Individual and Neighborhood Factors Associated with Undiagnosed Asthma in a Large Cohort of Urban Adolescents

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Published online: 15 January 2019
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Abstract Undiagnosed asthma adds to the burden of asthma and is an especially significant public health concern among urban adolescents. While much is known about individual-level demographic and neighborhood-level factors that characterize those with diagnosed asthma, limited data exist regarding these factors and undiagnosed asthma. This observational study evaluated associations between undiagnosed asthma and individual and neighborhood factors among a large cohort of urban adolescents. We analyzed data from 10,295 New York City adolescents who reported on asthma symptoms and diagnosis; a subset ($n = 6220$) provided addresses that we were able to geocode into US Census tracts. Multivariable regression models estimated associations between undiagnosed asthma status and individual-level variables. Hierarchical linear modeling estimated associations between undiagnosed

asthma status and neighborhood-level variables. Undiagnosed asthma prevalence was 20.2%. Females had higher odds of being undiagnosed (adjusted odds ratio (AOR) = 1.25; 95% confidence interval (CI) = 1.13–1.37). Compared to White, non-Hispanic adolescents, Asian-Americans had higher risk of being undiagnosed (AOR = 1.41; 95% CI = 1.01–1.95); Latinos (AOR = 0.67; 95% CI = 0.45–0.83); and African-Americans/Blacks (AOR = 0.66; 95% CI = 0.52–0.87) had lower risk; Latinos and African-Americans/Blacks did not differ significantly. Living in a neighborhood with a lower concentration of Latinos relative to White non-Latinos was associated with lower risk of being undiagnosed (AOR = 0.66; CI = 0.43–0.95). Living in a neighborhood with health care provider shortages was associated with lower risk of being undiagnosed (AOR = 0.80; 95% CI = 0.69–0.93). Public health campaigns to educate adolescents and their caregivers about undiagnosed asthma, as well as education for health care providers to screen adolescent patients for asthma, are warranted.

Jean-Marie Bruzzese and Sharon Kingston contributed equally to this work.

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Keywords Undiagnosed asthma · Urban · Adolescents ·
Demographics · Neighborhood factors · Disparities

Introduction

Asthma, the most common pediatric chronic illness, is a significant public health concern. When uncontrolled, asthma contributes significantly to morbidity, including reduced physical activity, lower cognitive functioning, more frequent school absences, reduced quality of life,

increased risk of comorbidities (e.g., obesity, lung infection, and symptoms of anxiety and depression), and greater use of urgent health care services [1, 2]. This is especially true for adolescents who have a higher prevalence of diagnosed asthma [3, 4] and greater asthma-related morbidity and mortality [5, 6] than elementary school age youth. Vulnerability to pediatric asthma changes in males and females with age. While in childhood boys have a higher asthma prevalence and worse severity than girls, a sex switch occurs in adolescence and continues into adulthood [7, 8]. Also, Latino and African-American/Black youth are at increased risk for asthma and its negative consequences when uncontrolled [4].

Not only do these individual-level demographic factors contribute to asthma disparities, neighborhood-level factors do as well. A higher proportion of non-Latino racial/ethnic minority residents in a neighborhood and increased neighborhood poverty rates have been found to be associated with increased asthma prevalence and severity, as well as the prevalence of hospitalizations and emergency room visits [9–11]. Low neighborhood education level has been found to be associated with children receiving an asthma diagnosis and greater utilization of asthma-related health care services [12, 13]. Lack of access to primary care at the individual and neighborhood levels have also been found to contribute to poor asthma-related outcomes among Latinos and African-Americans/Blacks [11, 14, 15].

In addition to the high prevalence of asthma among adolescents, a large proportion also suffer from undiagnosed asthma. Limited but important literature indicates that between 8 and 49% of 7- to 18-year olds with asthma symptoms are not diagnosed [16–20]. Youth with undiagnosed asthma experience significant asthma-related symptoms and morbidity [17], which are often comparable to or more severe than those of youth with diagnosed asthma [18, 21]. Undiagnosed asthma among adolescents is of particular concern because of the increased prevalence and morbidity of asthma in this age group [3–6], and because far fewer adolescents than young children are likely to visit a health care provider for routine care which limits their chances of being identified and diagnosed [4]. It is unclear whether the individual-level demographic and neighborhood-level factors that characterize disparities among those with diagnosed asthma similarly apply to youth with undiagnosed asthma.

Identifying risk factors for having symptoms of asthma but being undiagnosed is a critical first step in helping these vulnerable adolescents. Therefore, we sought to investigate if individual- and neighborhood-level factors are associated with having undiagnosed asthma among a large sample of primarily low-income Latino and African-American/Black adolescents living in New York City (NYC). At the individual level, we hypothesized that (1) girls would be more likely to be undiagnosed than boys due to the sex-switch of asthma prevalence beginning in adolescence [7, 8], and (2) Latino and African-American/Black adolescents would be more likely to be undiagnosed than White, non-Latino adolescents. At the neighborhood level, we predicted that having undiagnosed asthma would be associated with living in a neighborhood with (1) low neighborhood education status, (2) higher concentrations of individuals who identify as Latino or African-American/Black (racial/ethnic groups who experience health disparities) relative to the concentration of those who identify as White, non-Latinos, and (3) a lack of access to primary health care.

Methods

Study Overview We conducted a secondary analysis of data from a study testing the efficacy of a school-based intervention for high school students who present with symptoms consistent with asthma but who have not been diagnosed (i.e., have undiagnosed asthma) [22]. To identify adolescents for the study, students in NYC public high schools ($n = 44$ schools on 19 campuses) completed a screening survey. Schools were selected to participate if their students represented those most at risk for asthma (i.e., at least half the student body was lower income (defined as receiving free or reduced lunch) and Latino and/or African-American/Black. This paper makes use of the screening data from adolescents ages 13 to 18.9 collected during the 2008–2009, 2009–2010, 2010–2011, and 2011–2012 school years. We worked with two schools during the 2008–2009 school year and again in the 2011–2012 school year; duplicate surveys from the same student were excluded, resulting in sample of 33,596 unique adolescents. The institutional review boards (IRBs) of New York University School of Medicine, Columbia University Medical Center, and the New York City Department of Education (DOE) approved all study procedures related to data collection;

the IRBs of Columbia University Medical Center and Dickinson College approved the procedures for this study.

Procedures

Trained study personnel proctored administration of the screening survey, which adolescents completed in class during the fall semester of a given school year; the investigators obtained a waiver of parental consent for the screening survey. In addition to demographic questions, adolescents answered seven questions from a brief validated measure assessing *probable asthma* [23], indicating how often they experienced (0 = Never, 1 = Sometimes, 2 = A lot) signs and symptoms of asthma. Those who endorsed at least three symptoms were classified as having probable asthma because a score of 3 has been found to have an estimated sensitivity of 80% and specificity of 70% [23]. Adolescents also indicated if they were ever diagnosed with asthma. Inclusion criteria for this study were as follows: (1) meeting the criteria for probable asthma but reporting not having a diagnosis (i.e., undiagnosed asthma) or (2) reporting having a diagnosis of asthma, regardless of current symptoms. This resulted in a study sample size of $n = 10,295$.

On the screening survey, a subset of adolescents from the 2009–2010, 2010–2011, and 2011–2012 cohorts provided their addresses, which was emphasized as being optional. ArcGIS was used to geocode addresses into United States (US) Census tracts according to the NYC Department of Planning maps. Data on neighborhood characteristics were downloaded onto the maps from the 2010 US Census and the US Human Resources and Services Administration.

Measures

Outcome Variable Asthma diagnosis status was the outcome variable. Undiagnosed asthma was defined as meeting the criteria for probable asthma and reporting never being diagnosed with asthma. Diagnosed asthma was defined as reporting ever being diagnosed with asthma.

Individual-Level Predictors From the screening survey, we utilized date of birth, sex (male/female), and race/ethnicity (Latino, African-American/Black, Asian-

American, White non-Latino, and other). We computed age using the date of birth and the date of the survey completion.

Neighborhood-Level Predictors We considered three neighborhood-level factors: (1) education; (2) racial segregation; and (3) access to health care. Neighborhood education was assessed using census tract data on the percentage of residents with at least a high school diploma.

To assess racial segregation, we utilized the Index of Concentration at the Extremes (ICE), a measure that compares the concentration of individuals at the extremes of deprivation and privilege within a geographic area [24]. ICE indices assessing racial segregation have been used in the social sciences and to monitor health [25–30]. In our study, we defined deprivation as areas of high health disparities (i.e., high proportion of either Latino or African-American/Black residents) and privilege as having better health outcomes (i.e., high proportion of non-Latino Whites). ICE scores range from -1 , indicating that 100% of the area's residents are in the deprived group, to 1 indicating that 100% of the area's residents are in the privileged group [24]. The current study calculated two ICE indices: (1) ICE Latino, which compared Latinos (deprived group) to non-Latino Whites (privileged group) and (2) ICE African-American, which compared African-Americans (deprived group) to non-Latino Whites (privileged group).

The Primary Care Health Professional Shortage Area Index, developed by the US Health Resources and Services Administration (HRSA), was used to measure access to health care within participants' census tracts (<https://www.hrsa.gov/>). HRSA dichotomizes neighborhoods as being a shortage area or not using the following factors: the population to provider ratio; the percent of the population below the federal poverty level; an infant health index based on infant mortality rate or low birth rate (the index that provides the highest score is used); and the travel time to the nearest source of care. HRSA data was used to code neighborhoods as having a shortage of primary care providers or not having a shortage of primary care providers. Although the HRSA Primary Care Health Professional Shortage Area index does provide continuous scores for neighborhoods that are designated as shortage areas the dichotomous version of the variable was used for this study because the continuous scores on this index are not available for neighborhoods that are not rated as

Health Care Provider Shortage Areas. Because neighborhood-level poverty was included in this index, it was not measured separately.

Statistical Analysis

We first characterized the distributions of participant characteristics for the full sample and then stratified by diagnosis status. To compare undiagnosed and diagnosed adolescents regarding demographics, we used chi-squared tests or Fisher exact tests for categorical variables. To assess differences in continuous variables, pooled *t* tests were used.

Generalized linear mixed models were used to assess the associations between individual-level predictors (i.e., age, sex, race/ethnicity) and asthma diagnosis status (undiagnosed versus diagnosed), with school as a fixed effect to account for potential clustering by school. In the subset of adolescents with address-level data, hierarchical linear modeling (HLM) was used to test the association of being undiagnosed with census tract-level scores on neighborhood education level, racial/ethnic segregation, and lack of access to primary care providers, controlling for individual-level factors, which were entered into the hierarchical linear model at level one. Because we were interested in examining health disparities in Latino and African-American adolescents, we used White, non-Hispanic as the reference group in our models. However, given the relatively small size of this group, we checked the validity of these analyses by running models with Latino and with African-American as the reference groups. Because the results of the various models were consistent, to be parsimonious, we only present the results with White as the reference group given the study's focus on health disparities.¹

We utilized listwise deletion, excluding participants from model testing if they were missing a given predictor. All statistical tests were two sided. Statistical analyses were performed using R version 3.3.2. (R Core Development Team, Vienna, Austria), except for the HLM models, which were constructed using Hierarchical Linear Modeling (HLM 7.03: Hierarchical Linear & Nonlinear Modeling, SSI Inc., Skokie, IL).

Asthma severity is associated with greater asthma-related health care utilization [31]. As such, it is plausible that asthma severity may play a role in obtaining a

diagnosis as those with more severe asthma may seek care for the symptoms. Therefore, to explore the potential impact of asthma severity, all models were run with and without asthma severity using criteria established by the National Heart, Lung, and Blood Institute [1]. Severity was determined based on adolescent responses to a scale [32] that was part of the screening survey regarding the past year frequency (never or rarely, 5 or more days a year, 3 or more days a month, 3–6 days a week, every day but not all the time, or every day and all the time) of six asthma symptoms. The pattern of results did not change when asthma severity was controlled; to be parsimonious, we report the models without severity.²

Results

In total, 33,596 adolescents completed the screening survey. Among the subset who provided their addresses, we were able to link 79.1% ($n = 17,735/22,399$) of the addresses to their census tract. There were no significant differences in demographic characteristics of adolescents who provided addresses that could be geocoded compared to those without geocoded addresses. Table 1 details the demographic characteristics of the overall sample and the sample stratified by diagnosis status. Overall, the majority of students who completed the screening survey identified as Latino (45.3%, 14,446) or African-American/Black (31.1%, $n = 9932$); their mean age was 15.8 years, and a similar number were males and females. One-fifth (20.2%) reported symptoms of probable asthma but not being diagnosed, and 10.4% reported ever being diagnosed with asthma.

Overall, 30.6% of students who completed the screening survey met study inclusion criteria ($n = 10,295$); among these, 66.0% ($n = 6796$) had undiagnosed asthma. Because we used listwise deletion, we excluded from the models testing the individual-level factor students who were missing one or more of the demographic variables (14.5%; $n = 1488$), resulting in an analytic sample of 8807. There were no differences by diagnosis status in the percent of students missing age and sex variables; however, a lower percentage of those in the diagnosed group reported their race/ethnicity ($p < .0001$). Neighborhood-level data were available for 70.6% ($n = 6220$) of the analytic sample;

¹ Results available from the corresponding author upon request.

² Results of models controlling for asthma severity are available from the corresponding author upon request.

Table 1 Sample characteristics for the full sample and stratified by asthma diagnosis and results of individual-level multivariable model testing

	Full sample (<i>N</i> = 33,596) <i>n</i> (%)	Undiagnosed (<i>N</i> = 6796) <i>n</i> (%)	Diagnosed (<i>N</i> = 3499) <i>n</i> (%)	AOR (95% CI) ^a
Age (mean (SD))	15.84 (1.21)	15.82 (1.19)	15.74 (1.22)	1.05 (1.00, 1.09)
Female	15,739 (50.5)	4191 (65.8)	1968 (60.6)	1.25 (1.13, 1.37)
Race/ethnicity				
White, non-Hispanic	1483 (4.7)	257 (3.9)	101 (3.1)	Reference
Latino	14,446 (45.3)	2887 (44.3)	1511 (46.0)	0.67 (0.45, 0.83)
African-American	9932 (31.1)	2034 (31.2)	1066 (32.5)	0.66 (0.52, 0.87)
Asian-American	2148 (6.7)	466 (7.2)	113 (3.4)	1.41 (1.01, 1.95)
Other	3883 (12.2)	875 (13.4)	494 (15.0)	0.61 (0.47, 0.81)

AOR, adjusted odds ratio; CI, confidence interval; SD, standard deviation

^a Adjusted models include all three individual-level variables and school as a fixed effect

these students resided in 1023 unique census tracts. As detailed in Table 2, within these census tracks, the mean percent of high school graduates was 74% (SD = 13%; range 16 to 100%). With respect to segregation, the mean ICE Latino score was -0.11 (SD = 0.44; range = -0.88 to 0.96) and the mean ICE African-American/Black score was -0.12 (SD = 0.51; range = -0.93 to 0.96). Fifty-eight percent of the census tracts were designated as Primary Care Health Professional Shortage Areas.

Individual-Level Predictors of Undiagnosed Asthma

In the multivariable regression model (Table 1), accounting for school-level clustering, females had significantly higher odds of being undiagnosed (AOR, 1.05; 95% CI, 1.01–1.09). Compared to White, non-Latino adolescents, Asian-American adolescents had significantly higher odds of being undiagnosed (AOR, 1.41; 95% CI, 1.01–1.95), whereas Latinos and African-American/Blacks had lower odds of being undiagnosed (Latino = AOR, 0.67; 95% CI, 0.45–0.83; African-American/Black = AOR, 0.66; 95% CI, 0.52–0.87). Of note, Latinos and African-Americans did not differ significantly from one another (AOR, 0.98; 95% CI, 0.88–1.09).³

Neighborhood-Level Predictors of Undiagnosed Asthma

Table 3 details the HLM model results. Neighborhood-level education was not significantly associated with being undiagnosed. Living in a neighborhood with a lower concentration of Latino residents relative to White non-Latino residents was associated with a lower risk of being undiagnosed (AOR, 0.66; 95% CI, 0.45–0.95); the relationship between the concentration of African-American/Black residents relative to White non-Latino residents in a neighborhood was not significantly related to being undiagnosed. Living in an area designated as a Primary Care Health Professionals Shortage was associated with a lower risk of being undiagnosed (AOR, 0.71; 95% CI, 0.58–0.87).

Discussion

This is the first study to investigate individual-level and neighborhood-level factors associated with undiagnosed asthma in a large cohort of urban adolescents. At the individual level, sex and race/ethnicity were associated with having undiagnosed asthma. At the neighborhood level, living in a neighborhood with a lower concentration of Latino residents and a higher concentration of White non-Latino residents, and living in a neighborhood with limited access to primary care providers were associated with a lower risk of being undiagnosed. Perhaps the most striking finding of the study is the large proportion of adolescents who were identified as

³ AOR and CI from model with Latino as the reference group.

Table 2 Descriptive statistics of the neighborhood characteristics within the unique census tracts

	Census tract	
	(N = 1023)	
	Mean (SD)	Range
Education (% high school diploma)	74.30 (13.13)	15.90–100.00
Segregation		
ICE Black	− 0.12 (0.51)	− 0.93–0.96
ICE Latino	− 0.11 (0.44)	− 0.88–0.96
Primary Care HPSA Designation (n (%))	593 (58)	

ICE, Index of Concentration at the Extremes; SD, standard deviation

having undiagnosed asthma—approximately 20% of the sample reported having symptoms consistent with asthma, but not having ever been diagnosed, which was twice that of those who reported being diagnosed with asthma. These adolescents with undiagnosed and, thus, untreated asthma are at high risk for the negative consequences of asthma. Adolescents in general tend to be low users of health care services [4], which may prevent youth with onset of asthma during adolescence from receiving a diagnosis and treatment for a potentially life-threatening condition. Female and Asian/Asian-

American adolescents were found to be the highest risk for undiagnosed asthma, whereas Latino and African-American/Black adolescents were at the lowest risk.

The hypothesis that females in our sample of urban adolescents would be more likely than males to have undiagnosed asthma was supported. This suggests that adolescent females, particularly those attending urban schools serving predominately low-income Latino and African-American/Black students, are at risk of not receiving a timely diagnosis of asthma, preventing them from receiving adequate care related to their symptoms. These results might be explained by disparities in frequency and/or quality of health care provided to girls relative to boys. Not being diagnosed in childhood may lead to being undiagnosed in adolescence. Some studies have suggested that childhood asthma may be underdiagnosed in girls, who are less likely than boys to present with allergic asthma [33] and less likely to see a health care provider for their symptoms [34]. Therefore, failure of health care providers to adequately screen, diagnose, and treat asthma in childhood may have contributed to the over representation of girls among undiagnosed adolescents in our sample.

Alternatively, these sex disparities might be explained by research suggesting that there is a higher prevalence of adolescent-onset asthma in females than males [7, 8]. When the adolescent female develops symptoms, the adolescent and/or her caregivers may fail to consider that the symptoms are asthma because of the erroneous lay belief that asthma is a disease that presents in childhood.

The findings on the contribution of race/ethnicity to the probability of being undiagnosed run counter to the large body of evidence on health disparities regarding the prevalence of diagnosed asthma [4], and to our

Table 3 Hierarchical linear model associations of asthma diagnosis status and neighborhood-level factors

	AOR (95% CI)
Intercept	1.74 (1.26–2.39)
Level 1: individual predictors	
Age	1.05 (0.95–1.16)
Female	1.80 (1.52–2.15)
Race/ethnicity (reference group = White, non-Hispanic)	
Latino	0.46 (0.34–0.61)
African-American	0.56 (0.41–0.76)
Asian-American	1.15 (0.79–1.67)
Other	0.75 (0.46–1.22)
Level 2: neighborhood predictors	
Education (% high school diploma)	1.01 (1.00–1.02)
Segregation	
ICE Latino	0.66 (0.45–0.95)
ICE African-American	1.02 (0.78–1.33)
Primary Care HPSA Designation	0.71 (0.58–0.87)

AOR, adjusted odds ratio; CI, confidence interval; HPSA, Health Professional Shortage Area; ICE, index of concentration at the extremes

hypotheses that Latino and African-American/Black adolescents would be more likely to be undiagnosed. In our sample of predominately Latino and African-American/Black adolescents living in NYC, Latinos and African-American/Blacks were less likely to be undiagnosed than White, non-Hispanic adolescents, and Asian-American adolescents were more likely to be undiagnosed than White, non-Hispanics. It is plausible that health care providers are aware of the increased risk in asthma prevalence and morbidity asthma among Latino and African-American/Black children and, therefore, may more thoroughly screen for and diagnose asthma among this group of children and adolescents. Alternatively, our findings may be due to the relatively small sample size of White, non-Hispanics. However, the results of models with Latino and with African-American as the reference group were consistent with the models with White as the reference group. Therefore, while the magnitude of the race/ethnicity differences found might be an artifact of the relatively small sample size of White, non-Hispanics, we believe our results are accurate.

We are unaware of any previous research on the prevalence of undiagnosed asthma among Asian-American adolescents. However, multiple studies document barriers to health care faced by Asian-Americans in the USA, including language barriers, cultural challenges including a preference for traditional medicine, low health literacy, lack of health insurance, and immigrant status [35–37]. These studies also document low awareness and utilization of preventive health care in Asian-American communities. Limited access to health care and a lack of health literacy related to asthma may be contributing to the racial disparity in receiving a diagnosis and appropriate care for Asian-American youth.

Neighborhood factors in NYC have a mixed role in predicting the prevalence of undiagnosed asthma among adolescents. Neither neighborhood education level, nor living in a neighborhood with a high concentration of African-American/Black residents relative to White non-Latino residents predicted being undiagnosed. In contrast, living in a neighborhood with a low concentration of Latino residents relative to White non-Latino residents was associated with a lower risk of being undiagnosed. The finding that Latino segregation, but not African-American/Black segregation, was related to undiagnosed asthma was contrary to our hypotheses. It is possible that the burdens related to immigration and language barriers are more prevalent in Latino communities than African-American/Black communities in NYC. This is relevant

because children of immigrant caregivers, non-English-speaking caregivers, and undocumented caregivers are more likely to suffer from undiagnosed chronic illnesses, including asthma [38–40]. Our finding supports the argument that the ICE index can be a useful tool in measuring geographic risk factors in public health research [30].

Contrary to expectations, those living in health care provider shortage areas were less likely to be undiagnosed than adolescents living in areas without this designation. While it is not entirely clear what factors may account for this finding, it is plausible that the impact of neighborhood conditions on health outcomes are likely moderated by the environment of the larger community. Factors such as access to public transportation and availability of health care services in the larger surrounding community may reduce the influence of more local conditions for lower income individuals. For example, there is a link between transportation barriers and access to health care, particularly among those with lower incomes [41]. A study conducted in Philadelphia, PA, a city with a well-developed public transportation system like NYC, failed to find an association with neighborhood-level income and access to health care [42]. In contrast, low vehicle availability, a marker of neighborhood socioeconomic status, was found to be related to the least access to primary care in a study conducted in Cincinnati, OH, a city lacking an extensive public transportation system [43]. In a study of a nationally representative sample of caregivers of children with asthma, investigators found that residence in an urban area was associated with greater access to health care services [44]. NYC is a densely populated city with relatively easy access to public transportation and a large number of public and private health care facilities. As such, adolescents living in areas with a limited number of health care providers may have had access to medical services outside their immediate neighborhood, which they could access relatively easily on public transportation. Furthermore, as mentioned above, health care providers serving residents of poor communities maybe more likely to screen their patients for asthma. It is also plausible that other confounding variables that we did not measure may account for these results.

Strength and Limitations

The strength of this study is that it takes advantage of a large sample of adolescents and provides evidence that urban adolescents are at high risk of not receiving adequate diagnosis for asthma and, therefore, treatment for

a potentially life-threatening chronic illness. There are, however, several limitations. The data analyzed for this study consisted of screening data to identify adolescents for a parent study testing the efficacy of a school-based intervention designed to help undiagnosed adolescents access a medical evaluation and appropriate treatment for their asthma symptoms. As such, the study specifically focused on high schools serving adolescents at high risk for asthma, specifically low-income Latino and African-American/Black students. Although the sample was quite large with over 10,000 participants, there were just over 350 participants who identified as White, non-Latino and under 600 self-identified as Asian-Americans. The racial/ethnic and socioeconomic characteristics of the sample do not mirror the USA or NYC [45], and thus, the results may not be applicable to the general population. Related to this is the fact that we did not assess individual-level socioeconomic status, though our participants attended schools serving predominately low-income students. We also did not assess caregivers' immigration status or language spoken. Given that socioeconomic status is associated with asthma prevalence and morbidity, and that immigration status and not speaking English are associated with undiagnosed disease, these omissions are a study limitation.

The study also relied on adolescent self-report for both asthma symptoms and diagnosis. While the screening tool used to identify probable asthma is validated [23], we do not have confirmation of these symptoms by a health care provider. Some adolescents reporting undiagnosed asthma may not, in fact, have asthma. It is also possible that some adolescents reporting never having been diagnosed with asthma had at some point been diagnosed with asthma. However, given the sample consists of high school students with mean age of almost 16, we believe it is unlikely that a lack of awareness of having been diagnosed with a chronic illness was highly prevalent in our sample.

Our findings highlight an opportunity for intervention. Efforts to promote the screening and diagnosis of asthma among adolescent are warranted and could include public health campaigns designed to educate adolescents and their caregivers about the existence of the onset asthma in adolescence and the potential deleterious effects of undiagnosed and thus untreated asthma. It may be particularly important to target families with adolescent females, as well as Asian-American and Latino communities. Additionally, education for health care providers on the importance of screening adolescent patients for asthma symptoms is warranted.

Conclusion

Findings from this study highlight that undiagnosed asthma may be nearly twice as prevalent than diagnosed asthma in urban adolescents, and females and Asians-Americans are at increased risk for being undiagnosed, as are individuals living in neighborhoods with high concentrations of Latinos relative to White non-Latinos. Thus, greater effort to identify those with asthma symptoms but no diagnosis may be needed to ensure those at highest risk for being undiagnosed obtain diagnosis and treatment, as needed. Additionally, research should focus on systematically learning more about the prevalence and predictors of undiagnosed asthma through prospective, rigorous epidemiological studies among representative samples of adolescents.

Acknowledgments The authors would like to thanks Drs. Tonda Hughes and David Evans for their expert review of our manuscript.

Contributors J-M. B made substantial contributions to the study conceptualization, including the data acquisition and interpretation of the data; critically revised the manuscript for important intellectual content; approved the final version; and is accountable for all aspects of the work in ensuring the study's integrity.

S. K made substantial contributions to the study conceptualization, including the data acquisition, data analysis, and interpretation of the data; drafted parts of the manuscript and critically revised the manuscript for important intellectual content; approved the final version; and is accountable for all aspects of the work in ensuring the study's integrity.

K.A. F interpreted the data; drafted parts of the manuscript; approved the final version; and is accountable for all aspects of the work in ensuring the study's integrity.

E. B analyzed and interpreted the data; drafted parts of the manuscript; approved the final version; and is accountable for all aspects of the work in ensuring the study's integrity.

L. P conceptualized the study, including interpreting the data; critically revised the manuscript for important intellectual content; approved the final version; and is accountable for all aspects of the work in ensuring the study's integrity.

J-M. B was at the NYU School of Medicine when the data for this study was collected; S. K was at the NYU School of Medicine when part of the data for this study was collected. All other tasks related to this manuscript were conducted during J-M. B appointment at Columbia University and S. K appointment at Dickinson College.

Funding The National Institutes of Health (R01HL089493 to JMB) supported this work. The sponsor had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of this manuscript; and in the decision to submit the manuscript for publication.

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