# Well-Child Care Attendance and Risk of Asthma Exacerbations

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abstract

**BACKGROUND:** Asthma remains a leading cause of hospitalization in US children. Well-child care (WCC) visits are routinely recommended, but how WCC adherence relates to asthma outcomes is poorly described.

**METHODS:** We conducted a retrospective longitudinal cohort study using electronic health records among 5 to 17 year old children residing in Durham County with confirmed asthma and receiving primary care within a single health system, to compare the association between asthma exacerbations and previous WCC exposure. Exacerbations included any *International Classification of Diseases, Ninth Revision*, or *International Classification of Diseases, 10th Revision*, coded asthma exacerbation encounter with an accompanying systemic glucocorticoid prescription. Exacerbations were grouped by severity: ambulatory encounter only, urgent care, emergency department, hospital encounters $<$24 hours, and hospital admissions $\geq$24 hours. In the primary analysis, we assessed time to asthma exacerbation based on the presence or absence of a WCC visit in the preceding year using a time-varying covariate Cox model.

**RESULTS:** A total of 5656 children met eligibility criteria and were included in the primary analysis. Patients with the highest WCC visit attendance tended to be younger, had a higher prevalence of private insurance, had greater asthma medication usage, and were less likely to be obese. The presence of a WCC visit in the previous 12 months was associated with a reduced risk of all-cause exacerbations (hazard ratio: 0.90; 95% confidence interval: 0.83–0.98) and severe exacerbations requiring hospital admission (hazard ratio: 0.53; 95% confidence interval: 0.39–0.71).

**CONCLUSIONS:** WCC visits were associated with a lower risk of subsequent severe exacerbations, including asthma-related emergency department visits and hospitalizations. Poor WCC visit adherence predicts pediatric asthma morbidity, especially exacerbations requiring hospitalization.

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**WHAT'S KNOWN ON THIS SUBJECT:** Well-child care visits are recommended to maintain child health. The relationship between well-child care visit adherence and subsequent asthma-related health care use in children is poorly described.

**WHAT THIS STUDY ADDS:** In this retrospective cohort study involving 5656 children with asthma, a recent well-child visit was associated with 10% fewer any-type asthma exacerbations and 47% fewer asthma-related hospitalizations.

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Routine health supervision (ie, well-child care [WCC]) is a vital component of pediatrics.[1] In current guidelines, 31 distinct developmentally tailored WCC visits from birth to age 21 years are recomended.[2,3] WCC visits aim to promote child health through anticipatory guidance, immunizations, and disease prevention and screening. Age-specific supervision is guided by both evidence-based recommendations and expert opinion.[2–4] In the United States, it is estimated that more than one-half of recommended WCC visits are missed or delayed.[5–9] Missed WCC visits have been associated with higher all-cause pediatric emergency department (ED)[10] and hospitalization[4] rates. Efforts to improve WCC attendance may improve the management of chronic conditions, although this has not been well studied.[11]

Asthma is the most common chronic disease in children.[12] One-half of children with asthma have inadequate disease control, leading to >500 000 ED visits and 80 000 inpatient hospital stays each year.[13,14] A variety of factors contribute to poor asthma control, including exposure to environmental triggers, infrequent assessments of asthma control, suboptimal medication, lack of medication adherence, and comorbidities. Parents of children with recurrent asthma use more commonly possess misconceptions about asthma exacerbation prevention that would be amenable to routine primary care–based education.[15] Although the content of WCC visits is likely to vary by provider, primary care providers are called on to reevaluate asthma control, refill medications, teach about asthma home management, answer asthma action plan questions, and evaluate new comorbid symptoms that may be complicating asthma management. A number of studies have revealed that WCC visits are key to introducing asthma education and for supporting best practices.[16–18] Regular assessments of asthma control in a nonemergency setting have a significant impact on asthma control.[19,20] In expert guidelines, it is recommended that children with asthma receive regular monitoring at least every 6 months. Given their frequency and regularity, adherence to WCC visits could have a major positive influence on asthma control in children.

In several studies, researchers assessing the quality of a medical home have demonstrated improved reported asthma symptom control and reduced admissions.[21–24] Children without a consistent medical home and who have fewer primary care visits for asthma have more ED visits for asthma,[25,26] which may represent both more frequent exacerbations and care deferred to the ED setting. In a Cochrane review, researchers could not find any studies in which the effects of primary care–based asthma visits on exacerbation risk were assessed.[27] Indeed, in few studies have researchers specifically assessed the short-term temporal relationship between WCC visit attendance and subsequent asthma exacerbations.

## METHODS

### Data Sources

This study was evaluated by the Duke University Health System (DUHS) Institutional Review Board (Pro00091342). The requirement for informed consent was waived under 45 CFR 46.116. DUHS is a comprehensive medical system consisting of a large tertiary pediatric hospital, two community hospitals, a network of primary and urgent care pediatric and family medicine clinics, and both inpatient and outpatient subspecialty services. DUHS serves as the primary health care provider in Durham County, with an estimated 85% of Durham residents receiving primary and specialty care within DUHS.

### Study Design

We abstracted patient records from the DUHS electronic health record (EHR) system to conduct a retrospective cohort study to assess the impact of a yearly WCC visit on the hazard rate for asthma exacerbations over the following year.

### Participant Selection

We first identified all patients with study-defined asthma ages 5 to 17 receiving care at DUHS between January 1, 2014, and December 31, 2019. To meet the criteria for study-defined asthma, patients had to have (1) either an asthma-appropriate *International Classification of Diseases, Ninth Revision*, (ICD-9) (493.x) or *International Classification of Diseases, 10th Revision*, (ICD-10) (J45.x) diagnosis code documented in the EHR problem list section or ≥2 outpatient or ED encounters (or 1 hospital encounter) with the appropriate ICD-9 or ICD-10 coding and (2) documented prescription of ≥1 asthma medications. We required patients to reside within Durham County to increase the capture of unscheduled asthma encounters (ie, exacerbations). Each participant's person-time was censored at age 18, after moving out of Durham County, or at their last recorded health encounter.

### Exposure of Interest

The main exposure of interest was a WCC visit, defined as a scheduled primary care office-based encounter or initial consult that also had an accompanying primary diagnosis code representing routine health supervision (see Supplemental Information, for specific codes). We treated WCC visits as a time-varying exposure and set up the data in a "counting process" format. A participant becomes eligible when they meet the eligible age, have a Durham residence, and have a documented asthma diagnosis. At the start of each participant's earliest eligibility, the WCC exposure status was considered unknown. From the start of earliest eligibility, we determined a time 0 for each participant, which was either the first indicated WCC visit or the 1-year time point from earliest eligibility (eg, if a 5 year old child had a WCC visit 3 months after their earliest eligibility, their WCC visit would constitute time 0; otherwise, if no WCC visits occurred in that year, time 0 would be 1 year after earliest eligibility). From time 0, we assessed whether there was a WCC visit in the following 11 to 15 months. If so, the participant was considered "exposed"; otherwise, we set the child to unexposed at the 12-month time point. We generated exposures and person-time in this manner until the individual was censored. We further classified patients as having full, partial, or no WCC visit attendance during their individual study periods. Full attendance included a WCC visit in each eligible year, whereas partial attendance included children with ≥1 well-child visit but not in every year.

To further contextualize possible effects of WCC visits, we assessed the frequency of asthma-related practices in each encounter, including asthma medication orders, preventive therapies (influenza and pneumococcal polyvalent vaccines), lung function testing, assessment of comorbidities important in asthma management, and asthma severity assessment.

## Asthma Exacerbations

The main outcome of interest was asthma exacerbation. We defined an exacerbation as a health care encounter, regardless of setting, that resulted in an ICD-9 code of 493.x or ICD-10 code of J45.x and included the prescription of a systemic glucocorticoid (prednisone, prednisolone, dexamethasone, hydrocortisone, or methylprednisolone). We further grouped asthma exacerbations by severity from the lowest to highest severity, on the basis of the degree of use (ie, exacerbation requiring outpatient encounter only, requiring urgent care visit, requiring ED visit, and requiring a hospital admission).

## Additional Covariates

We abstracted age, sex, race and ethnicity, insurance status (public, private, or other), atopy status, obesity status, all medication prescriptions, and the number of (all type) encounters in the previous year. The insurance status at the time of the most recent inpatient or outpatient visit before or on the same day as a WCC (or expected WCC) visit was used. The number of encounters in the previous year included any type of DUHS encounter, excluding WCC visits. Atopy was defined as having a documented appropriate ICD-9 code (see Supplemental Information for specific codes) at any time during the observation period. Obesity was defined as a BMI >95th percentile (as defined by Centers for Disease Control and Prevention growth charts), measured at the closest visit date before a WCC visit. Asthma medication use was collected and analyzed as inhaled corticosteroid (ICS) alone, combined ICS and long-acting β agonist, long-acting muscarinic antagonist (LAMA), leukotriene receptor antagonist (LTRA), and monoclonal antibody-based biological therapies. Prescribed medications were grouped into 3 levels of controller treatment intensity: low (no medication use), medium (ICS or LTRA monotherapy), and high (≥2 concurrent therapies). Medications were considered active for 1 year after prescription and treated as a time-varying covariate.

## Statistical Analysis

The primary objective of the study was to assess the impact of WCC visits on the risk of asthma exacerbation. We, first, described patient baseline characteristics, stratifying by WCC visit attendance (complete, partial, and none). We calculated the rate of all type and severity-specific (ambulatory, urgent care, ED, or hospital admission) asthma exacerbations per 100 person-years with and without previous WCC visit exposure.

In our primary analysis, we assessed time to asthma exacerbation based on presence or absence of a WCC visit in the preceding year. We used a time-varying covariate Cox model. To account for recurrent events, we used a Prentice, Williams, and Peterson[28] correction to create strata of patients based on the number of events. This model is most appropriate when the occurrence of one event increases the risk of the next event, as may occur with asthma exacerbations. Participants were eligible for a next event immediately after a previous event. We estimated both unadjusted and adjusted Cox models, with one adjustment model adjusting for age, sex, and race and a second additionally adjusted for insurance type, number of encounters in the past year, atopy, obesity, and medication category. For the final model, the number of encounters was log transformed to avoid skewness. We assessed the hazard ratio (HR) for both any exacerbation and severity-specific exacerbations. We also assessed heterogeneity in the effect of WCC visits on the basis of patient demographic characteristics. We report HRs with 95% confidence intervals (CIs). Data management and analyses were performed by using R version 3.6.1, RStudio version 1.2.1335, and SAS version 9.4 (SAS Institute, Inc, Cary, NC).

## Sensitivity Analyses

As a sensitivity analysis, we used the Andersen-Gill correction,[29] including a model in which patients are not stratified by event number (ie, asthma exacerbations). We also completed a Prentice, Williams, and Peterson analysis, wherein the patients were censored at 7 events. Neither changed the overall inferential results.

## RESULTS

### Patient Characteristics

Of the 273 240 children ages 5 to 17 with ≥1 health care encounter during the study period, 6395 (8.5%) met the criteria for asthma diagnosis and Durham County residency (see Fig 1). Of these, 5656 (88.4%) had an observation period ≥12 months and were, therefore, included in the primary analysis. The demographic characteristics of the participants by WCC visit adherence are shown in Table 1. The frequency of public insurance was highest among children with full WCC attendance, whereas the percent of Hispanic children was highest in the group without any WCC attendance.

### WCC Visits and Asthma Exacerbations

The associations between WCC visit attendance and subsequent asthma exacerbations are shown in Table 2. There were a total of 2974 asthma exacerbations (19.44 per 100 patient-years). In the fully adjusted model, a WCC visit in the previous 12 months nominally reduced all-cause exacerbations by 10% (HR: 0.90; 95% CI: 0.83–0.98; Fig 2) and reduced asthma hospitalizations by 47% (HR: 0.53; 95% CI: 0.39–0.71). Conversely, we saw a slight but insignificantly increased risk for asthma exacerbation-related outpatient encounters (HR: 1.17; 95% CI: 0.96–1.19). There were no significant interactions in the association between WCC visit adherence in the previous year, all exacerbations, and age, race, or insurance status (Table 3); however, there was some heterogeneity in the association between WCC visit attendance and severe hospital-based exacerbations on the basis of race (Supplemental Table 5), although this association would not be significant after a formal correction for multiple testing.

Most visits revealed ≥1 examples of asthma-specific care (Table 4). Among all WCC visits, 9.9% involved a new or changed asthma medication prescription, 28.2% delivered the seasonal influenza vaccine, and 11% involved an assessment or management of a known asthma-

**TABLE 1** Characteristics of the Pediatric Asthma Population by Well-Child Adherence

| Characteristic | Well-Child Attendance Groups | | | *P* |
|---|---|---|---|---|
| | Children With Full Visit Attendance | Children With Partial Visit Attendance | Children With No Visit Attendance | |
| Total, *n* (%) | 1855 (32.8) | 3033 (53.6) | 768 (13.6) | — |
| Male sex, *n* (%) | 1029 (55.5) | 1723 (56.8) | 438 (57.0) | .6125[a] |
| Race and/or ethnicity, *n* (%) | | | | <.0001[a] |
| Hispanic | 186 (10.0) | 330 (10.9) | 168 (21.9) | — |
| Non-Hispanic Black | 981 (52.9) | 1911 (63.0) | 429 (55.9) | — |
| Non-Hispanic white | 480 (25.9) | 533 (17.6) | 124 (16.1) | — |
| Other | 164 (8.8) | 204 (6.7) | 36 (4.7) | — |
| Unavailable or unknown | 44 (2.4) | 55 (1.8) | 11 (1.4) | — |
| Age group, *n* (%) | | | | <.0001[a] |
| 5–11 | 1242 (67.0) | 2076 (68.4) | 461 (60.0) | — |
| 12–18 | 613 (33.0) | 957 (31.6) | 307 (40.0) | — |
| Insurance status, *n* (%) | | | | <.0001[a] |
| Public | 827 (44.6) | 1033 (34.1) | 196 (25.5) | — |
| Private | 987 (53.3) | 1892 (62.4) | 515 (67.1) | — |
| Self-pay | 39 (2.1) | 106 (3.5) | 57 (7.4) | — |
| Atopy at any time, *n* (%) | 1183 (63.8) | 2036 (67.1) | 358 (46.6) | <.0001[a] |
| BMI for age percentile, median (IQR) | 75.2 (45.4–94.0) | 79.8 (51.4–95.6) | 86.6 (49.8–97.9) | <.0001[b] |
| Obesity, *n* (%) | 426 (23.0) | 803 (26.5) | 259 (33.7) | <.0001[a] |
| Medication category, *n* (%) | | | | <.0001[a] |
| No ICS, LABA, LTRA, LAMA, or biological | 1469 (79.2) | 2544 (83.9) | 627 (81.6) | — |
| Only ICS or only LTRA | 311 (16.8) | 391 (12.9) | 90 (11.7) | — |
| All other categories | 75 (4.0) | 98 (3.2) | 51 (6.6) | — |
| No. encounters in the past y, median (IQR) | 3.0 (1.0–5.0) | 3.0 (1.0–5.0) | 3.0 (2.0–6.0) | <.0001[b] |

IQR, interquartile range; LABA, long-acting β-2 agonist; —, not applicable.
[a] $\chi^2$ test.
[b] Kruskal-Wallis test: For patients with at least 1 well-child visit, these represent the values on the date of the first well-child visit. For patients without at least 1 well-child visit, these represent the values on the date the patient became eligible for the asthma cohort.

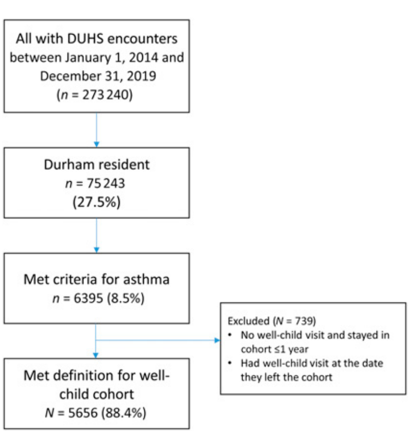


**FIGURE 1**
Consolidated Standards of Reporting Trials diagram.

**TABLE 2** Association Between Well-Child Visits and Asthma Exacerbations in Durham Pediatric Asthma Patients With At Least 1 Well-Child Visit

| Asthma Exacerbation Type | Total No. Exacerbation | Exacerbation Rate[a] | Unadjusted HRs (95% CI) | Adjusted HRs Model 1 (95% CI)[b] |
|---|---|---|---|---|
| All asthma exacerbations | 2974 | 19.44 | 0.95 (0.88–1.03) | 0.93 (0.85–1.01) |
| Hospital encounters >24 h | 207 | 1.35 | 0.53 (0.39–0.71) | 0.51 (0.38–0.70) |
| ED and hospital encounters <24 h | 629 | 4.11 | 0.65 (0.55–0.77) | 0.65 (0.55–0.77) |
| Urgent care encounters | 673 | 4.4 | 0.84 (0.72–0.98) | 0.82 (0.70–0.97) |
| Outpatient encounters | 1465 | 9.58 | 1.26 (1.12–1.42) | 1.21 (1.07–1.36) |

Values represent HRs (95% CIs) for having the event for patients who had expected well-child visits versus those who did not among patients in the well-child cohort. All models are stratified by number of events.
[a] Per 100 per y.
[b] Adjusted for age, sex, and race.

related comorbidity that can affect asthma control. Rates were similar between older and younger children.

## DISCUSSION

Our study revealed a significant association between annual WCC visit attendance and reduced occurrence of total asthma exacerbations and more severe exacerbations and associated health care use. Roughly one-third and one-half of our cohort had full and partial WCC visit attendance, respectively, whereas 14% had no WCC attendance. The relationship between WCC and reduced asthma-related ED and hospital care remained significant after adjustment for age, sex, race and ethnicity, insurance status, atopy, obesity, medication use, and previous health care encounters. Overall, this work underscores 2 important messages. First, the role of primary care pediatricians in chronic asthma management is, likely, a key component of good asthma management, and, second, improving access to and attendance of WCC visits (especially for previously low-adhering families) may be an important public health intervention to reduce the problems of severe exacerbations and outcome disparities.

WCC and age-appropriate health supervision are intended to take place during periods of relative health at key age milestones and aim to advance child health through the promotion of healthy behaviors and appropriate vaccinations, anticipatory guidance, and evidence-based disease prevention and screening.[2–4] Unfortunately, WCC visit attendance for children in the United States is far from optimal. In 2013, Abdus and Selden[7] analyzed WCC visit adherence data over a 13-year period from across the United States and found that WCC visit attendance improved from 46% in 1996–1998 to nearly 60% in 2007–2008. They found that low WCC attendance was associated with lower income, lower parental education, and African American race. Wolf et al,[9] again, found that WCC attendance was well below American Academy of Pediatrics goals. They noted that attendance was highest in the visits before 6 months of age. Several studies have revealed that early-life WCC visit attendance can be generally protective against all-cause urgent care and ED use. Tom et al[4] found

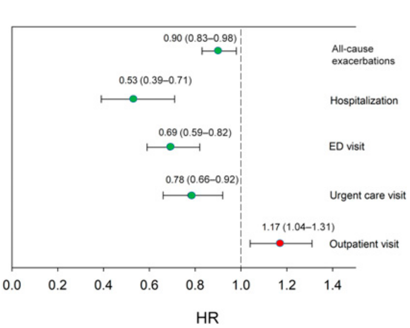


**FIGURE 2**
Forest plot of adjusted HRs revealing the association between recent well-child visits and various severities of asthma exacerbations. Data are adjusted for age, sex, race, insurance type, atopy, obesity, medication use, and the number of encounters in the past year.

**TABLE 3** Association Between Well-Child Adherence and All Asthma Exacerbations

| Stratum | *n* | Unadjusted HR (95% CI) | Adjusted HR Model 1 (95% CI)[a] | Adjusted HR Model 2 (95% CI)[b] | Interaction *P*[c] |
|---|---|---|---|---|---|
| Overall | 5656 | 0.95 (0.88–1.03) | 0.93 (0.85–1.01) | 0.90 (0.83–0.98) | — |
| Age 5–11 y | 4107 | 0.97 (0.89–1.07) | 0.97 (0.89–1.06) | 0.93 (0.85–1.03) | .10 |
| Age 12–18 y | 1549 | 0.82 (0.67–1.00) | 0.82 (0.67–0.99) | 0.84 (0.68–1.03) | — |
| Male sex | 3190 | 0.99 (0.89–1.10) | 0.97 (0.87–1.08) | 0.93 (0.83–1.03) | .33 |
| Female sex | 2466 | 0.92 (0.81–1.05) | 0.90 (0.79–1.02) | 0.89 (0.78–1.02) | — |
| Non-Hispanic white | 1137 | 1.04 (0.83–1.30) | 1.03 (0.83–1.28) | 1.07 (0.87–1.33) | .13 |
| Non-Hispanic Black | 3321 | 0.90 (0.81–0.99) | 0.88 (0.79–0.97) | 0.84 (0.76–0.94) | — |
| Hispanic | 684 | 1.23 (0.97–1.56) | 1.20 (0.94–1.53) | 1.08 (0.84–1.40) | — |
| Private insurance | 2260 | 0.95 (0.83–1.09) | 0.94 (0.82–1.09) | 0.96 (0.84–1.10) | .35 |
| Public insurance | 3625 | 0.93 (0.84–1.03) | 0.89 (0.80–0.99) | 0.85 (0.77–0.95) | — |
| Self-pay | 509 | 1.04 (0.63–1.73) | 0.93 (0.53–1.62) | 1.01 (0.56–1.80) | — |

Values represent HRs (95% CIs) for having the event for patients who had expected well-child visits versus those who did not among patients in the well-child cohort. All models are stratified by the number of events. —, not applicable.
[a] Adjustment variables are age, sex, race, insurance type, number of encounters in the past year, atopy, obesity, and medication use. Models stratifying by a variable do not additionally adjust for that variable.
[b] Age groups represent age at time of first well-child visit. Insurance status strata include patients who have had the insurance status at any point during their follow-up (so, some patients may be counted in multiple categories).
[c] Interaction models include all covariates and the interactions of interest alone; reference groups are age 5–11 y, Non-Hispanic white race, and private insurance.

**TABLE 4** Characteristics of the All Well-Child Visits From Asthma Cohort

| Characteristic | WCC From 5- to 11-y-Old Patients | WCC From 12- to 18-y-Old Patients | Total |
|---|---|---|---|
| Total | *n* = 10 324 (63.2%) | *n* = 6022 (36.8%) | *N* = 16 346 |
| Medication order, *n* (%) | | | |
| No ICS, LABA, LTRA, LAMA, or biological | 9433 (91.4) | 5433 (90.2) | 14 866 (90.9) |
| Only ICS or only LTRA | 803 (7.8) | 452 (7.5) | 1255 (7.7) |
| All other categories | 88 (0.9) | 137 (2.3) | 225 (1.4) |
| Procedures, *n* (%) | | | |
| Pneumovax vaccination | 6 (0.1) | 12 (0.2) | 18 (0.1) |
| Flu vaccination | 2954 (28.6) | 1662 (27.6) | 4616 (28.2) |
| Spirometry | 2 (0.0) | 14 (0.2) | 16 (0.1) |
| Comorbidities, *n* (%) | | | |
| Rhinitis | 1218 (11.8) | 587 (9.7) | 1805 (11.0) |
| Conjunctivitis | 9 (0.1) | 3 (0.0) | 12 (0.1) |
| Postnasal drip | 3 (0.0) | 0 (0.0) | 3 (0.0) |
| Nasal congestion | 17 (0.2) | 5 (0.1) | 22 (0.1) |
| Esophageal reflux | 56 (0.5) | 52 (0.9) | 108 (0.7) |
| Asthma[a] | 3405 (33.0) | 1903 (31.6) | 5308 (32.5) |
| General asthma | 1170 (11.3) | 786 (13.1) | 1956 (12.0) |
| Mild intermittent | 1206 (11.7) | 658 (10.9) | 1864 (11.4) |
| Mild persistent | 685 (6.6) | 291 (4.8) | 976 (6.0) |
| Moderate persistent | 394 (3.8) | 183 (3.0) | 577 (3.5) |
| Severe persistent | 21 (0.2) | 10 (0.2) | 31 (0.2) |

LABA, long-acting β-2 agonist.
[a] Subtypes of asthma diagnosis are not mutually exclusive. For example, general asthma and mild intermittent could be diagnosed at the same well-child visit.

children in the lowest quartile of WCC visit attendance had 1.9 times the risk of all-cause hospitalizations, compared with those in the highest quartile. Notably, in few studies have researchers assessed the association between WCC use and immediate risk of exacerbations. Several studies have revealed that continuity with the same primary care provider during WCC, presumably facilitating an advanced dialogue about asthma, provides significant protection from exacerbations.[22,23] In a retrospective, single center cohort study of mainly African American children in a large northeast US city, Utidjian et al[30] assessed several ambulatory care best practices and their links with pediatric asthma hospitalization. They found that children with ≤1 WCC visit in the previous 2 years experienced a 39% increased rate of asthma-related hospitalization.

In our study, we add to the literature in two key ways. First, our design allowed us to assess the yearly risk of exacerbation, depending on the recent presence or absence of a WCC visit. With this design, we provide increased confidence, compared to past studies, in inferring a close temporal connection between recent WCC and asthma outcomes. Second, in our study, we evaluate the temporal relationship of WCC and exacerbation risk and severity. Protection against severe exacerbations may be of particular importance because of their association with loss of lung function and adult respiratory disability.[31–36]

We speculate that WCC visits reduce asthma hospitalization through enhanced parental understanding of disease management (proper use of controller medications, trigger avoidance, etc), disease prevention (eg, influenza vaccine and dietary and healthy weight counseling), and comorbidity management (eg, allergic rhinitis, etc). It is likely that families with greater primary care contact during times of wellness develop greater management self-efficacy. As we saw in our data, children with recent WCC were more likely to have an exacerbation seen in the ambulatory setting, possibly preventing further disease progress. Children with greater WCC visit attendance were slightly more likely to be prescribed a daily monotherapy of asthma preventive medication (ICS or LTRA). Our study did not reveal a reduction in lower acuity exacerbations, suggesting that the protective mechanisms of WCC visits may stem from more than just improved daily self-management at the onset of mild exacerbations. WCC visit attendance may reflect numerous person-level factors, including health literacy, financial resources, more secure transportation, and insurance coverage, all of which may protect from asthma hospitalizations. Attending WCC may promote general health through immunizations, yearly influenza vaccine, obesity avoidance, and comorbidity management (allergies and reflux disease), which can affect asthma. Although we did not have measures of health literacy, children (and guardians) seen annually may be more knowledgeable about asthma, able to recognize early symptoms, and better able to seek timely care. Low health literacy has consistently been associated with lower WCC visit adherence and greater use of emergency care and hospitalizations.[37]

With these results, we add to the cache of evidence that WCC helps children. However, the implications extend further. Especially for children with severe asthma or frequent exacerbations, our results suggest that pediatric health systems may reduce asthma ED visits and hospitalizations via investments into primary care–based adherence monitoring of WCC. Our data reveal that children without a WCC in the past 12 months are at significantly increased risk for severe exacerbations and would benefit from health system contact. Secondly, pediatricians should conclude that disease specific targeted management is worth the time investment during busy WCC visits.

Our study has some notable strengths and weaknesses. The study cohort was derived from a single university-based health system and, thus, was not able to capture fragmented care. It is possible that some participants both attended WCC visits and sought care for exacerbations outside of DUHS. We attempted to limit missed data by focusing only on children residing in Durham County and with established primary care at DUHS. Although we tried to account for potential confounding factors, such as demographics, asthma severity, and health care use history, there are potentially missed confounding factors. A confounding factor affecting our results could be an “enabled parent effect”; that is, parents or guardians who complete WCC visits may display different health-related behaviors that promote asthma control.[38,39] We speculate that these behaviors may include better daily adherence to asthma controller medications or asthma trigger avoidance. It is likely that WCC attendance is more than just a surrogate for an enabled parent because we found that WCC visits frequently documented asthma-specific practices (medication orders, respiratory-related vaccines, and asthma severity and comorbidity assessment) proven to promote asthma control.[40–43]

Strengths included the fact that we were able to abstract granular data from our EHR system to capture the time-varying effects of factors such as insurance status, obesity status, and WCC visits. In this diverse city, we were able to assess effects based on sociodemographic factors, such as race and insurance status. Our results are likely to provide important insights for other cities and health systems attempting to improve pediatric asthma control.

## CONCLUSIONS

In future work, researchers should seek to replicate these findings and further investigate the mechanisms of WCC visit attendance in promoting asthma control. For children with chronic medical conditions, like asthma, WCC visit adherence should become a renewed public health priority to reduce the worst outcomes in chronic disease, including severe asthma exacerbations.

## ATOPIC CONDITIONS

Codes for atopic conditions include the following:

ICD-9: 477.x, 372.05, 372.14, V15.0x, 995.6x, 995.7, 691.x; and

ICD-10: J30.x, H10.1x, H10.45, Z91.0x, T78.x, and L20.

## DIAGNOSIS CODES REPRESENTING ROUTINE HEALTH SUPERVISION

Diagnosis codes representing routine health supervision include the following: z00.110, z00.111, z00.121, and z00.129.

### ABBREVIATIONS

CI: confidence interval
DUHS: Duke University Health System
ED: emergency department
EHR: electronic health record
HR: hazard ratio
ICD-9: *International Classification of Diseases, Ninth Revision*
ICD-10: *International Classification of Diseases, 10th Revision*
ICS: inhaled corticosteroid
LAMA: long-acting muscarinic antagonist
LTRA: leukotriene receptor antagonist
WCC: well-child care

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