to 15 and able to complete the cardiovascular function with an estimated VO2 max
- ages 5 to 15 and able to complete the upper body muscle strength test
- ages 6 to 15 and able to complete the lower body muscle strength test

Exclusion criteria: Patients excluded were those who:

- outside of the respective age ranges
- unable to be complete the respective exam to completion

Data Collection

The publically available NNYFS data and documentation files were directly downloaded from the NNYFS data page by Dr. Jeannette Manger. For the cardiovascular fitness component, data obtained for this study include the following: time spent on treadmill (minutes), maximum heart rate, average heart rate at end of treadmill exam, average recovery time, maximal endurance time, and estimated CV fitness level using the estimated VO2 max. For the muscle strength component, data obtained for this study include the following: total number of modified pull-ups and average knee extension force (pounds).

Data Analysis

The publically available deidentified patient data collected by Dr. Jeannette Manger will be shared with myself. I will organize the data to identify the average cardiovascular fitness tests and muscle strength scores of patients with asthma versus patients without. I will compare the average cardiovascular function tests and muscle strength by analyzing research questions #1-8 using an independent T-test.

Results

This study included cardiovascular and muscle strength evaluations of 1640 individuals total, with 817 females and 823 males. This group involved children aged 3 to 15 years old with the average age being 8 years old. In this large exercise evaluation, 285 individuals reported a history of asthma (17.4% of total). We used two-tailed t-tests to evaluate significance of each of our variables (RQ #1-6) to compare the cardiovascular fitness and muscle strength in children with a history of asthma versus without.

Comparing the total time spent on treadmill exam (RQ1), we found children with history of asthma had significantly lower total time than children without asthma (p = .006) (Table 1). The maximal heart rate on treadmill exam (RQ2) were not significantly different between children with asthma versus without, even though children with history of asthma had a lower maximal heart rate on treadmill exam (p = .493) (Table 2). There was no significant effect of asthma history on heart rate at the end of treadmill exam (RQ3), even though children with history of asthma had a lower heart rate at the end of treadmill exam than children without (p = .491) (Table 3). There was no significant effect of asthma history on recovery time (RQ4) between children with history of asthma versus without (p = .703) (Table 4). Comparing the maximal endurance time (RQ5), children with history of asthma had significantly lower maximal endurance time than children without asthma (p = .006) (Table 5). The overall cardiovascular fitness level was calculated using the VO2max (RQ6) and there was no significant difference between children with history of asthma and children without (p = .658) (Table 6).

There was no significant effect of asthma history on the average number of correct pullups (RQ7) completed by children with history of asthma versus without (p = .446) (Table 7). There was also no significant effect of asthma history on the average combined leg strength (RQ8) performed by children with history of asthma versus without (p = .097) (Table 8).

Table 1: Average Total Time Spent on Treadmill Exam (sec).

	n	**Mean**	**SD**
With History of Asthma	112	806.63[a]	124.65
Without History of Asthma	560	844.48	140.36

Abbreviation: SD, Standard Deviation

[a]statistically significantly different compared to no asthmatic history ($p < 0.05$)

Table 2: Average Maximal Heart Rate on Treadmill Exam (bpm).

	n	**Mean**	**SD**
With History of Asthma	122	198.70	14.19
Without History of Asthma	560	227.15	457.45

Abbreviation: SD, Standard Deviation

Table 3: Average Heart Rate at End of Treadmill Exam (bpm).

	n	**Mean**	**SD**
With History of Asthma	122	196.25	19.28
Without History of Asthma	560	224.82	457.76

Abbreviation: SD, Standard Deviation

Table 4: Average Time Spent in Recovery at End of Treadmill Exam (sec).

	n	**Mean**	**SD**
With History of Asthma	122	128.52	10.94
Without History of Asthma	560	128.11	10.80

Abbreviation: SD, Standard Deviation

Table 5: Average Maximal Endurance Time during Treadmill Exam (sec).

	n	Mean	SD
With History of Asthma	122	618.11[a]	123.59
Without History of Asthma	560	656.36	140.49

Abbreviation: SD, Standard Deviation

[a]statistically significantly different compared to no asthmatic history ($p < 0.05$)

Table 6: Assumed cardiovascular fitness level (using VO2max)

	n	Mean	SD
With History of Asthma	96	2.01	0.95
Without History of Asthma	355	1.96	0.92

Abbreviation: SD, Standard Deviation

Table 7: Average Upper Body Strength (Number of Pullups)

	n	Mean	SD
With History of Asthma	245	4.70	5.65
Without History of Asthma	1065	5.00	5.53

Abbreviation: SD, Standard Deviation

Table 8: Average Lower Body Strength (Combined Knee Extensions, lbs)

	n	Mean	SD
With History of Asthma	232	57.47	31.50
Without History of Asthma	966	53.91	28.71

Abbreviation: SD, Standard Deviation

Discussion

While we found that children with a history of asthma had a significantly shorter time on the treadmill and shorter maximal endurance time than those without asthma, in general, our findings suggest a history of asthma does not have a significantly impact cardiovascular fitness (Table 1-6). In addition, our findings suggest that a history of asthma does not have significantly impact upper and lower body strength performances (Table 7-8). This study supports, alongside numerous other studies, that children with asthma may achieve the same level of cardiovascular fitness and upper and lower muscle strength with proper endurance training, weight training, and medical management of disease.[5,7–10,14,15]

The significantly shorter total time on the treadmill and shorter maximal endurance time identified in children with a history of asthma may be attributed to a general lack of cardiovascular training (through recreational sports, free play, or an exercise regimen). This is easily appreciated given the global decline in physical activity in children, which is associated with a rise in obesity, diabetes, and cardiovascular risk in otherwise healthy children.[5] Further, children with history of asthma may avoid exercise to a greater extent due to the association of exertion with episodes of dyspnea and wheezing. Understandably so, this fear of breathlessness during exercise can be a trigger of anxiety for both the patient and their parents. However, a history of asthma does not directly cause weaker cardiovascular performance or skeletal muscle fitness in children at baseline. It is important to understand a weaker cardiovascular health often seen in asthmatics is not directly caused by airway obstruction or spasm; but rather, it is attributable to a sedentary lifestyle.[5,7–11] This is valuable news in that the cardiovascular health and associated quality of life can be considerably improved in the asthmatic population. Numerous studies have shown cardiovascular training regimens were well-tolerated in mild to moderate asthmatics, with improved cardiovascular function or quality of life.[2,5,9,10,12] Specific exercise protocols and conditioning (i.e. inducing refractory periods), awareness of environmental triggers (i.e cold, dry environments), and proper medical management (i.e. beta blockers and steroids) can reduce risk of symptoms and associated anxiety for a child during exercise and sports participation.

Another factor that may attribute to the significantly shorter total time on the treadmill and shorter maximal endurance time seen in children with a history of asthma may be misuse, underuse, or lack of prescribed inhalers used prior to these fitness exams. Inhaler use in asthmatic children has been identified as poor or suboptimal in many studies.[22,23] Children may also consciously choose to not use their inhaler due to embarrassment of inhaler use because of asthma stigma or suffering side effects of treatment.[24] There are numerous barriers to proper inhaler use that need to be addressed for optimal receival by children. Lastly, it is important to note the extremely large prevalence and burden of undiagnosed and untreated asthma; which can range from 20% to as high as 70%.[25]

Limitations of this study may involve the unknown number of asthmatic children that were being treated with prescription inhalers at the time of exam. This may alter the significance of data if a proportion of asthmatic children were not receiving proper prescription inhaler management of their disease. Further research might explore the specified use of prescription inhalers in studied asthmatics in cardiovascular fitness and muscle strength exams. It would also be interesting to research these same variables in the adult asthmatic population.

Conclusion

In this study, we evaluated the cardiovascular fitness in children with asthma versus children without asthma by looking at the following variables: total time spent on treadmill exam, maximal heart rate, heart rate at end of treadmill exam, total recovery time, total maximal endurance time, and assumed cardiovascular fitness using VO2max. We also evaluated the upper body strength via pullups and lower body strength via weighted knee extensions in children with asthma versus children without asthma. Other studies have also evaluated these variables, however, this study speaks to the baseline cardiovascular fitness and muscle strength in asthmatics during their childhood health.

Children with asthma did not have significantly different cardiovascular fitness exam results, except for the total time spent on treadmill exam and total maximal endurance time. Children with asthma did not have significantly different upper and lower muscle strength exams too. We conclude that children with asthma are not significantly hindered from achieving optimal cardiovascular fitness or upper and lower muscle strength in comparison to their counterparts without asthma. Our findings support the growing research that encourages the importance of individuals with asthma to pursue a healthy, active lifestyle alongside proper medical management; rather than habituating a sedentary lifestyle.

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