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journal homepage: www.elsevier.com/puhe

Original Research

Efficacy of an exercise intervention among children with comorbid asthma and obesity

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ARTICLE INFO

Article history:

Received 9 August 2017

Received in revised form

12 February 2018

Accepted 14 February 2018

Available online xxx

Keywords:

Obesity

Pediatric

Asthma

Exercise-induced bronchospasm

Physical activity

Intervention

ABSTRACT

Objectives: Children with comorbid asthma and obesity present with more severe and harder-to-control disease than asthmatic children at healthy weight. Weight loss has been shown to improve asthma symptoms, yet physical activity may be difficult due to exercise-induced bronchospasm. Children with asthma have lower exercise rates than non-asthmatics. The objective of this study was to retrospectively evaluate attrition rates and program outcome measures (Body Mass Index [BMI] and maximum oxygen consumption [VO₂max]) among asthmatic and non-asthmatic participants.

Study design: Clinical data were collected from the Healthy Hearts Program, a 12-week nutrition and activity intervention program for children who are overweight, obese, or at risk for heart disease and other conditions, and used for the study.

Methods: Intervention data and demographics were obtained from medical records at the Children's Heart Center Nevada. Descriptive statistics, paired t-tests, Cox regression analysis, and analysis of covariance were conducted.

Results: The mean age of this population ($N = 232$) was 11 years; 54% were male, 64% were Hispanic, and 37% had asthma. Median time in the program was 9 weeks, and 58% of the population completed the program. Unadjusted analyses showed significant BMI decreases in asthmatic ($P = 0.002$) and non-asthmatic ($P = 0.001$) participants and increases in cardiorespiratory function for asthmatic males and females ($P = 0.003$, $P = 0.004$) and non-asthmatic males and females ($P < 0.001$ for both). Asthmatic and non-asthmatic children both had improved exercise intensity ($P = 0.033$, $P < 0.001$).

Conclusions: This program is both beneficial and practical for obese children with asthma for losing weight and improving cardiorespiratory function.

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<https://doi.org/10.1016/j.puhe.2018.02.014>

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Introduction

Obesity affects nearly 13 million children in the United States and is a risk factor for the development of asthma and reduced asthma control when compared with those patients who are not obese.^{1,2} Physical activity (PA) interventions have been shown to improve symptoms in obese children with asthma, yet PA can be difficult for asthmatics due to exercise-induced bronchospasm (EIB), which influences lower participation rates in obese asthmatics than obese non-asthmatics.^{4,5,6}

Excess weight in childhood can lead to adult obesity and chronic conditions such as cardiovascular disease, type II diabetes, and metabolic syndrome.^{7,8} Furthermore, certain risk factors for obesity are more likely to be present in asthmatic children than in non-asthmatic children. Research demonstrated that children with asthma have >50% increased risk of becoming obese than non-asthmatics.⁸ Weight loss has been shown to increase lung function and cardiovascular health and lead to control of asthma symptoms.^{2,3,5,9}

An evaluation of a pediatric exercise intervention targeted children at risk for obesity.¹⁰ The program included PAs, nutrition, and behavioral health components. Most participants were obese at the start of the program, although not necessarily asthmatic. Studies show that children are more likely to participate in PAs in group settings in which peer encouragement occurs and that children with asthma are more likely to participate when their asthma is not treated as a barrier.^{11,12}

The Body Mass Index (BMI) is a convenient and inexpensive tool used to measure weight status. The BMI for children and adolescents (aged 2–20 years) is adjusted for age and sex and reported in percentiles.¹³ Maximum oxygen consumption (VO_2max) is a commonly used measure of cardiorespiratory fitness and is measured in milliliters by kilograms per minute (mL/kg/min).¹⁴

The objective of this study is to retrospectively evaluate attrition rates and program outcome measures (BMI and VO_2max) among asthmatic and non-asthmatic participants in the Healthy Hearts Program (HHP), a 12-week nutrition and PA intervention program for children who are overweight/obese or at risk for heart disease.

Methods

Healthy Hearts Program description

The HHP, created in 2002 at the Children's Heart Center Nevada (CHC), promotes lifestyle changes by improving diet and PA levels in children and adolescents who are at risk for heart disease. The program is available statewide. Children may be referred to the HHP if diagnosed as overweight (>85th percentile); with high cholesterol (>170 mg/dL) or a parent with high cholesterol (>240 mg/dL); with family history of premature heart disease, or with risk factors for heart disease. After referral, the child meets with a cardiologist, the child and family meet with a registered dietician, and the child immediately enters the 12-week program.

Exercise sessions are 40-min long and include warmup, instruction, and PAs. Exercise physiologists design activities and coach participants in one of six exercises each week. The children also play games or participate in other types of PAs, which varies depending on the size and demographics of the participants. Treadmills are present but are used for the Rockport 1-mile walk test to calculate relative VO_2max (mL/kg/min) pre-intervention and postintervention. Treadmill speed is adjusted based on the child's tolerance to exertion. VO_2max is estimated using Klein et al.'s equation.¹⁵ The child may also meet with a psychologist for motivational therapy. Those who do not enter the program may still receive nutritional counseling and follow-up appointments with dieticians, and the program may be repeated multiple times. During the program, height, weight, percent body fat, waist circumference, and blood pressure are measured at weeks 1, 6, and 12. The goal is weight maintenance for those entering the program with a BMI between the 85th and 96th percentiles if there are no other risk factors for heart disease, and the goal for those entering with a BMI percentile ≥ 97 th is weight loss.

Data collection and variables

Data were collected to create a dataset of overweight/obese pediatric participants in the HHP, including those with asthma and a control group of those without asthma. The HHP patient information forms located in the electronic medical records (EMRs) contained most of the data collected. All children in this study participated in the 12-week intervention ($n = 232$).

Overweight/obese status in this study was defined as having a BMI of ≥ 90 th percentile at the beginning of the intervention to avoid misclassification of weight status. Asthma was defined as having a physician diagnosis of asthma or reactive airway disease by evidence of a prescription for one or more asthma rescue or control medications. Inclusion criteria included participation in the study from 2004 to 2014 and age ≤ 18 years ($n = 232$). Exclusion criteria included records from those with developmental delay, severe congenital heart disease, or other medical inability to participate in the program (other than asthma).

The main outcome variables in this study were pre-intervention and postintervention BMI z-score and VO_2max . Pre-intervention and postintervention BMI percentiles and metabolic equivalents (METs) were collected to examine mean change. METs measure the intensity of activity as a ratio of active to resting metabolic rate. MET of 1 is equivalent to the energy expended sitting, MET of 3.0–6.0 is the range for moderate activity, and vigorous activity is >6.0 METs.¹⁴

Sociodemographic data included age in years, race/ethnicity (collapsed to Hispanic/non-Hispanic), sex (m/f), and insurance status (insured/uninsured, or Medicaid recipient—uninsured and Medicaid categories were combined to ensure adequate sample size). In addition, asthma status (y/n) and comorbid diagnoses were collected.

Program completion variables included number of weeks the child attended the program (coded 1–12) and whether the staff coded the program as completed (coded yes/no). If a child missed a week during the program, but participated the following week, the visits could be combined. For this reason,

many patients completed the program by week 10, and one child finished as early as week 6. The definition of completion is determined by the HHP staff, wherein the patient met the 'completion' requirements of the intervention, even if the child had combined visits.

Analysis

Frequencies and distribution statistics were conducted on demographics and other characteristics at baseline and stratified by asthma status. Paired *t*-tests or Wilcoxon signed-rank tests were performed depending on variable distribution to examine unadjusted pre-post mean change in program outcomes BMI percentile and *z*-score, METs, and VO₂max between asthmatic and non-asthmatic populations. Cox proportional hazards regression was performed to examine attrition rates. Time was measured as 'weeks in the program,' and the outcome was binary (completed/incomplete). Adjusted models included age in years, race/ethnicity (Hispanic/non-Hispanic), sex (m/f), and insurance status (insured/Medicaid recipient).

Repeated measures analysis of covariance models was used to examine outcome measures in the patients who completed the intervention. Asthma status is the predictor variable, and time (weeks) is included in each model. Time for BMI *z*-score has three measures (weeks 1, 6, and 12), and VO₂max has two measures (weeks 1 and 12). The BMI, BMI percentile, and BMI *z*-score were calculated and interpreted using the formulas and standards developed by the Centers for Disease Control and Prevention (CDC).¹³ Analyses for both boys and girls were conducted to examine the pre-post difference in VO₂max. VO₂max reference values were based on standards developed by the Cooper Institute.¹⁶ Adjusted models included age in years, race/ethnicity, sex, and insurance status.

Comorbid diagnoses were considered confounders. Comorbid diagnoses included metabolic disorders (metabolic syndrome >60% of children had this diagnosis), as well as type II diabetes, and elevated cholesterol, lipids, or insulin levels. Non-metabolic conditions included cardiac diagnoses, such as hypertension or functional murmur, vitamin deficiencies, and behavioral disorders. Comorbid diagnoses were classified using International Classification of Disease 9 or 10 codes. The comorbid diagnosis variable was added as a covariate to all multivariable analyses but was not used in any final models because the comorbid variable did not yield significance. Power analyses, using G*Power, version 3.1.9.2 developed by Universität Düsseldorf, were conducted to determine and ensure adequate sample size. Other analyses were conducted using IBM SPSS Statistics, version 23.

An exemption was received from the University of Nevada, Las Vegas, Institutional Review Board (Protocol #1412-5020M) due to the previous full review by the Sunrise Health Institutional Review Board.

Results

The total population was comprised of 232 children; 86 had asthma, and 146 were non-asthmatic. The mean age of the population was nearly 11 years with a range from approximately 6.5 years to 18 years, 54.3% (*n* = 126) of the population

were male, 64.2% were Hispanic (*n* = 149), and 55.2% received Medicaid (*n* = 128). Most participants lived in Las Vegas (91.4%, *n* = 212); however, between 2006 and 2009, 20 children (8.6%) participated in the program in Reno. The median time in the program was 9 weeks, with a range of 1–12 weeks, and 58.2% of the population completed the program (*n* = 135). At baseline, the BMI percentile and *z*-score were slightly higher in non-asthmatic children, whereas VO₂max and METs were slightly lower (Table 1). Age was statistically significantly higher in the asthmatic group at baseline (*P* = 0.047), as was METs (*P* = 0.024). The unadjusted weeks in the program variable was significantly greater among those without asthma (*P* = 0.047) (Table 1).

Nearly 98% of this population had at least one existing comorbid diagnosis (not including asthma, which is a separate variable) (Table 1). Three patients did not have an existing diagnosis; one had only an asthma diagnosis, 47% of the population (*n* = 109) had two comorbid diagnoses, 22% (*n* = 51) had

Table 1 – Baseline population characteristics of Healthy Hearts Program participants stratified by asthma status (N = 232).

Variable	Non-asthmatic (<i>n</i> = 146)	Asthmatic (<i>n</i> = 86)	Total
Age (years)^a mean (SD) Range: 6.44–18.02	10.57 (2.418)	11.26 (2.621)	10.83 (2.512)
Sex <i>n</i> (%)			
Male	75 (32.2)	51 (22.0)	126 (54.3)
Female	71 (30.6)	35 (15.1)	106 (45.7)
Race/Ethnicity <i>n</i> (%)			
Black/African-American	16 (6.9)	12 (5.2)	28 (12.1)
Hispanic	96 (41.4)	53 (22.8)	149 (64.2)
White	24 (10.3)	15 (6.5)	39 (16.8)
Other	10 (4.3)	6 (2.6)	16 (6.9)
Insurance status <i>n</i> (%)			
Private insurance	66 (28.4)	28 (12.1)	94 (40.5)
Medicaid	73 (31.5)	55 (23.7)	128 (55.2)
No insurance	7 (3.0)	3 (1.3)	10 (4.3)
Comorbid diagnoses <i>n</i> (%)			
Yes	142 (61.1)	85 (36.6)	227 (97.8)
No	4 (1.7)	1 (0.4)	5 (2.2)
Weeks in program^a median (range)	9.00 (1–12)	8.00 (1–12)	9.00 (1–12)
Finished program <i>n</i> (%)			
Yes	91 (39.2)	44 (19.0)	135 (58.2)
No	55 (23.7)	42 (18.1)	97 (41.8)
BMI percentile mean (SD) Range: 90–99	98.44 (1.213)	98.14 (1.125)	98.13 (1.319)
BMI <i>z</i>-score mean (SD) Range: 1.29–3.09	2.36 (0.338)	2.25 (0.372)	2.32 (0.348)
VO₂max mean (SD)			
Male	32.29 (8.150)	34.48 (5.916)	32.55 (7.980)
Range: 5.0–44.5			
Female	23.75 (8.133)	26.00 (6.773)	24.56 (7.281)
Range: 4.4–38.5			
METs^a mean (SD) Range: 2.3–4.4	3.29 (0.427)	3.49 (0.273)	3.28 (0.426)

BMI, Body Mass Index; METs, metabolic equivalents; SD, standard deviation; VO₂max, maximum oxygen consumption.

^a Statistical difference between asthmatic and non-asthmatic groups.

three comorbid diagnoses, and 10% ($n = 23$) had four or more comorbid diagnoses in the EMR. The number of comorbid diagnoses significantly differed between asthmatic (median of two diagnoses) and non-asthmatic children (median of one diagnosis) (Mann–Whitney $U = 5235.0$, $P = 0.022$) (data not shown).

Among the population with asthma, the BMI percentile decreased significantly (mean change = -0.26 , $P < 0.042$) from 98.14 to 97.88. The BMI z-score also decreased significantly (mean change = -0.05 , $P = 0.002$) from 2.25 to 2.20. The BMI percentile also decreased among non-asthmatic children (mean change = -0.28 , $P = 0.002$) from 98.44 to 98.16, as did BMI z-score (mean change = -0.05 , $P = 0.001$) from 2.36 to 2.31 (Table 2).

VO₂max levels increased in males with asthma from 34.48 mL/kg/min to 38.65 mL/kg/min (mean change = 4.17, $P = 0.003$) and females with asthma from 26.00 mL/kg/min to 29.79 mL/kg/min (mean change = 3.79, $P = 0.004$). VO₂max levels for non-asthmatic males increased (mean change = 6.17, $P < 0.001$) from 32.29 mL/kg/min to 38.46 mL/kg/min as did VO₂max levels for females without asthma (mean change = 5.0, $P < 0.001$) from 25.75 mL/kg/min to 28.84 mL/kg/min.

Exercise intensity (METs) increased significantly for patients with asthma from 3.49 to 3.79 (mean change = 0.30, $P = 0.033$). METs also increased for those without asthma from 3.29 to 3.58 (mean change = 0.29, $P < 0.001$) (Table 2).

Cox regression analyses, to examine attrition, showed no significant difference between the asthmatic and non-asthmatic groups ($P = 0.300$), nor were any other variables statistically significant (Table 3).

When examining weight loss among HHP participants with and without asthma, time in the program was the only variable which significantly affected change in the BMI z-score, $F(1.3, 166.4) = 5.33$, $P = 0.014$. The association between the BMI z-score and time in the program was inverse. The adjusted mean z-score decreased from 2.314 to 2.265, showing that the mean BMI significantly decreased among the entire HHP population who finished the program. The adjusted models for both males and females measuring VO₂max determined that none of the variables were associated with VO₂max.

Discussion

The main findings suggest that the HHP may be an effective and feasible intervention program for weight loss and

increased cardiorespiratory function in children who are obese and have asthma. This was demonstrated by weight loss and increased VO₂max, and there was no statistically significant difference from non-asthmatic children in attrition rates and program outcomes. In addition, children with asthma in this intervention had significantly more comorbid health disorders than non-asthmatic peers, and by evidence of the short beta agonist prescriptions, they were likely prone to EIB.

While the population was still overweight/obese, the unadjusted BMI percentile showed significant weight loss in both asthmatic and non-asthmatic patients, particularly given the short time frame for initial enrollment and the degree of overweight/obesity in the population (≥ 90 th percentile). This is important clinically for asthma patients as weight loss can lead to more controlled and less severe asthma symptoms.

For males, the unadjusted baseline mean values of VO₂max were below the lowest reference range of <37.3 mL/kg/min (Needs Improvement – health risk) provided by Meredith and Welk (2013) but increased slightly above the lowest range in both groups.^{15,16} For females, the mean values did not reach the lowest value provided, 35.3 mL/kg/min;¹⁵ however, the mean VO₂max did increase in both groups.

The Cox regression showed that asthmatic children successfully completed the intervention compared with non-asthmatic children regarding attrition. This suggests that this intervention may be a feasible approach for weight loss and cardiopulmonary function improvement, even among children who experience EIB.

Adjusted BMI and VO₂max analyses further suggest that asthma was not a significant barrier to exercise among the children who participated in the HHP intervention. The only significant finding from these results demonstrated that quitting the program had a negative effect on weight loss. This study is consistent with literature, which shows that nutrition and PA interventions can improve lung function and promote weight loss.^{3,5,10} It also demonstrates the effectiveness of a program that children with asthma could participate in and chose to continue.^{4,6}

Limitations of this study include the use of secondary data collected by multiple people. The data were collected from EMR databases, in both electronic and handwritten/scanned format. Owing to these limitations, differential misclassification is possible. The use of BMI as a weight measure is also a limitation

Table 2 – Mean change in select outcome measures of Healthy Hearts Program participants stratified by asthma status (N = 232).

Calculation	Non-asthmatic			Asthmatic		
	n	Mean change (P) ^a	95% CI of difference	n	Mean change (P) ^a	95% CI of difference
BMI percentile	91	-0.28 (0.002) ^b	-0.10 to -0.45	43	-0.26 (0.042) ^b	-0.03 to -0.54
BMI z-score	91	-0.05 (0.001) ^b	-0.03 to -0.70	43	-0.05 (0.002) ^b	-0.02 to -0.08
VO ₂ max						
Male	38	6.17 (<0.001) ^b	3.76 to 8.59	21	4.17 (0.003) ^b	1.14 to 6.91
Female	42	5.09 (<0.001) ^b	2.63 to 7.51	19	3.79 (0.004) ^b	1.11 to 6.47
METs	55	0.29 (<0.001) ^b	0.15 to 0.42	7	0.30 (0.033) ^b	0.03 to 0.62

Abbreviations: CI, confidence interval; BMI, Body Mass Index; METs, Metabolic equivalents; VO₂max, maximum oxygen consumption.

^a Calculated using paired t-test or Wilcoxon signed-rank test.

^b Statistically significant at $P < 0.05$.

Table 3 – Attrition among the Healthy Hearts Program participants (N = 232).

Variable	n (%)	Crude hazard rate (95% CI)	P-value	Adjusted hazard rate (95% CI)	P-value
Asthma (n = 232)					
Yes	86 (37.07)	^a		^a	
No	146 (62.93)	0.79 (0.52–1.14)	0.207	0.82 (0.56–1.19)	0.300
Age				1.01 (0.94–1.07)	0.860
Race/Ethnicity (n = 125)					
Non-Hispanic	81 (64.80%)			^a	
Hispanic	44 (35.20%)			0.80 (0.55–1.17)	0.251
Sex (n = 125)					
Female	49 (39.20%)			^a	
Male	76 (60.80%)			1.05 (0.74–1.49)	0.792
Insurance status (n = 124)					
Insured	93 (75.00%)			^a	
Medicaid	31 (25.00%)			1.24 (0.87–1.77)	0.236
CI, confidence interval.					
^a Reference category.					

as the tool cannot distinguish lean mass (muscle) from fat mass.¹⁷ All patients were overweight/obese and were weighed numerous times by the same clinical staff; therefore, it is unlikely that weight status was misclassified. Furthermore, the non-asthmatics had a larger sample size than the asthmatics in the study population (63% and 37%, respectively), which may have influenced the overall results. Ideally, group sizes would be equitable; however, another limitation points to enrollment. Although the 12-week program is feasible, follow-up is still necessary. A challenge that presents is finding time to drive the children to the CHC which would directly affect attrition. As this is an active clinical practice, missing data points in the database were noted, which reflects clinicians using only information relevant to a patient's care. Variables with a substantial amount of missing data were not used in any analysis. One of the main strengths of this study is that data were comprised of clinically measured variables collected by clinicians or staff, which limits possibility of recall bias.

This research is a pilot study, observing the feasibility of an intervention for obese asthmatic children. In addition, this study examined the feasibility of an intervention in an underserved community. Children who participated in the HHP increased the intensity of exercise from below a moderate level to moderate-to-vigorous intensity. The unadjusted values for METs fell within the 'moderate activity' range of 3.0–6.0 provided by Heyward and Gibson (2014).¹⁴ Many children with asthma and obesity show lower rates of activity than their non-asthmatic peers; the increase in the ability to exercise more intensely is an important finding, especially given the conflicting definitions of low, moderate, and vigorous activity in the literature.^{6,12,14} Future research to examine the relationship between exercise intensity and improvements in pulmonary function in asthmatic children is encouraged. The study itself was impactful due to the significant change in the BMI in both asthmatics and non-asthmatics; however, the improvement hinges on the child following up periodically with the HHP intervention. Further studies need to be carried out to ensure sustainability of the habits practiced during the program. Sustainability is a large factor in dietary change and weight management; the adaptation of healthy habits is a lifestyle change, and research in the field is limited.

Additional studies should be conducted with larger populations, particularly among those at greater risk for asthma and obesity, including minority and uninsured children. Partnerships with after-school programs and community-based non-profit programs provide a safe place for children to engage in PAs such as the HHP intervention program. The 2015 Youth Risk Behavior Surveillance System reported that 18.6% of high school students had been bullied on school property or electronically and 10.7% attempted suicide. Having a staff psychologist on board is an integral aspect of the HHP and may help to reveal the identifying factors contributing to such risky behaviors.

Conclusion

In this evaluation of the HHP, children with asthma completed the intervention at the same rate as children without asthma. Furthermore, children experienced weight loss and increased exercise intensity and cardiorespiratory function. These outcomes were statistically the same among those with and without asthma, indicating that this program is realistic and beneficial for children who might experience respiratory distress while exercising as well as children who do not.

Author statements

Acknowledgements

The authors wish to thank Dr. Humberto Restrepo and Shalethia Turner for their assistance in preparing the study, Anissa Gustafson, Karolina Balkenbush, and Lorie Coviello for their assistance with data collection and program details, and Julia Anderson for assistance with formatting.

Ethical approval

Not required. The Sunrise Health Institutional Review Board conducted a full review and approved the protocol for this study (Protocol # 14-025). A waiver of informed consent was also approved. An exemption was received from the University of Nevada, Las Vegas, Institutional Review Board (Protocol

#1412-5020M) due to the previous full review by the Sunrise Health Institutional Review Board. All data were de-identified by the office of the Director of Research at the Children's Heart Center before analyses.

Funding

None declared.

Competing interests

None declared.

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