School-based asthma therapy: Improving medication adherence, asthma control, and health care utilization

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Background: Undertreatment and poor adherence remain prevalent for children with persistent asthma. School-based asthma therapy (SBAT) provides guideline-based treatment by systematic school-based asthma screenings and direct administration of daily controller medications.
Objective: We examined asthma control and health care utilization for children enrolled in the SBAT program in Columbus, Ohio, from 2013 to 2019.
Methods: Six-year retrospective medical records were reviewed for 1 year before and 1 year after SBAT enrollment for children aged 5 to 19 years from 2 metropolitan school districts. Asthma control was assessed by the Asthma Control Test (ACT) and health care provider (HCP) ratings. Information was collected regarding asthma-related health care utilization, including emergency department (ED), urgent care, and acute care visits; hospitalizations; and pediatric intensive care unit (PICU) admissions.
Results: Percentage increases in well-controlled asthma were 37% (ACT) and 56% (HCP). Asthma-related ED visits decreased by 49%, hospitalizations 50%, PICU admissions 71%, urgent care visits 41%, and acute care visits 38%. Black and Latino children had significant improvements. Black children saw 40% (ACT) and 66% (HCP) increases in well-controlled asthma, with reductions of 42% in ED and urgent care visits, 52% in acute care visits, and 49% and 67% declines in hospitalizations and PICU admissions, respectively. Latino children had 55% (ACT) and 33% (HCP) asthma control improvements, with 62%, 81%, and 50% drops in ED, urgent care, and acute care visits, respectively; hospitalizations decreased by 40% and PICU admissions by 100%.
Conclusions: The SBAT program would serve well as a model for enhancing controller medication adherence, reducing morbidity, and bridging the health disparities gap for children with poorly controlled asthma. (J Allergy Clin Immunol Global 2025;4:100428.)

Key words: *Controller medication adherence, asthma control, health care utilization, school-based care*

Asthma affects over 4 million US children, causing significant morbidity and cost.[1,2] Despite the effectiveness of preventive medications that are covered by most insurance plans,[3,4] undertreatment is common, especially in historically marginalized communities.[5,6] Many children struggle with poor adherence, improper inhaler technique, ongoing trigger exposure, lack of medication optimization or step up in therapy, and lack of follow-up care, leading to suboptimal asthma control.[7-10] In the United States, long-standing inequities in asthma outcomes that are based on race, ethnicity, income, and geography rooted in systemic racism and segregation have been reported.[11-14] Numerous studies have documented disparities in adherence to guideline-recommended medications, health care utilization, and outcomes among historically marginalized patients with asthma in low-resource communities.[15-18]

Schools and school nurses can play a crucial role in delivering guideline-based health care for children, improving health, reducing absences, and lowering disease management costs. Our school-based asthma therapy (SBAT) program provides guideline-based treatment for children with persistent asthma through school-based screening and directly observed therapy of asthma controller medications.[19] The SBAT program has the potential to be high impact because school-based programs can reach children at highest risk for asthma morbidity and optimize their care in the setting where they spend most of their week, regardless of their contact with the health care system. Randomized controlled trials (RCTs) have shown that SBAT improves asthma care, reduces asthma-related health care utilization, and increases symptom-free days.[20-23] The SBAT program also demonstrated an incremental cost-savings difference of $1583 and gain of 1 symptom-free day cost at only $10 per child.[24] Despite its promise in RCTs, widespread dissemination of SBAT has been slow as a result of implementation barriers (ie, without research staff support) and lack of program effectiveness evaluation in real-world settings.

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Abbreviations used
ACT: Asthma Control Test
COI: Child Opportunity Index
ED: Emergency department
EHR: Electronic health record
HCP: Health care provider
ICER: Incremental cost-effectiveness ratio
NCH: Nationwide Children's Hospital
PICU: Pediatric intensive care unit
RCT: Randomized clinical trial
SBAT: School-based asthma therapy
SD: Standard deviation

We assessed the health outcomes (ie, asthma control due to improved controller medication adherence and asthma-related health care utilization) from a real-world implementation of SBAT (without the constraints of an RCT and research staff support) in Columbus, Ohio, over the course of 6 years. We found it to be effective in improving asthma health outcomes for all children and reducing health disparities among historically marginalized children.

METHODS

Study design and participants

This retrospective record evaluation examined health outcomes for students in the SBAT program from 2013 to 2019 who attended 2 metropolitan school districts serving historically marginalized children in Columbus. All students received asthma health care from Nationwide Children's Hospital (NCH). Health outcomes were compared for 1 year before and 1 year after SBAT enrollment. The analysis period ended in 2019 because of the coronavirus disease 2019 school shutdowns in 2020-21. Schools resumed full-time, in-person instruction in 2021-22. Caregivers consented to allow their children's NCH medical and school record data to be abstracted for program evaluation. The study adhered to the Declaration of Helsinki and was approved by the NCH institutional review board (approval 00000236, approved April 22, 2019).

SBAT program overview

The SBAT program is unique for its integration of the delivery system, decision support, and community resources.[25-27] It enhances care coordination between school nurses, caregivers, pharmacy services, and health care providers (HCPs) via the SBAT nurse, improving communication about symptoms, reframing beliefs and expectations, and increasing controller medication adherence, ultimately improving clinical and functional outcomes and reducing costs.[19]

Given low medication adherence, the SBAT program supports adherence by administering preventive medications at school through directly observed therapy. The HCP oversees the child's care and approves all interventions. Enrollment is initiated via referral from HCPs or school nurses, often for students disconnected from the medical system. Children may remain enrolled for multiple school years. The Columbus SBAT program is staffed and funded by NCH and its accountable care organization, Partners for Kids. The HCP prescribes medication according to the child's asthma severity. Prescriptions are sent to pharmacies providing delivery services, with one canister of controller medication and spacer delivered to the family for home use and a second canister delivered to school for administration per HCP orders. Dose delivery time varies according to convenience for the student and nurse. The nurse reminds children to rinse their mouths after medication doses. The nurse ensures adherence on days the child attends school and encourages adherence on days the child does not attend school. SBAT nurses may suggest medication adjustments for children with continued poor asthma control, per National Heart, Lung, and Blood Institute guidelines, subject to HCP approval.[28]

Procedures

From 2013 to 2019, annual SBAT student rosters were maintained via spreadsheets and subsequently within the electronic health record (EHR). These rosters, which included school district enrollment, were used to identify students in the 2 largest school districts in Columbus. Each student was assigned a unique study ID number for all analyses, and the medical record number and other personally identifying information were removed. Demographic data (eg, age, sex, race, ethnicity, insurance type), Asthma Control Test (ACT) scores, HCP ratings of asthma control, and asthma-related health care utilization data were extracted. The date when SBAT program medication administration began was used as the anchor for calculating the dates for the 1-year periods before and after enrollment. Once enrolled onto SBAT, ACT scores were obtained by the SBAT nurse every 4 to 6 weeks until good disease control was documented in the EHR and then every 3 months thereafter. HCP ratings of asthma control were obtained from the primary care network EHR for well-child and acute care visits. We were unable to access the school nurses' medication administration logs, which prevented us from obtaining data on received medication doses.

Primary outcome measures

Asthma control was assessed using 2 methods: the validated 5-item ACT for children aged ≥12 years or the Childhood ACT for children aged <12 years,[29-31] which were administered by the SBAT nurse; and HCP ratings of disease as "not well controlled" or "well controlled" that were based on clinical assessment using information regarding concurrent ACTs, recent acute asthma events, and history/physical. This was a drop-down menu item in the EHR, and relevant data were extracted with the other EHR variables. ACT scores of ≤19 indicate uncontrolled asthma, coded as 0 = disease not well controlled; and ACT scores above 19 were coded as 1 = disease well controlled. HCP ratings were recoded as 0 = poor and 1 = good. The proportion of time in each category was calculated.

Asthma-related health care utilization data, including emergency department (ED), urgent care, and acute care visits; hospitalizations; and pediatric intensive care unit (PICU) admissions were extracted from NCH and its primary care network EHRs. For ED and urgent care visits, arrival/discharge dates, primary or secondary asthma diagnosis code, discharge disposition, and visit duration were extracted. Hospitalization data included admission/discharge dates, length of stay, primary or secondary asthma diagnosis code, PICU admission, and PICU length of stay. Raw visit counts by time period were

created to examine frequency. ED visits followed by a hospitalization were coded as 1 ED visit and 1 hospitalization; the same applied to hospitalizations with PICU admissions. Acute care office visit data were extracted from NCH's primary care network EHR, including visit date, primary or secondary asthma diagnosis code, HCP control rating, and visit type. Pre- and postenrollment visits and differences were computed, with no visits coded 0.

Additional measures

Sociodemographic data included the child's age at SBAT program medication administration, sex (male and female), race and ethnicity, insurance type, and Child Opportunity Index (COI). Race and ethnicity were originally coded in the EHR in 9 categories, but because of small cell sizes, these were collapsed into the 4 categories Black, Latino, White, and multiracial. Five Asian and 1 Native Hawaiian/other Pacific Islander cases, along with 9 preschool-age children, were omitted because of small sample sizes. Insurance was coded as Medicaid, commercial, self-pay, and other, but subgroup analyses were not conducted because 85% of children were enrolled onto Medicaid. The COI is a composite measure of 29 neighborhood educational, health and environmental, and social and economic resources and conditions that influence children's health.[32] For each domain, the most granular-level data were used (eg, latitude/longitude, school level, census block), which were then aggregated to census tracts using an annual 5-year moving average approach. On the basis of the child's census tract of residence, the overall COI is coded from 1 to 100 according to composite z scores and categorized as very low, low, moderate, high, and very high.[32] Subgroup analyses were not conducted because over 84% of children had very low or low COI.

Sample size and power calculations

Because these are retrospective data analyses, conducting a *post hoc* power calculation is not a valid statistical strategy.[33]

Data analysis

Descriptive statistics (mean, standard deviation [SD], number, and proportion) characterized the sample. Analyses were conducted for the whole sample and by ethnicity, age category, and sex by SAS v9.4 software. Repeated measures analyses (PROC MIXED for continuous and PROC GENMOD for categorical variables) accounted for observation nonindependence. ACT scores and HCP control ratings were analyzed by number of observations per child, while health care utilization models were based on number of children. Pre- and postenrollment visit totals were computed. Our full cost-effectiveness analysis results will appear elsewhere; however, preliminary incremental cost-effectiveness ratios (ICERs) for each visit type averted are reported. Results report numbers and percentages, means with SDs, test statistic (chi-square or t test value), P value, and effect size estimate (odds ratio or Cohen d). Findings are presented as changes in mean scores showing between-group and within-group changes before and after SBAT enrollment with 95% confidence intervals and P values. Statistical significance was set at $P \leq .05$.

RESULTS

A total of 633 NCH medical records of SBAT-enrolled children were extracted. Children ranged in age from 5 to 19 years (mean = 13.29, SD = 2.21); 59% were male; 72% were Black, 16% White, 4% Latino, and 8% multiracial; and 84% had low or very low COI scores. Eighty-five percent of the children were insured by Medicaid, 9% commercial insurance, 5% self-pay, and 1% other insurance. HCP asthma control ratings and asthma-related acute care office visits were obtained for 545 children who attended the NCH primary care network.

Table I presents the results for ACT scores, HCP control ratings, and health care utilization for the whole sample for 1 year before and 1 year after SBAT enrollment, along with preliminary ICERs for each visit type. Table II and Figs 1-3 report the subgroup findings for asthma control and health care utilization, respectively. Effect size estimates/odds ratios and percentage change results are presented in Table III for the whole sample and by subgroup.

Asthma control

Statistically significant increases in asthma control (ACT scores and HCP ratings) were observed for the whole sample from 1 year before to 1 year after SBAT enrollment ($P < .0001$ for both) (Table I).

There was a 16–percentage point increase (absolute percentage increase, 36.91%) based on ACT scores and a 27–percentage point increase (absolute percentage increase, 56.47%) based on HCP ratings (Table III). Table II presents the within- and between-group change-over-time results by subgroup, summarized below.

Age. One year before SBAT enrollment, there were no differences in well-controlled asthma by age group according to ACT score. After enrollment, 9-12-year-olds had the highest proportion of disease rated as well controlled (64.6%), followed by 5-8-year-olds (58.64%) and those ≥13 years old (50.00%). All age groups showed significant increases in well-controlled asthma (ACT) after enrollment, with absolute percentage increases ranging from 28% (age ≥13) to 40% (age 5-8) (Table III). Before SBAT enrollment, older children had a lower proportion of HCP-rated good control compared to 5-8-year-olds, and after enrollment, only the youngest and oldest age groups differed significantly. All age groups demonstrated significant increases after SBAT enrollment in HCP ratings of good control, with the age ≥13 group having the greatest absolute percentage increase (85.86%) (Table III).

Sex. There were no differences in well-controlled asthma according to ACT score by sex for either period. Both groups demonstrated significant increases in the proportion of disease rated as well controlled after SBAT enrollment, with a 42% increase for boys and 29% increase for girls. Before SBAT enrollment, HCP ratings showed a difference between sexes, but the groups were equivalent after enrollment. The within-sex absolute percentage increases were 64% for boys and 48% for girls (Table III).

Race and ethnicity. Before SBAT enrollment, White (50%) and multiracial (52%) children had the highest proportion of well-controlled asthma according to ACT score. Black and Latino children had significantly lower proportions of well-controlled asthma compared to White children (42%, $P = .03$ and 37%, $P = .04$, respectively). After enrollment, all groups improved. The difference between White and Latino children was no longer

TABLE I. Clinical outcomes before and after enrollment for entire sample

Outcome	Before enrollment, % (no.)	After enrollment, % (no.)	SBAT effect (95% CI)	*P* value	—
ACT score (633 children, 3928 observations)					
Well controlled	43.24 (592)	59.20 (1515)	15.96 (12.73, 19.19)		
Overall effect			$\chi^2 = 93.53$	<.0001	
HCP rating (633 children, 3635 observations)					
Well controlled	46.98 (992)	73.51 (2643)	26.54 (23.20, 29.88)		
Overall effect			$\chi^2 = 242.44$	<.0001	
Characteristic	**1 Year before enrollment, mean (SD)**	**1 Year after enrollment, mean (SD)**	**SBAT effect (95% CI)**	***P* value**	**ICER**
ED visits (633 children)	0.73 (1.21)	0.37 (0.85)	−0.36 (−0.45, −0.27)		
Overall effect			$t = 9.17$	<.0001	$1,993
UC visits (463 children)	0.29 (0.68)	0.17 (0.49)	−0.12 (−0.18, −0.07)		
Overall effect			$t = 4.25$	<.0001	$150
Hospitalizations (633 children)	0.36 (0.72)	0.18 (0.50)	−0.18 (−0.24, −0.13)		
Overall effect			$t = 6.26$	<.0001	$14,787
PICU admissions (628 children)	0.14 (0.41)	0.04 (0.22)	−0.10 (−0.13, −0.07)		
Overall effect			$t = 5.70$	<.0001	$46,961
Acute care office visits (538 observations)	0.26 (0.60)	0.16 (0.45)	−0.10 (−0.16, −0.04)		
Overall effect			$t = 3.66$	.0003	$100

significant, although the difference between Black and White children remained statistically significant (5.80%, $P = .04$). All groups demonstrated absolute percentage increases in ratings of well-controlled asthma, ranging from 12% to 55% (Table III). The largest increases were among Black (40%) and Latino (55%) children, with significant increases for White ($P = .001$), Black ($P < .0001$), and Latino ($P = .004$) children. The 6% increase for multiracial children was not statistically significant. Before SBAT enrollment, the highest proportion of well-controlled ratings by the HCP were for Latino (65%) children, followed by White (56%), multiracial (53%), and Black (43%). Compared to White children, significantly fewer Black children had disease rated as well controlled (−13%, $P = .004$), while the disease of Latino children had ratings 9% points higher (not statistically significant). After enrollment, disease of Latino children had the highest well-controlled ratings (86%), followed by White (76%), multiracial (75%), and Black (72%) children. Only the difference between White and Latino children after SBAT was significant (mean difference = 10.18, $P = .03$). All ethnic groups had statistically significant increases in HCP ratings of well-controlled asthma after SBAT enrollment: 20% for White ($P < .0001$), 29% for Black ($P < .0001$), 21% for Latino ($P = .002$), and 22% for multiracial ($P = .0004$) children, with absolute percentage increases ranging from 33% to 66% (Table III).

Health care utilization

Data regarding 1124 ED and 488 urgent care visits, 373 hospitalizations, and 165 PICU admissions for 633 children were abstracted from the NCH EHR. Additionally, data for 5079 primary care network visits (384 acute asthma visits flagged and 3712 HCP asthma control ratings) were abstracted for 545 children. Statistically significant reductions ($P < .0001$) were observed for all visit types across the whole sample: mean ED visits decreased by −0.36 (49%), urgent care visits by −0.12 (41%), hospitalizations by −0.18 (50%), PICU admissions by −0.10 (71%), and asthma-related acute care office visits by −0.10 (38%, $P = .0003$) (Tables I and III). ICER for each visit type averted was calculated, as follows: $100 per acute care visit; $150 per urgent care visit; $1,993 per ED visit; $14,787 per hospitalization; and $46,961 per PICU admission.

Age. Fig 1 reveals that before and after enrollment, there were no differences by age for mean ED visits, hospitalizations, PICU admissions, and acute care office visits. Compared to 5-8-year-olds, children aged ≥13 years had significantly fewer mean urgent care visits (0.35 vs 0.16, $P = .02$) before enrollment. After enrollment, no between-age group differences were noted for any visit type. All ages groups had statistically significant reductions in mean ED visits after enrollment: −0.35 (50%) for 5-8-year olds, −0.37 (48%) for 9-12-year olds, and −0.39 (49%) reduction for ≥13 years (Fig 1 and Table III). In addition, within-group–over–time differences were noted for the 5-8-year olds and 9-12-year-olds for urgent care visits, hospitalizations, and PICU admissions. The 5-8-year-olds had mean decreases of −0.17 (49%), −0.24 (61%), and −0.12 (71.00%), while the 9-12-year-olds had average decreases of −0.09 (35%), −0.16 (46%), and −0.09 (82%), respectively. Although not statistically significant, the ≥13-year-old children had a 31% decrease in urgent care visits, 26% reduction in hospitalizations, 42% decrease in PICU admissions, and 26% reduction in acute care office visits.

Sex. Fig 2 and Table III present the results for types of health care visits according to sex before and after SBAT enrollment and the within-group change over time. There were no sex differences in any type of health care visit before enrollment. After enrollment, girls had significantly fewer acute care visits than boys (mean difference = −0.09, $P = .01$). Within-sex group differences were observed for all visit types. Average reductions in ED visits were −0.36 (49%) for boys and −0.37 (50%) for girls. Mean urgent care and acute care office visits, respectively, decreased by −0.14 (43%) and −0.10 (31%) for boys; and −0.11 (37%) and −0.13 (57%) for girls. Average hospitalizations declined −0.20 (56%) for boys and −0.17 (46%) for girls, while mean PICU admissions decreased −0.11 (79%) for boys and −0.08 (62%) for girls.

TABLE II. Asthma control before and after enrollment by child age, sex, and race and ethnicity

	Before enrollment			After enrollment			SBAT effect	
Outcome	**% (no.)**	**Δ (%) (95% CI)**	***P* value**	**% (no.)**	**Δ (%) (95% CI)**	***P* value**	**DiD (%) (95% CI)***	***P* value**
ACT score (633 children, 3928 observations)								
Age								
5-8 years (ref)	41.70 (279)			58.39 (734)			−16.69 (−21.30, −12.08)	<.0001
9-12 years	46.67 (238)	−4.96 (−10.62, 0.70)	.09	63.93 (585)	−5.54 (−9.73, −1.36)	.009	−17.27 (−22.59, −11.95)	<.0001
≥13 years	39.47 (75)	2.23 (−5.69, 10.15)	.58	50.65 (196)	7.75 (2.15, 13.34)	.007	−11.17 (−19.7, −2.64)	.01
Overall effect							χ^2 *value*	
Time period							63.97	<.0001
Age category							18.04	<.0001
Time × age							1.53	.47
Sex								
Male (ref)	41.55 (344)			59.19 (908)			−17.65 (−21.81, −13.48)	<.0001
Female	45.84 (248)	−4.30 (−9.63, 1.04)	.12	59.22 (607)	−0.03 (−3.92, 3.87)	.99	−13.38 (−18.51, −8.25)	<.0001
Overall effect							χ^2 *value*	
Time period							84.66	<.0001
Sex							1.64	.20
Time × sex							1.60	.21
Race								
White (ref)	50.00 (94)			64.23 (237)			−14.23 (−22.87, −5.59)	.001
Black	41.66 (417)	−8.34 (−16.01, 0.68)	.03	58.43 (1088)	−5.80 (−11.29, −0.31)	.04	−16.77 (−20.55, −12.99)	<.0001
Latino	36.90 (31)	13.10 (−25.75, 0.44)	.04	57.14 (68)	−7.09 (−17.25, 3.08)	.17	−20.24 (−33.98, −6.50)	.004
Multiracial	52.08 (50)	2.08 (−10.01, 14.81)	.74	58.37 (122)	−5.85 (−14.20, 2.49)	.17	−6.29 (−18.18, 5.60)	.30
Overall effect							χ^2 *value*	
Time period							30.33	<.0001
Race category							11.81	.008
Time × race							3.24	.36
HCP rating (633 children, 3635 observations)								
Age								
5-8 years (ref)	52.08 (286)			74.14 (625)			−22.06 (−27.01, −17.12)	<.0001
9-12 years	42.82 (149)	9.26 (3.10, 15.42)	.003	77.03 (872)	−2.89 (−6.95, 1.17)	.16	−34.22 (−39.62, −29.12)	<.0001
≥13 years	35.96 (41)	16.11 (6.90, 25.33)	.0006	66.77 (446)	7.37 (2.75, 12.00)	.002	−30.80 (−39.85, −21.76)	<.0001
Overall effect							χ^2 *value*	
Time period							213.85	<.0001
Age category							20.00	<.0001
Time × age							10.86	.004
Sex								
Male (ref)	44.44 (264)			73.02 (1150)			−28.57 (−32.88, −24.26)	<.0001
Female	50.51 (199)	−6.06 (−11.88, −0.25)	.04	74.81 (775)	−1.79 (−5.37, 1.79)	.33	−24.30 (−29.60, −19.00)	<.0001
Overall effect							χ^2 *value*	
Time period							230.19	<.0001
Sex							5.08	.02
Time × sex							1.50	.22
Race (n = 3556)								
White (ref)	56.48 (61)			76.15 (265)			−19.67 (−29.50, −9.83)	<.0001
Black	43.47 (323)	−13.01 (−22.22, −3.81)	.004	72.01 (1366)	−4.14 (−9.35, 1.07)	.12	28.54 (−32.40, −24.67)	<.0001
Latino	65.00 (39)	8.52 (−5.86, 22.90)	.25	86.33 (120)	10.18 (1.22, 19.14)	.03	−21.33 (−35.12, −7.54)	.002
Multiracial	52.78 (38)	−3.70 (−17.29, 9.88)	.59	75.13 (142)	−1.02 (−9.09, 7.05)	.80	−22.35 (−34.72, −9.99)	.0004
Overall effect							χ^2 *value*	
Time period							71.32	<.0001
Race category							32.90	<.0001
Time × race							3.89	.27

DiD, Difference in differences.
*Within-group change from before enrollment to after.

Race and ethnicity. Fig 3 and Table III present the results for health care visits according to race and ethnicity before and after SBAT enrollment as well as the within-group change over time. Before SBAT enrollment, there were no statistically significant differences by race and ethnicity in ED and acute care visits, hospitalizations, and PICU admissions. Black children had significantly more urgent care visits than White children (0.33 vs 0.17, $P = .03$). After enrollment, no statistically significant

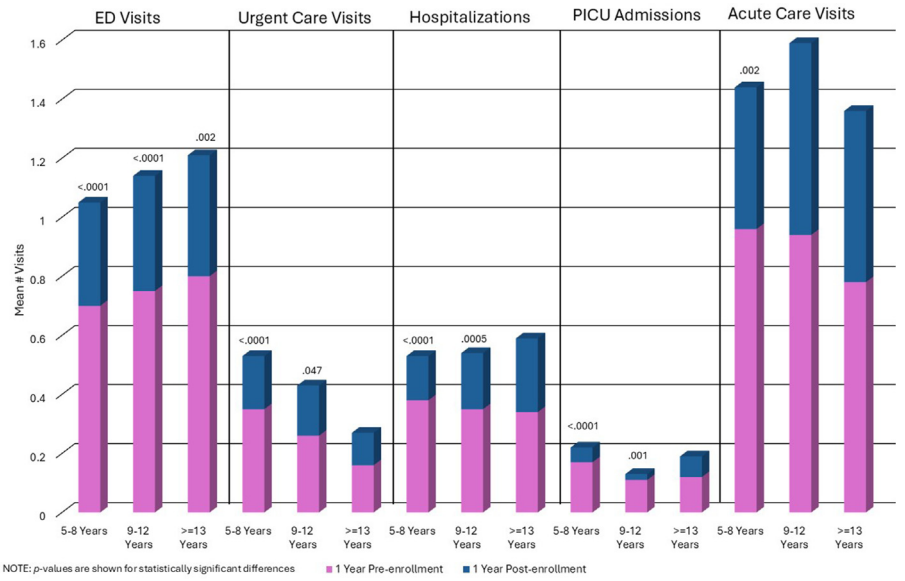

FIG 1. Asthma-related health care utilization in 633 children before and after enrollment by age.

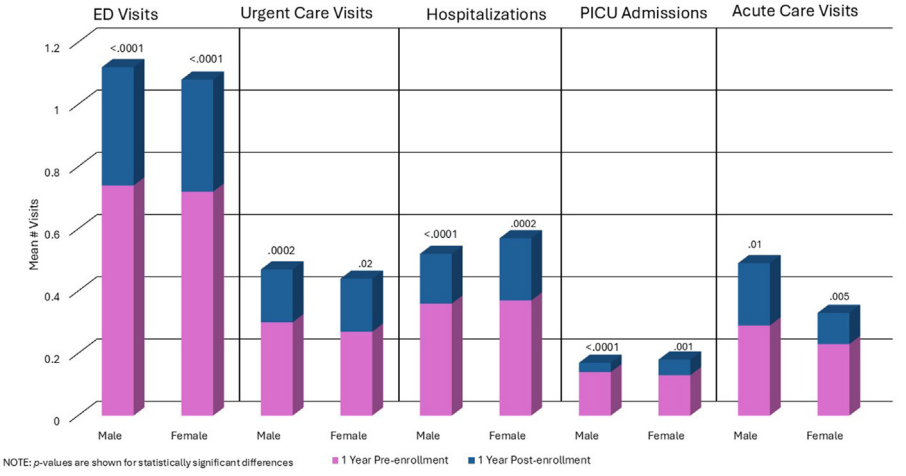

FIG 2. Asthma-related health care utilization in 633 children before and after enrollment by sex.

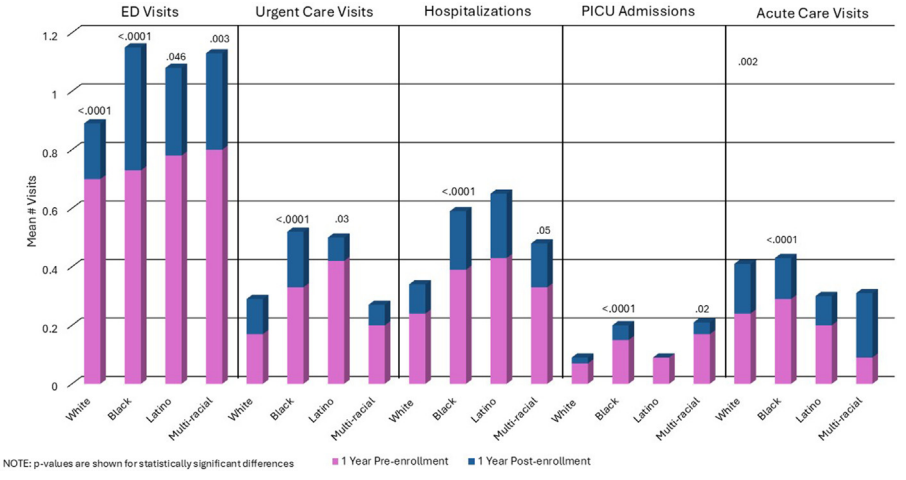

FIG 3. Asthma-related health care utilization in 633 children before and after enrollment by ethnicity.

TABLE III. SBAT program percentage change and effect sizes 1 year before to 1 year after enrollment

Asthma control	Characteristic	Variable	% Change	Odds ratio
ACT score	Whole sample		+36.91	0.85
	Age	5-8 years	+40.02	0.85
		9-12 years	+36.98	0.84
		≥13 years	+28.33	0.89
	Sex	Male	+42.36	0.84
		Female	+29.19	0.87
	Race/ethnicity	Black	+40.25	0.85
		Latino	+54.85	0.82
		Multiracial	+12.08	0.94
		White	+28.46	0.87
HCP rating	Whole sample		+56.47	0.77
	Age	5-8 years	+42.36	0.80
		9-12 years	+78.89	0.71
		≥13 years	+85.68	0.73
	Sex	Male	+64.31	0.75
		Female	+48.11	0.78
	Race/ethnicity	Black	+65.65	0.75
		Latino	+32.82	0.81
		Multiracial	+42.35	0.80
		White	+34.83	0.82
Health care sought	**Characteristic**	**Variable**	**% Change**	**Effect size***
ED visits	Whole sample		−49.32	0.34
	Age	5-8 years	−50.00	5.75
		9-12 years	−48.00	5.09
		≥13 years	−48.75	3.49
	Sex	Male	−48.65	7.06
		Female	−50.00	5.92
	Race/ethnicity	Black	−42.47	6.08
		Latino	−61.54	2.20
		Multiracial	−58.75	3.62
		White	−72.86	4.81
Urgent care visits	Whole sample		−41.38	0.20
	Age	5-8 years	−48.57	4.81
		9-12 years	−34.62	2.55
		≥13 years	−31.25	0.82
	Sex	Male	−43.33	3.68
		Female	−37.04	2.83
	Race/ethnicity	Black	−42.42	5.49
		Latino	−80.95	2.80
		Multiracial	−65.00	1.61
		White	−29.41	0.82
Hospitalizations	Whole sample		−50.00	0.29
	Age	5-8 years	−60.53	6.51
		9-12 years	−45.71	2.55
		≥13 years	−26.47	0.82
	Sex	Male	−55.56	5.66
		Female	−45.95	4.81
	Race/ethnicity	Black	−48.72	7.45
		Latino	−48.84	1.60
		Multiracial	−54.55	2.09
		White	−58.33	2.30
PICU admissions	Whole sample		−71.43	0.30
	Age	5-8 years	−70.59	7.59
		9-12 years	−81.82	4.03
		≥13 years	−41.67	1.58
	Sex	Male	−78.57	6.96
		Female	−61.54	3.14
	Race/ethnicity	Black	−66.67	6.33
		Latino	−100	1.24
		Multiracial	−76.47	2.74
		White	−71.43	1.58

(Continued)

TABLE III. *(Continued)*

Health care sought	Characteristic	Variable	% Change	Effect size*
Acute care office visits	Whole sample		−38.46	0.19
	Age	5-8 years	−50.00	5.30
		9-12 years	−30.85	3.05
		≥13 years	−25.64	1.14
	Sex	Male	−31.03	3.53
		Female	−56.52	3.68
	Race/ethnicity	Black	−51.72	5.88
		Latino	−50.00	0.89
		Multiracial	+144.44	1.70
		White	−29.17	1.15

*Calculated for difference between 1-year before SBAT enrollment and 1-year SBAT program period. Cohen *d* effect sizes are as follows: 0.2 = small effect size; 0.5 = medium effect size; and 0.8 = large effect size.

differences by race and ethnicity were observed for urgent care and acute care visits, hospitalizations, and PICU admissions. Black children had more ED visits (0.42 vs 0.19, $P = .02$) than White children. Statistically significant reductions in mean ED visits were noted for all racial and ethnic groups, with White (−0.50, 73%) and Latino (−0.48, 62%) children experiencing the largest reductions, followed by multiracial (−0.46, 59%) and Black children (−0.31, 43%). Only Black and Latino children demonstrated statistically significant reductions in urgent care visits (−0.13, 42%; −0.33, 81%, respectively). All racial and ethnic groups exhibited reductions in hospitalizations, but only Black and multiracial children had statistically significant reductions (−0.19, 49% for both). A similar pattern was noted for PICU admissions, with significant reductions for Black (−0.10, 67%) and multiracial (−0.13, 76%) children. Only Black children exhibited significant reductions in acute care visits (−0.15, 52%). Although multiracial children had an increase in acute care visits (144%), it was not statistically significant.

To confirm that the findings were the result of the SBAT program and not other NCH quality improvement initiatives, we compared children continuously enrolled onto SBAT from 2015 to 2017 (n = 175) against a matched group of NCH children who never participated in SBAT and had ≥1 ED visit during this period (n = 422). All pre/post SBAT changes were significant: 39% reduction in ED visits, 72% reduction in inpatient stays, and 80% reduction in PICU admissions. In the comparison group, only inpatient stays decreased significantly (51%). These results validate that the substantial improvements reported were due to SBAT participation.

DISCUSSION

This is the third evaluation of health outcomes for children in a real-world implementation of the school-based asthma therapy (SBAT) program[34,35] and the first to examine effects by age, sex, race, and ethnicity. Our retrospective analyses reveal striking improvements in asthma control and reduced asthma-related health care utilization from 1 year before enrollment to 1 year after enrollment and demonstrated progress toward closing the health disparities gap for Black, Latino, and multiracial children.

Our findings reveal asthma-related ED visits decreased by 43.76%, compared to the 68% reduction reported by Shillan et al.[35] Asthma-related hospitalizations were greatly reduced by 50% in our study and 86% in the study of Shillan et al. In 2 RCTs of SBAT, Halterman et al reported declines in ED visits and hospitalizations of 87.18%[20] and 84.62%.[22] Gerald et al[36] in 2009 reported a reduction of slightly more than 10% in poorly controlled asthma among children receiving directly observed therapy in school, compared to 16% in our study. These studies were conducted in Boston, Mass; Rochester, NY; Birmingham, Ala; and Columbus, Ohio, lending preliminary support for generalizability to diverse regions of the United States. Our findings demonstrated significant improvements in asthma control ratings (ACT scores and HCP ratings) for all children and by age, sex, race, and ethnicity, suggesting that improved asthma control is associated with reduced health care utilization. Future analyses will test a multigroup model examining whether changes in asthma control are related to changes in health care utilization.

Importantly, the preliminary cost-effectiveness estimates for each type of health care visit averted suggest the potential for significant reductions in overall health care costs for SBAT-enrolled children. Our results indicate that the SBAT program is highly effective in improving children's asthma outcomes in a real-world setting, and we demonstrated progress in narrowing the health disparities gap for historically marginalized children with asthma. To achieve widespread adoption and sustainability, future empirical and practice-based work is needed to ensure all schools, especially those in low-resource communities, have the training and support to sustainably offer SBAT. Engaging key stakeholders will help ensure a match of program elements to available resources.

Strengths and limitations

The analyses have several notable strengths. First, we extracted medical record data over 6 years for a large number of participating children. Second, we had demographic data allowing subgroup analyses by child age, sex, race, and ethnicity, which had not been previously reported. Last, the analyses allowed between-group comparisons for each time period and within-group change over time. We conducted a validation analysis to confirm that the notable findings we observed were due to the SBAT program and not other quality improvement initiatives occurring during this time frame.

These results must be interpreted with caution because of its inherent limitations as a retrospective record review. First, only records for children in the SBAT program in the 2 school districts and who received care through NCH and its primary care network were included, thus missing external health care encounters. Second, we lacked access to school nurses' medication logs, so we could not assess controller medication administration. Third, small sample sizes for the Latino and multiracial subgroups

limited statistical power, although percentage change and effect size estimates suggested benefits for these groups. Finally, because this was a real-world implementation, there was no comparison group investigating whether children with asthma not enrolled onto the SBAT program would have shown natural improvement.[37] This concern is minimized by the data we present here and in our earlier publication,[38] which demonstrated that health care utilization increased for 2 years before SBAT enrollment.

Conclusions

Asthma remains a significant challenge in low-resource communities, exacerbated by poverty and racial segregation, impeding health care access and treatment adherence. This real-world implementation of the SBAT program demonstrated school-based asthma care benefits children with poorly controlled asthma, regardless of race, ethnicity, and poverty, through preventive medication administration. Our results build on previous trials demonstrating significant reductions in asthma-related ED visits and hospitalizations.[20,22,34,36]

This interprofessional, multidimensional program could serve as a model to improve asthma care and controller medication adherence, reduce morbidity, and close the health disparities gap for historically marginalized children with poorly controlled asthma. SBAT addresses factors related to health care access and quality, environment, and social contextual influences hindering optimal asthma management. Effective, community-tailored implementation strategies could reimagine school-based asthma care, creating a national model to significantly reduce asthma morbidity. This model could be adapted to other pediatric chronic conditions to support optimal health and academic success for these children.

DISCLOSURE STATEMENT

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Data sharing statement: A deidentified public-use dataset is deposited with ICPSR (www.icpsr.umich.edu). In addition, K. Arcoleo will make available project-specific, deidentified datasets to investigators or graduate students for secondary analysis through completion of a data use agreement.

Key messages

- **The SBAT program demonstrated improvements in children's asthma control and decreases in acute health care utilization in RCTs and a small real-world implementation study.**
- **Results were due to directly observed therapy of controller medications in school.**
- **This real-world SBAT implementation highlights benefits of school-based controller medication administration on children's asthma outcomes and demonstrates progress in closing the health disparities gap for Black and Latino children at high risk of poor asthma outcomes.**
- **The interprofessional SBAT program could serve as a model to improve asthma care, reduce morbidity, and close health disparities gaps for marginalized children with poorly controlled asthma, many of whom have limited contact with the health care system.**

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