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Anxiety contributes to poorer asthma outcomes in inner-city Black adolescents

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Abstract

Background—The factors associated with poor asthma control, exacerbations, and healthcare utilization in Black adolescents are complex and not well understood. Although psychological co-morbidities such as anxiety are common in asthma patients, these have not been studied in this population.

Objective—This study characterized anxiety and associated asthma features in a cohort of Black inner-city adolescents with persistent asthma and determined the association between anxiety symptoms, persistent uncontrolled asthma and prospective healthcare utilization over one year.

Methods—Eighty-six Black adolescents were enrolled, phenotyped, and screened for anxiety symptoms with Hospital Anxiety and Depression Scale anxiety subscale (HADS-A). Participants were telephoned every 2 months and a second study visit was completed at one year. Primary outcomes included persistent uncontrolled asthma, asthma exacerbations requiring systemic corticosteroids, and unscheduled healthcare utilization during the one-year study period.

Results—31% (n = 27) of adolescents had probable anxiety (i.e., HADS-A score >7) and 27% (n = 23) had possible anxiety (i.e., HADS-A score 5–7) at the baseline visit. Anxiety symptoms were associated with poorer asthma control, more impaired quality of life, and more insomnia symptoms. Adolescents with probable anxiety disorders also had increased odds of persistent uncontrolled asthma and Emergency Department utilization, with no differences in physician visits or systemic corticosteroid receipt.

Conclusion—Inner-city Black adolescents with persistent asthma have a high prevalence of anxiety symptoms associated with poorer asthma control, impaired quality of life, insomnia, and increased prospective Emergency Department utilization for asthma. Routine screening for anxiety disorders may be useful in the clinical management of adolescents with asthma.

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Keywords

Asthma control; Asthma comorbidity; Asthma disparity; Asthma exacerbation; Mental health; Psychopathology

INTRODUCTION

Despite numerous efforts to improve asthma outcomes in the United States, asthma control remains suboptimal,[1] and nearly 50% of children experience an asthma exacerbation each year.[2] Although the prevalence of asthma exacerbations is highest in school-age children, adolescents also have significant asthma burden.[2, 3] As they develop a sense of autonomy, adolescents learn to gain greater responsibility for treating their symptoms. However, this transition can result in impaired perception of asthma symptoms necessitating treatment,[4] decreased preventive asthma medication use,[5] and an increased risk of adverse outcomes including asthma-related mortality as compared to younger children.[6] These behaviors may ultimately place adolescents with asthma at increased risk for anxiety symptoms and anxiety-related disorders as their asthma functional status (i.e., ability to complete schoolwork, participate in activities and regulate emotions) deteriorates.[7]

Asthma treatment guidelines recommend accurate diagnosis and management of co-morbid illnesses, including anxiety.[8, 9] Although no there are no available federal surveillance data on mental health disorders in U.S. youth,[10] the estimated prevalence of anxiety disorders in children and adolescents age 6–18 years is approximately 6.5% worldwide[11] and may be significantly higher in adolescents with asthma. In separate analyses of adults with asthma treated at primary[12] and specialty[13] care centers, the prevalence of probable anxiety disorders was 31.6% and 36.9%, respectively. Anxiety symptoms are also greater in adults with severe, corticosteroid refractory asthma than in adults with corticosteroid responsive asthma.[14, 15] There is also some emerging evidence of racial disparities in anxiety in Black versus White populations. For example, adolescents at poorer schools, which tend to have a larger proportion of Black students, report more anxiety symptoms.[16] Interactions between income and asthma have also been demonstrated, whereby individuals with asthma and incomes less than $25,000 per year experience the highest number of days with anxiety symptoms.[17] More concerning are trends related to psychological functioning and minimally adequate outpatient mental health service utilization. Blacks with anxiety disorders (and particularly those with low income), compared to Whites, have significantly worse global assessment of functioning and global psychosocial functioning,[18] yet they are treated markedly less frequently for anxiety disorders in early and middle adulthood.[19] This disparity worsened by14.2 percentage points over one decade[20] and is more pronounced among Blacks residing in the South.[21] The reasons underlying these disparities are complex and likely related to a variety of socioeconomic and ecological variables that similarly influence disparities in asthma-related healthcare utilization.[22]

Despite the potential importance of anxiety in asthma management, anxiety can be difficult to identify in the clinical setting or overlooked entirely since the symptom manifestation of anxiety is quite similar to that of asthma and includes respiratory difficulty (i.e., shortness of

breath and/or chest tightness)[23] and sleep disturbances.[24] Limited studies of anxiety in adolescents and in Black populations are also an existing limitation. Moreover, no studies have examined the contribution of anxiety symptoms to key asthma outcomes such as exacerbations and healthcare utilization. Therefore, the purpose of this study was to: 1) characterize the pattern and prevalence of anxiety and associated asthma features in a well-phenotyped cohort of Black inner-city adolescents with asthma, and 2) to determine the association between anxiety symptoms and prospective asthma outcomes over one year of follow-up. Using a validated questionnaire of anxiety symptoms[25, 26], we hypothesized that adolescents with increased anxiety symptoms would have greater features of asthma severity and poorer asthma control and, moreover, that anxiety symptoms would predict future exacerbations and unscheduled healthcare utilization for asthma.

METHODS

Self-reported Black adolescents 12 to 21 years of age were recruited for the study through community-based advertisements across metropolitan Atlanta, Georgia. Inclusion criteria were ability to read and speak English, a physician diagnosis of asthma and either ≥ 12% reversibility in the forced expiratory volume in one second **(FEV_1)** after bronchodilator administration or airway hyperresponsiveness to methacholine, evidenced by a provocative concentration of methacholine ≤ 16 mg/mL. Exclusion criteria included premature birth before 35 weeks gestation or other co-morbid airway disorders such as aspiration or vocal cord dysfunction. Permission to proceed with this study was granted by the Emory University Institutional Review Board. Informed written consent and assent were obtained.

Study design and procedures

Participants completed a baseline study visit and a second study visit at one year. Study visits were postponed if participants were acutely ill or if an asthma exacerbation treated with systemic corticosteroids was reported within the preceding four weeks. Between visits, participants were telephoned every two months to assess for adverse events. Spirometry (KoKo® PDS, Ferraris, Louisville, CO) was performed at baseline and after bronchodilator reversibility testing with 4 inhalations of albuterol sulfate (90μg per inhalation). Participants withheld short-acting bronchodilators for 4 hours and long-acting bronchodilators for 12 hours prior to spirometry testing. The best of three forced vital capacity **(FVC)** maneuvers was interpreted according to population reference equations.[27] Allergy skin prick testing was performed after a three-day antihistamine withhold using 12 allergen extracts: tree mix (*Quercus alba, Ulmus americana, Platanus acerifolia, Salix caprea, Populus deltoides*), grass mix (*Cynodon dactylon, Lolium perenne, Phleum pratense, Poa pratensis, Sorghum halepense, Paspalum notatum*), weed mix (*Artemisia vulgaris, Chrysanthemum leucanthemum, Taraxacum vulgare, Solidago virgaurea*), common ragweed (*Ambrosia artemisiifolia*), *Alternaria alternata*, *Aspergillus fumagatis*, *Cladosporium herbarum*, dog dander, cat dander, German cockroach (*Blatella germanica*), *Dermatophagoides farinae,* and *Dermatophagoides pteronyssinus*) (Greer® Laboratories, Lenoir, NC). Histamine and saline served as positive and negative controls, respectively. Tests were considered positive if a wheal of 3 mm diameter or greater and flare 10 mm or more was present 15 minutes after application. Exhaled nitric oxide concentrations were measured online (NIOX MINO®,

Circrassia Pharmaceuticals, Chicago, IL) according to recommended standards.[28] Demographic and medial history questionnaires, the Hospital Anxiety and Depression Scale **(HADS)**,[26] the Asthma Control Test **(ACT)**,[29] the Asthma Quality of Life Questionnaire **(AQLQ)**,[30] and the Insomnia Severity Index **(ISI)**[31] were also completed. Neighborhood characteristics were obtained from the 2010–2014 American Community Survey available at www.factfinder.census.gov.[32] Crime rates were obtained from the Federal Bureau of Investigation, local police departments and municipalities and were accessed through the City Profile feature available at www.moving.com.

Anxiety classification and primary outcome measures

Participants were classified into three groups according to baseline HADS anxiety subscale **(HADS-A)** scores as follows: 1) no anxiety, HADS-A score <5; 2) possible anxiety, HADS-A score 5–7; and 3) probable anxiety, HADS-A score >7.[26, 33] Primary outcome measures at the one year visit included persistent uncontrolled asthma defined by an ACT score ≤19[29] at both visits, receipt of systemic corticosteroids for an asthma exacerbation,[34] and unscheduled healthcare or Emergency Department utilization for asthma.

Statistical analyses

Data were analyzed with SPSS® Statistics (Version 24, IBM, Armonk, NY). Variables that were not normally distributed were logarithmically transformed prior to analysis. Differences between groups were assessed with ANOVA. Tukey's Least Significant Difference Tests were used for post-hoc comparisons. Univariate logistic regression was performed to obtain crude odds ratios to estimate the probability of outcomes of interest at the one year study visit. Final estimates were adjusted for age group (12–17 years versus 18–21 years), sex, and household income level. Analyses were performed on participants with complete data at one year (N = 67) and on all participants after multiple imputation (N = 86). Little's chi square tests were performed on the expectation-maximum covariance matrix of key study variables (including age, sex, income, education, asthma controller medications, exhaled nitric oxide, $FEV_{1,}$ HADS-A score, ACT score, AQLQ score) to determine whether the missing values at one year were missing completely at random. Multiple imputation was performed using a fully conditional specification (Markov Chain Monte Carlo algorithm) with 5 iterations to assess primary outcome occurrence in an ideal scenario with no missing data. The imputed dataset was based on age, sex, income, education, asthma controller medications, exhaled nitric oxide, FEV_1, HADS-A score, ACT score, and AQLQ score.

RESULTS

Eighty-six Black adolescents from metropolitan Atlanta were enrolled between January 2014 and December 2016 through community-based advertisements. Thirty one percent (n = 27) had probable anxiety (i.e., HADS-A score >7) and 27% (n = 23) had possible anxiety (i.e., HADS-A score 5–7) at the baseline visit. Demographic features of the participants are shown in Table 1. Adolescents with probable anxiety were slightly older, had lower rates of higher education completion and lower household incomes, and were more likely to reside in neighborhoods with a higher percentage of rental homes and public insurance (Table 1).

Adolescents with probable anxiety also had more depressive symptoms evidenced by the HADS depression subscale (1.4 ± 1.7 vs. 2.7 ± 2.3 vs. 4.2 ± 3.2 for no anxiety vs. possible anxiety vs. probable anxiety, $p < 0.001$); however, only one child with possible anxiety and 6 children with probable anxiety had HADS depression scores above 7,[25, 26] preventing further analysis of this variable.

Asthma severity and control

Baseline asthma characteristics of the participants are shown in Table 2. Features of asthma severity, including controller medication use and pulmonary function values, were not significantly different between groups. However, adolescents with probable anxiety were more likely to miss school or work and were more likely to have visited an Emergency Department in the previous year. Adolescents with probable anxiety also had a higher prevalence of comorbid conditions, namely obesity and gastroesophageal reflux, in addition to greater allergic sensitization and exhaled nitric oxide values (Table 2).

Asthma control as reflected by the ACT score was poorest in adolescents with probable anxiety (Figure 1A) and there was a significant linear trend between greater anxiety symptoms (i.e., higher HADS-A scores) and poorer asthma control (i.e., lower ACT scores, $r = -0.517$, $p < 0.001$). Asthma-related quality of life reflected by the total AQLQ score was also poorest in adolescents with probable anxiety (Figure 1B). Similar trends were noted for each domain of the AQLQ (symptom domain: 6.0 ± 0.9 vs. 5.5 ± 1.3 vs. 4.8 ± 1.2 for no anxiety vs. possible anxiety vs. probable anxiety, $p = 0.001$; activity domain: 6.1 ± 0.7 vs. 5.5 ± 0.9 vs. 4.9 ± 1.0, $p < 0.001$; emotion domain: 6.3 ± 0.9 vs. 5.8 ± 1.3 vs. 5.2 ± 1.5, $p = 0.001$; environment domain: 5.9 ± 1.1 vs. 5.9 ± 1.0 vs. 4.5 ± 1.2, $p = 0.002$). Insomnia symptoms measured by the ISI were also greatest in adolescents with probable anxiety (Figure 1).

Asthma features at one year

Nineteen participants (22%) were lost to follow-up during the one year study period (n = 10 with no anxiety, n = 5 with possible anxiety, and n = 4 with probable anxiety) resulting in a sample size of 67 participants for outcome assessment. Participants who were lost to follow-up did not differ with regard to age (15.9 ± 2.9 vs. 15.7 ±3.0 years for lost vs. retained, $p = 0.801$), sex (53 vs. 55% male, $p = 0.841$), household education (63% vs. 43% with Associate or college degree, $p = 0.397$), household income (58 vs. 43% with income <$25,000/year, $p = 0.256$), or baseline HADS-A score (5.1 ± 3.8 vs. 5.9 ± 3.8, $p = 0.385$). However, participants who were lost to follow-up were treated with fewer asthma medications (53% vs. 12% taking no medications, $p < 0.001$) and had significantly higher ACT scores (22 ± 2 vs. 18 ± 4, $p < 0.001$) and higher total AQLQ scores (6.1 ± 0.6 vs. 5.5 ± 1.1, $p = 0.022$) at the baseline visit, suggestive of better asthma control and greater asthma-related quality of life, respectively. However, Little's test was not significant (Chi-Square = 108.12, degrees of freedom = 110, $p = 0.553$), suggesting that participants who dropped out early were not different overall and their data were missing completely at random.

HADS-A scores at the one-year visit were relatively stable as compared to the baseline visit ($r = 0.581$, $p < 0.001$) (Figure 2A). Asthma features including lung function values and

exhaled nitric oxide concentrations did not differ between groups at one year (Table 3). However, adolescents with probable anxiety (i.e., HADS-A score >7) at the baseline visit continued to have significantly poorer asthma control (Figure 2B) and poorer overall asthma-related quality of life (Figure 2C) (symptom domain: 6.0 ± 1.0 vs. 6.1 ± 1.1 vs. 5.3 ± 1.3 for no anxiety vs. possible anxiety vs. probable anxiety, p = 0.046; activity domain: 6.2 ± 0.8 vs. 6.2 ± 1.0 vs. 5.1 ± 1.3, p = 0.002; emotion domain: 6.2 ± 1.1 vs. 6.6 ± 1.0 vs. 5.5 ± 1.6, p = 0.049; environment domain: 5.3 ± 2.1 vs. 5.9 ± 1.5 vs. 3.7 ± 1.3, p = 0.051). Insomnia symptoms also remained greater in adolescents with probable anxiety at one year (Figure 2D).

Primary asthma outcomes at one year

Associations between baseline HADS-A score groupings and primary asthma outcomes of interest are shown in Table 4. In univariate analyses, adolescents with probable anxiety (i.e., HADS-A score >7) at the baseline visit had higher odds of persistent uncontrolled asthma at one year, reflected by an ACT score ≤19 at both visits. Although the odds of systemic corticosteroid receipt and unscheduled physician visits for acute asthma exacerbations did not differ between groups, adolescents with probable anxiety also reported more missed school or work days during the 3 months prior to the study visit (mean days missed, 0.9 ± 1.4 vs. 1.1 ± 1.1 vs. 2.9 ± 3.9 for no anxiety vs. possible anxiety vs. probable anxiety, p = 0.016). Adolescents with probable anxiety also had higher odds of Emergency Department utilization. The odds of persistent uncontrolled asthma and Emergency Department utilization remained significantly higher in adolescents with probable anxiety after adjustment of the models for age, sex, and household income level. Multiple imputation was performed as a sensitivity analysis given the relatively high degree of participant drop-out (22%) and results were similar (Table 3).

CONCLUSIONS

Although asthma control is suboptimal in a majority of adolescents, the factors associated with poor control and adverse asthma outcomes in this population are not completely understood. In this prospective study of inner-city Black adolescents with persistent asthma in Atlanta, Georgia, we identified a high prevalence (i.e., 31%) of co-morbid anxiety symptoms associated with poorer asthma control, poorer asthma-related quality of life, increased insomnia and higher odds of healthcare utilization, namely Emergency Department utilization for asthma, over one year of follow-up. The fact that nearly one-third of our participants had a probable anxiety disorder is quite striking and similar to recent analyses of adolescent and adult outpatient populations with asthma from Sweden[35] and Italy[36] that found current and lifetime anxiety prevalence statistics of approximately 20 to 30%. A recent analysis of adolescents with cystic fibrosis similarly identified an anxiety prevalence of 22% overall,[37] with higher prevalence in girls than boys.[38] Interestingly, while those findings in cystic fibrosis populations prompted an International Committee on Mental Health and consensus statements for screening and treating anxiety in affected patients,[39] similar efforts for asthma are lacking and are likely needed. However, the best approach for the identification and treatment of anxiety in adolescents still requires investigation. While a recent meta-analysis did identify improvement in asthma control, quality of life and anxiety

in adults with persistent asthma undergoing cognitive behavioral therapy, the quality of evidence was low, with considerable variation in therapy delivery and no available evidence in adolescents.[40]

Our findings confirm existing studies that have shown associations between anxiety symptoms and poorer asthma control independent of airflow limitation.[13, 41, 42] Our observations of impaired asthma-related quality of life and increased insomnia in patients with probable anxiety are also similar to other reports,[35, 42–44] but here we extend those results to an understudied adolescent population. To our knowledge, this is also the first analysis of anxiety symptoms in an exclusively Black population. Whether there are racial disparities associated with anxiety is not entirely clear, but there is some evidence that race may be a risk factor for poorer psychological health. In a recent, large study of adults with anxiety disorders, Black participants had more impaired clinician-rated Global Assessment of Functioning and poorer global psychosocial functioning as compared to White participants.[18] There was also a significant interaction between Black race and income, with Black participants earning <$20,000/year at highest risk.[18] A separate analysis of the Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance System similarly noted a significant three-way interaction among race/ethnicity, income, and history of chronic asthma on self-reported days of poor mental health.[17] However, other analyses have shown White versus non-White race to be a risk factor for anxiety disorders,[45, 46] suggesting that associations between race and anxiety are likely multifactorial and complex.

To our knowledge, this is the first study to prospectively assess the association between anxiety and key asthma outcomes of exacerbations and healthcare utilization. Similar to the cross-sectional study of Di Marco et al.,[41] which noted a higher prevalence of historical urgent care visits and ED utilization in asthma patients with anxiety disorders, we also found that probable anxiety was associated with persistent uncontrolled asthma and greater odds of ED use over one year. However, we are unable to comment on the causal and temporal association between anxiety and asthma outcomes given the present study design. It is possible that our outcome measures (ACT scores and ED utilization) were influenced by subjective perception of symptoms and were not independent of anxiety. Thus it is unclear whether anxiety precedes poorer asthma outcomes, or alternatively, whether poor asthma control promotes anxiety symptoms. To this point, objective measures of corticosteroid use and lung function did not associate with anxiety despite greater Emergency Department utilization. This observation suggests that anxious patients may not necessarily have more intrinsic disease severity, but rather, more heightened subjective symptom perception prompting urgent healthcare utilization. Nonetheless, our observation of a strong association between anxiety and asthma control is clinically significant. Although it is well established that patients with uncontrolled versus controlled asthma have higher medical expenditures,[47] co-morbid psychiatric disorders (including anxiety) have also been identified as the largest component of excess medical costs[48, 49] and productivity loss[50] in patients with asthma, arguing for further study of the role and importance of anxiety in asthma populations.

Whereas HADS-A scores >7 have been previously validated as an indicator of generalized anxiety disorder in multiple inpatient and outpatient populations with a sensitivity and specificity of approximately 0.80 across studies,[33, 51] the exact cut-point that should be used

for the identification of adolescents with probable anxiety for further evaluation remains controversial. Although the HADS instrument was initially developed for use in a hospital-based outpatient medical clinic,[26] lower anxiety cut-points of 3 have been recommended for medically stable adult primary care populations given a negative predictive value for anxiety of 95%.[52] However, in a large study that randomly sampled 300 adolescents age 13 to 23 years from the general population according to sex, age group and region, mean HADS-A anxiety scores were 4.66 ± 3.35.[53] Given the uncertainty with cut-point selection in adolescents, we elected to use a three-group design with a "possible" anxiety group with HADS-A scores of 5–7 to minimize false negative detection. While this did limit our sample size for statistical analysis, the fact that 2 participants (13%) in the "possible" anxiety group developed "probable" anxiety (i.e., HADS-A score >7) at the follow-up visit suggests that a cut-point of 7 for determination of "normal" may be inappropriate. Moreover, the fact that adolescents with possible anxiety also had significant impairment in asthma control and asthma-related quality of life suggests that this group may benefit from closer monitoring.

Although the strengths of this study include the comprehensive phenotyping of enrolled participants and prospective follow-up over one year, there are limitations. First, anxiety was not confirmed by a psychiatric evaluation or diagnosis, but was instead identified by a screening questionnaire. Additional studies are needed to understand the performance of the screening questionnaire (and cultural sensitivity) in the detection of physician-diagnosed anxiety in our study population. Second, our inclusion criteria which included full-term birth and evidence of reversible airflow limitation or airway hyperresponsiveness may not be generalizable to the larger population of physician-diagnosed "asthma" in the United States. The regional nature of the analysis may also prohibit generalization to other adolescent populations including populations of differing race. Third, there are a number of potentially confounding variables such as access to care and asthma controller medication adherence that were not fully addressed. In a recent study of children seeking Emergency Department care, nearly one-third of families reported inadequate access to primary or outpatient specialty care as the primary reason for their visit.[54] Similarly, Black children and adolescents may have fewer asthma preventive medications[5] and may be less likely to adhere to asthma prescriptions.[55] Finally, the high drop out rate is also potentially problematic, but supports results of other large longitudinal studies which noted nearly two-fold higher dropout rates in Black versus White participants.[56] Although the factors associated with study attrition in this population are not well understood, a recent study of depression treatment strategies found that overall attrition was strongly associated with treatment satisfaction independent of socioeconomic and psychosocial factors.[57] In that same study, early attrition was also associated with less psychiatric comorbidity and higher perceived physical functioning.[57]

In conclusion, the findings of this study demonstrate a high prevalence of co-morbid anxiety symptoms in inner-city Black adolescents with persistent asthma associated with poor asthma control, impaired asthma-related quality of life, insomnia, and increased prospective Emergency Department utilization for asthma. Routine screening for anxiety disorders may be useful in the clinical management of adolescents with asthma, particularly in those with poor asthma control and frequent healthcare utilization. Future studies of anxiety management strategies in adolescents with asthma are needed.

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ABBREVIATIONS

ACT	Asthma Control Test
$FEF_{25–75}$	Forced expiratory flow at 25 to 75 % of vital capacity
FEV_1	Forced expiratory volume in one second
FVC	Forced vital capacity
HADS	Hospital Anxiety and Depression Scale
HADS-A	Hospital Anxiety and Depression Scale, Anxiety subscale
ISI	Insomnia Severity Index

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HIGHLIGHTS BOX

What is already known about this topic?

- Co-morbid psychiatric disorders including anxiety are common in asthma patients and contribute to poor control and increased costs. Anxiety has not been studied in Black adolescent asthma populations at high risk for adverse asthma outcomes (word count = 35).

What does this article add to our knowledge?

- Nearly one third of inner-city Black adolescents with persistent asthma have probable anxiety disorders that are associated with poorer asthma control, impaired quality of life, insomnia, and increased Emergency Department utilization for asthma (word count = 33)

How does this study impact current management guidelines?

- Routine screening for anxiety disorders may be useful in the clinical management of inner-city Black adolescents with asthma and may help identify subgroups at risk for poorer asthma outcomes (word count = 29)

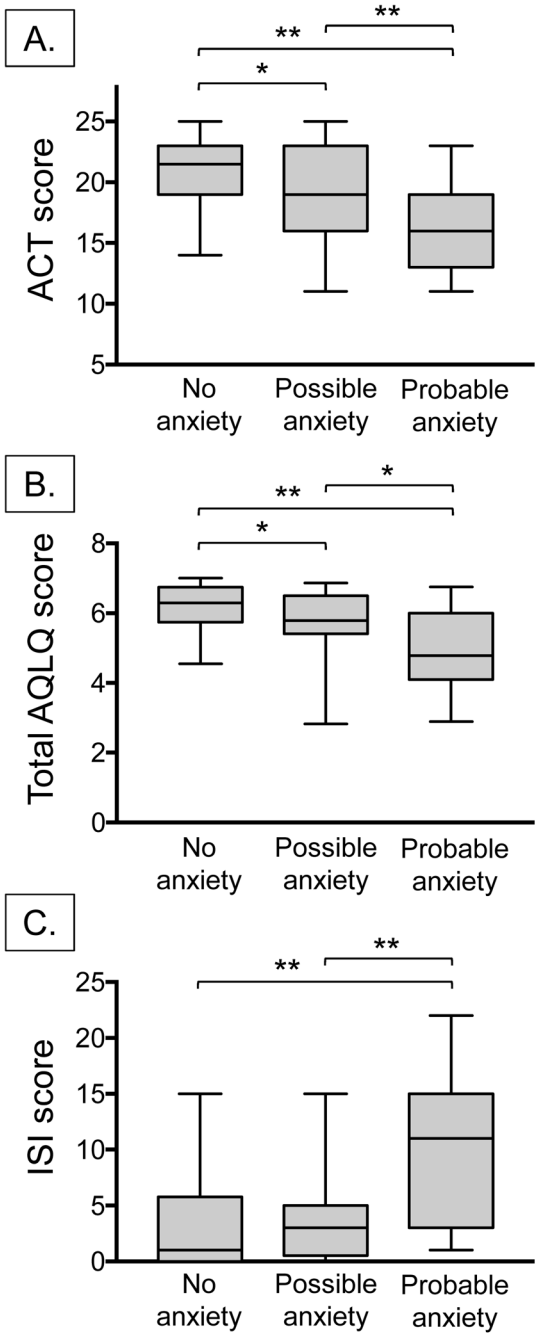

Figure 1.

(A) Asthma Control Test **(ACT)** scores, (B) total Asthma Quality of Life Questionnaire **(AQLQ)** scores, and (C) Insomnia Severity Index **(ISI)** scores in adolescents with no anxiety (HADS-A score <5), possible anxiety (HADS-A score 5–7), and probable anxiety (HADS-A score >7) at the baseline visit. *p < 0.05, ** p <0.01

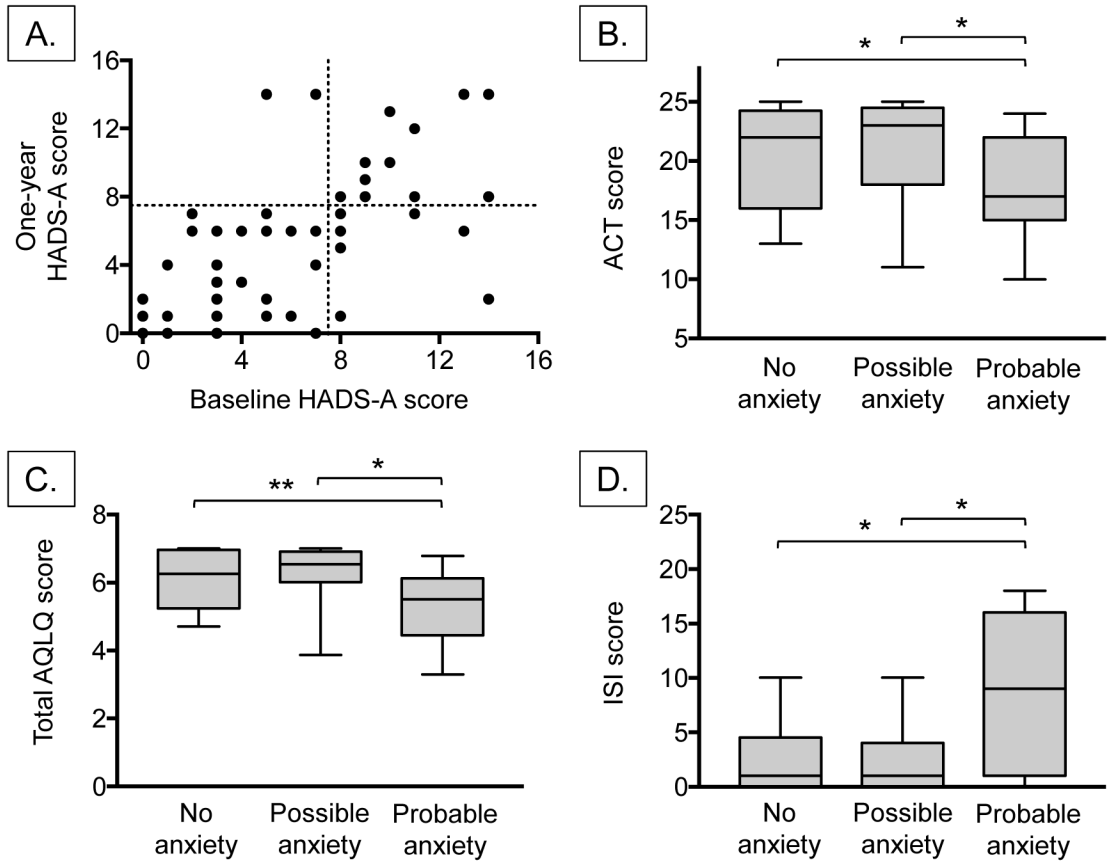

Figure 2.

(A) Baseline versus one-year HADS-A scores, (B) Asthma Control Test **(ACT)** scores, (C) total Asthma Quality of Life Questionnaire **(AQLQ)** scores, and (D) Insomnia Severity Index **(ISI)** scores in adolescents with no anxiety (HADS-A score <5), possible anxiety (HADS-A score 5–7), and probable anxiety (HADS-A score >7) at the one-year follow-up visit. *p < 0.05, ** p <0.01

Table 1

Demographic features and neighborhood characteristics of the participants at enrollment. Data represent the number of participants (%) or the mean ± SD.

	No anxiety HADS-A score <5 N = 36	Possible anxiety HADS-A score 5–7 N = 23	Probable anxiety HADS-A score >7 N = 27
Age (years)	15.2 ± 2.7	15.0 ± .22	17.1 ± 3.5 *,**
Male	22 (61.1)	13 (56.5)	12 (44.4)
Hispanic	1 (2.8)	-	1 (3.7)
Highest household education level			
High school or equivalent	6 (16.7)	5 (21.7)	7 (25.9)
Some college or technical training	9 (25.0)	5 (21.7)	9 (33.3)
Associate or college degree	20 (55.6)	13 (56.5)	8 (29.6) *
Decline to answer	1 (2.8)	-	3 (11.1)
Household income (yearly estimate)			
Individuals supported	3.5 ± 1.8	3.5 ± 1.6	3.7 ± 2.9
< $25,000	14 (38.9)	10 (43.5)	16 (59) *
$25,000 to $49,999	8 (22.2)	5 (21.7)	2 (7.4)
≥ $50,000	12 (33.3)	4 (17.4)	4 (14.8)
Decline to answer	2 (5.6)	4 (17.4)	5 (18.5)
Neighborhood household characteristics			
Median yearly income (thousand $)	43.8 ± 16.7	42.9 ± 15.8	40.9 ± 12.2
Families below poverty (%)	20.2 ± 12	20.0 ± 7	20.0 ± 10.1
Households with no car access (%)	10.5 ± 7.8	11.1 ± 8.4	13.5 ± 9.2
Rented homes (%)	35.6 ± 12.6	39.1 ± 12.8	44.3 ± 15.1 *
Other neighborhood features			
Unemployment (%)	14.6 ± 5.0	17.5 ± 7.3	14.5 ± 6.5
Associate or Bachelors degree (%)	36.1 ± 12.4	33.6 ± 15.5	35.2 ± 12.2
Insurance coverage			
Private insurance (%)	59.1 ± 14.3	55.1 ± 12.0	54.9 ± 13.8
Public insurance (%)	32.5 ± 11.4	33.7 ± 8.5	37.7 ± 9.1 *
No insurance (%)	17.1 ± 6.7	19.6 ± 6.0	17.3 ± 7.9
Crime [1]			
Total crime risk	226 ± 171	234 ± 150	212 ± 159
Personal crime risk	219 ± 200	215 ± 185	220 ± 172
Property crime risk	214 ± 143	224 ±122	198 ± 130

* $p < 0.05$ vs. no anxiety,

** $p < 0.05$ vs. possible anxiety

[1]Data refer to the risk of rape, murder, assault, robbery, burglary, larceny and vehicle theft over seven years compared to the national average of 100. A score of 200 indicates twice the national average.

Table 2

Asthma characteristics of the participants at enrollment. Data represent the number of participants (%), the median (IQR), or the mean ± SD.

	No anxiety HADS-A score <5 N = 36	Possible anxiety HADS-A score 5–7 N = 23	Probable anxiety HADS-A score >7 N = 27
Asthma controller medications			
None	6 (16.7)	5 (21.7)	7 (25.9)
ICS monotherapy	10 (27.8)	6 (26.1)	2 (7.4)
ICS + LABA	7 (19.4)	5 (21.7)	7 (25.9)
ICS + LABA + LTRA	13 (36.1)	7 (30.4)	11 (40.7)
Healthcare utilization (previous year)			
Emergency Department visit	9 (25.0)	9 (39.1)	14 (51.9) *
Hospitalization	5 (13.9)	5 (21.7)	5 (18.5)
Intubation for asthma (lifetime)	2 (5.6)	1 (4.3)	5 (18.5)
Asthma prevented school or work (previous year)	17 (47.2)	17 (73.9) *	19 (70.4) *
Co-morbid conditions			
Hypertension	2 (6)	1 (4)	3 (11)
Obesity	10 (28)	8 (35)	14 (52) *
Nasal polyps	3 (8)	1 (4)	3 (11)
Chronic sinusitis	9 (25)	8 (35)	2 (7)
Recurrent pneumonia	14 (39)	8 (35)	13 (48)
Gastroesophageal reflux	8 (22)	5 (22)	13 (48) *
Allergic sensitization[1]			
Dust mite *	18 (52.9)	14 (63.6)	24 (88.9) *,**
Pets	20 (58.8)	13 (59.1)	21 (77.8)
Cockroach *	12 (35.3)	9 (40.9)	19 (70.4) *,**
Pollen	24 (70.6)	16 (72.7)	23 (92.0)
Mold	22 (64.7)	11 (50.0)	18 (66.7)
Exhaled nitric oxide (ppb)[2]	22.0 (12.0, 57.0)	31.0 (20.0, 62.0)	48 (28.0, 69.8) *
Pulmonary function			
FVC (% predicted)	101.2 ± 13.6	96.1 ± 14.8	96.6 ± 21.5
FEV_1 (% predicted)	88.7 ± 15.7	84.5 ± 17.5	80.9 ± 21.6
$FEF_{25–75}$ (% predicted)	68.2 ± 25.5	69.3 ± 30.5	57.3 ± 27.6
FEV_1 bronchodilator reversibility (absolute % change from baseline)	12.7 ± 9.5	16.6 ± 13.3	18.0 ± 13.7

ICS = inhaled corticosteroid

IQR = interquartile range

LABA = long-acting beta agonist

LTRA = leukotriene receptor antagonist

* $p < 0.05$ vs. no anxiety,

** $p < 0.05$ vs. possible anxiety

1 No anxiety, N = 34; possible anxiety, N = 22; probable anxiety, N = 27

2 Statistical analyses were performed after logarithmic transformation

Table 3

Exhaled nitric oxide and lung function values at the one year follow-up visit. Data represent the median (IQR) or the mean ± SD. Differences between groups are not statistically significant.

	No anxiety HADS-A score <5 N = 26	**Possible anxiety HADS-A score 5–7 N = 18**	**Probable anxiety HADS-A score >7 N = 23**
Exhaled nitric oxide (ppb)[1]	27.0 (13.5, 51.5)	57.0 (16.5, 78.8)	34.5 (21.8, 63.8)
Pulmonary function			
FVC (% predicted)	100.9 ± 12.7	97.7 ± 11.6	101.1 ± 13.6
FEV_1 (% predicted)	88.6 ± 12.4	88.8 ± 14.9	81.3 ± 12.3
$FEF_{25–75}$ (% predicted)	70.2 ± 26.1	72.5 ± 30.5	57.9 ± 23.2
FEV_1 bronchodilator reversibility (absolute % change from baseline)	11.7 ± 11.7	9.4 ± 10.8	11.2 ± 9.1

[1] Statistical analyses were performed after logarithmic transformation

Table 4

Primary asthma outcomes in participants with possible anxiety (HADS-A score 5–7; N = 18) and probable anxiety (HADS-A score >7; N = 23) at one year. Participants with no anxiety (HADS-A score <5, N = 26) served as the reference group.

Outcome	n (%)with outcome	Original dataset (N = 67)		Imputed dataset (N = 86)	
		Crude OR (95% CI)	Adjusted OR (95% CI)[1]	Crude OR (95% CI)	Adjusted OR (95% CI)[1]
Persistent uncontrolled asthma[2]					
Possible anxiety	4 (22)	1.29 (0.29, 5.71)	1.13 (0.23, 5.48)	1.41 (0.35, 5.73)	1.12 (0.25, 5.06)
Probable anxiety	12 (52)	5.60 (1.52, 20.61) **	4.24 (1.07, 16.82) *	5.88 (1.49, 23.14) *	4.55 (1.14, 18.22) *
Exacerbation treated with systemic corticosteroids					
Possible anxiety	8 (44)	1.51 (0.44, 5.18)	1.29 (0.33, 5.15)	1.49 (0.31, 7.31)	1.42 (0.22, 9.13)
Probable anxiety	12 (52)	2.06 (0.65, 6.51)	2.55 (0.67, 9.77)	2.26 (0.71, 7.20)	3.09 (0.75, 12.69)
Unscheduled physician visit					
Possible anxiety	7 (39)	1.02 (0.30, 3.50)	1.31 (0.32, 5.45)	1.15 (0.30, 4.40)	1.42 (0.23, 8.82)
Probable anxiety	8 (35)	0.85 (0.27, 2.74)	1.39 (0.34, 5.74)	0.88 (0.30, 2.62)	1.66 (0.41, 6.66)
Emergency Department visit					
Possible anxiety	9 (50)	3.33 (0.91, 12.21)	2.01 (0.46, 8.85)	2.83 (0.80, 10.01)	2.02 (0.46, 8.97)
Probable anxiety	14 (61)	5.18 (1.50, 17.89) *	6.89 (1.47, 32.17) *	4.05 (1.19, 13.78) *	7.40 (1.54, 35.56) *

* $p < 0.05$,

** $p \leq 0.01$

[1] Adjusted for age group (12–17 years versus 18–21 years), sex, and household income level.

[2] Defined by and ACT score <19 at both visits.