

UNDERSERVED POPULATIONS

Preventive asthma medication discontinuation among children enrolled in fee-for-service MedicaidDavid E. Capo-Ramos, MD, MPH¹, Catherine Duran, BS¹, Alan E. Simon, MD¹, Lara J. Akinbami, MD^{1,2}, and Kenneth C. Schoendorf, MD^{1,2}¹Infant, Child & Women's Health Statistics Branch (ICWHSB), Office of Analysis & Epidemiology (OAE), National Center for Health Statistics (NCHS), Centers for Disease Control & Prevention (CDC), Hyattsville, MD, USA and ²United States Public Health Service, Rockville, MD, USA**Abstract**

Objective: Local-area studies demonstrate that preventive asthma medication discontinuation among Medicaid and Children's-Health-Insurance-Program (CHIP) enrolled children leads to adverse outcomes. We assessed time-to-discontinuation for preventive asthma medication and its risk factors among fee-for-service Medicaid/CHIP child beneficiaries. **Methods:** National-Health-Interview-Survey participants (1997–2005) with ≥ 1 Medicaid- or CHIP-paid claims when 2–17 years old ($n = 4262$) were linked to Medicaid-Analytic-eXtract claims (1999–2008). Multivariate Cox proportional-hazards models to assess time-to-discontinuation (i.e. failing to refill prescriptions < 30 d after previous supplies ran out) included demographic factors and medication regimen (inhaled corticosteroids [ICS], long-acting β_2 -agonists, leukotriene modifiers, mast cell stabilizers, and monoclonal antibodies). **Results:** Sixty-three percent discontinued preventive asthma medications by 90 d after the first prescription. Adolescents and toddlers had slightly higher hazards of discontinuation (adjusted hazard ratios [aHR], 1.13; 95% CI, 1.05–1.23; and 1.12; 1.03–1.21, respectively) versus 5–11-year-olds, as did Hispanics (aHR, 1.24; 1.13–1.35) and non-Hispanic blacks (aHR, 1.17; 1.07–1.28) versus non-Hispanic whites, children in households with one adult and ≥ 3 children (aHR, 1.17; 1.05–1.30) versus multiple adults and ≤ 2 children, and children with caregivers' educational-attainment ≤ 12 th grade (aHR, 1.11; 1.02–1.20) versus caregivers with some college. Compared to regimens including both ICS and leukotriene modifiers, discontinuation was greater for those on ICS without leukotriene modifiers or on other preventive asthma medications (aHR, 1.67; 1.56–1.80; and 2.23; 1.78–2.80, respectively). **Conclusion:** More than 60% of children enrolled in fee-for-service Medicaid/CHIP discontinued preventive asthma medications by 90 d. Risk was increased for minorities and children from disadvantaged households. Understanding these factors may inform future pediatric asthma guidelines.

Keywords

Asthma control, children's health insurance program, inhaled corticosteroids, medication persistence, patient adherence, patient compliance, preventive medicine

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Introduction

Asthma is among the most prevalent childhood chronic diseases in the United States (US) [1] and is associated with considerable healthcare costs, missed school days, and even death [2]. Preventive asthma medications are a cornerstone of preventive treatment to reduce morbidity and adverse outcomes, and include inhaled corticosteroids (ICS), long-acting β_2 -agonists, leukotriene modifiers, mast cell stabilizers, and monoclonal antibodies [3,4].

Unfortunately, under-use and discontinuation of preventive asthma medications are widespread among US children [4–7] and lead to potentially avoidable exacerbations, greater use of

rescue medications, emergency room visits, and hospitalizations [2,7]. Despite recent evidence that use of preventive asthma medications is generally increasing among children nationwide [4], socially disadvantaged children, and racial/ethnic minority groups [2,8], who are most likely to be enrolled in Medicaid and the Children's Health Insurance Program (CHIP) [5,9], still have the lowest rates of use [4,8,10].

Regional and state-specific studies have characterized Medicaid pharmacotherapy usage by children with asthma [9,11–21], although it is unknown whether existing study results reflect national patterns. Also, few of these studies have employed objective measurements of medication usage such as pharmacy claims [9,21]. Additionally, long-term follow-up of preventive asthma medication refill patterns and time-to-discontinuation have not been described. Medication “discontinuation”, in this context, is consistent with the concept of “persistence” used by other researchers (i.e. the length of time medication is taken continuously before reaching an unacceptable gap in usage) [22].

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The aim of this study was to assess preventive asthma medication time-to-discontinuation and its socio-demographic predictors among fee-for-service Medicaid/CHIP child beneficiaries.

Methods

Data sources

We used the National Health Interview Survey (NHIS)/Medicaid Analytic eXtract (MAX) linked data files. These files comprised participants from the 1997 to 2005 NHIS linked to their MAX claims data from 1999 to 2008, representing the most recently available linked data from these data sources. Details of the linkage algorithm can be found elsewhere [23]. Both the NHIS and the subsequent MAX linkage were approved by the NCHS Institutional Review Board (IRB).

The NHIS is a nationally representative continuous survey of a cross-sectional probability sample of the US non-institutionalized population. Detailed socio-demographic and health information [24] is obtained for a sample adult and a sample child through in-person home interviews. The unweighted 1997–2005 NHIS household response rate ranged from 87% to 92% [24].

The MAX files contain fee-for-service and managed care Medicaid and CHIP data on hospital, outpatient, and pharmacy claims, reported quarterly by each state to the CMS Medicaid Statistical Information System. States may cover CHIP enrollees by expanding Medicaid (Medicaid-expansion CHIP) or creating separate CHIP programs (separate-CHIP). Unfortunately, encounter data from states administering separate-CHIP and managed care Medicaid plans is incomplete. Furthermore, those data do not undergo the same validation and quality checks as fee-for-service Medicaid and Medicaid-expansion CHIP data [25]. Thus, we restricted our sample to Medicaid and Medicaid-expansion CHIP participants within fee-for-service plans.

Of the 879 342 children and adults in the NHIS years 1997–2005, 51.8% were eligible for linkage to the MAX files, meaning consent for linkage and sufficient information (Social Security Number and date of birth) was provided. Linkage eligibility among children (2–17 years old) was 52.9%. Although bias could result from the absence of data for those who were not linkage-eligible, characteristics of linkage-eligible and non-linkage-eligible groups were similar (Supplementary Table 1). In addition, reweighting [26–28] was conducted to adjust for linkage-eligibility, as described below.

Study design

NHIS survey participants from 1997 to 2005 who were linkage eligible and who had any Medicaid/CHIP fee-for-service claim when 2–17 years old during 1999–2008 were included in the study ($n=56\ 136$) (Figure 1). We included respondents with at least one MAX file pharmacy claim for a National Drug Code (NDC) representing a prescription for preventive asthma medication during the 10-year observation period beginning 1 January 1999, and ending 31 December 2008 ($n=6576$). Preventive asthma medication was defined to include ICS (i.e. beclomethasone, budesonide,

ciclesonide, flunisolide, fluticasone, mometasone, or triamcinolone); long-acting β_2 -agonists (i.e. formoterol, or salmeterol); combined ICS and long-acting β_2 -agonists (i.e. budesonide/formoterol, fluticasone/salmeterol, or mometasone/formoterol); leukotriene modifiers (i.e. montelukast, zafirlukast, or zileuton); mast cell stabilizers (i.e. cromolyn, or nedocromil); and monoclonal antibodies (i.e. omalizumab). Respondents with codes for both ICS and long-acting β_2 -agonists or for both leukotriene modifiers and long-acting β_2 -agonists were categorized as ICS or leukotriene modifiers, respectively. Fifty-nine percent of patients with claims for asthma rescue medications ($n=9463$) were excluded because they had no claims for preventive asthma medications, a figure roughly corresponding to the frequency of mild intermittent asthma found in other studies [29,30]. Prescriptions filled when respondents were <2 years old were excluded to minimize diagnostic confusion in young children who may wheeze transiently with respiratory infections [3,29]. Prescriptions filled when respondents were >17 years old were also excluded because the NCHS-IRB does not allow linkage of NHIS respondents to MAX files if their claims were filled when the respondent was >17 years old.

We excluded observations with *International Classification of Diseases-9th Revision Clinical Modification* (ICD-9-CM) diagnosis codes from the MAX files for cystic fibrosis (ICD-9 = 277.0), bronchopulmonary dysplasia (770.7), tracheomalacia (748.3 or 519.19), or with leukotriene modifier prescriptions unaccompanied by a code for asthma (493) or by other asthma-related drug claims (93 observations excluded). Children with claims associated only with Medicaid comprehensive managed care or with separate-CHIP coverage, or with incomplete claims data were excluded (2200 observations) (Figure 1).

Most children (65.5%) had multiple Medicaid enrollment periods. In these cases, the longest period of continuous fee-for-service coverage with a claim was used to ensure that each patient was followed during their most prolonged stretch of continuous Medicaid/Medicaid-expansion CHIP enrollment. Only one period was analyzed to avoid uncertainty in preventive asthma medication compliance between coverage periods, and to avoid multiple discontinuation events per respondent.

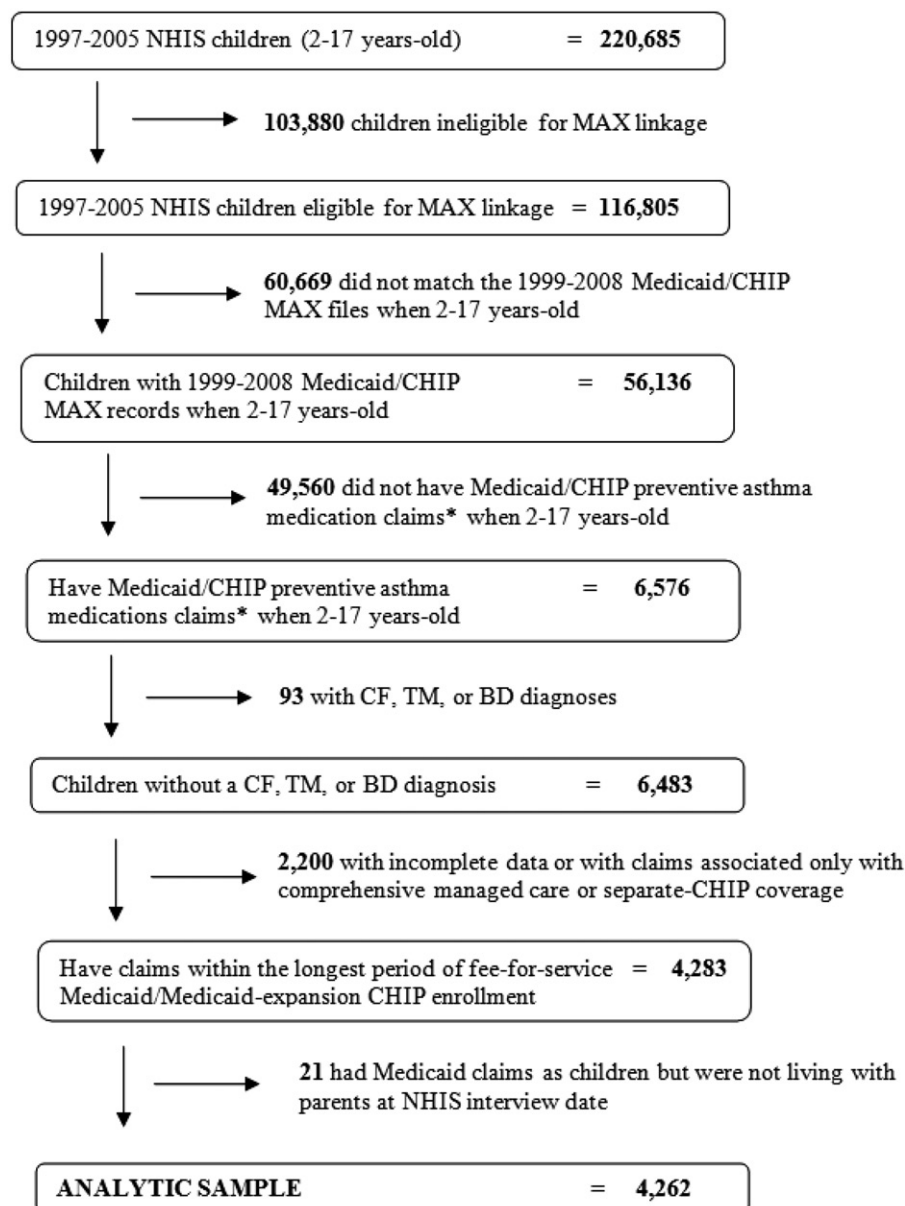
Finally, we excluded NHIS respondents who had claims at <18 years old, but were already living independently of their parents' household at the time of the NHIS survey (21 excluded) because their socio-demographic circumstances at the time of the survey might differ from those at the time of the claims. The final analytic sample included 4262 children 2–17 years old at the time of preventive asthma medications claims within fee-for-service Medicaid/Medicaid-expansion CHIP programs.

Variables and measures

Our main dependent variable was time-to-preventive asthma medication discontinuation. We defined initiation as the time of the first claim reported in the MAX files for a filled preventive asthma prescription, and discontinuation as the absence of another preventive asthma medication claim within 30 d after the previous prescription claim was

Figure 1. Unweighted sample selection and exclusions to assess childhood preventive asthma medication discontinuation in fee-for-service Medicaid/Medicaid-expansion CHIP (United States, 1999–2008).

Abbreviations: BD, bronchopulmonary dysplasia; CF, cystic fibrosis; CHIP, Children's Health Insurance Program; MAX, Medicaid Analytic eXtract; NHIS, National Health Interview Survey; TM, tracheomalacia. *Preventive asthma medications include inhaled corticosteroids, long-acting β_2 -agonists, leukotriene modifiers, mast cell stabilizers, or monoclonal antibodies.



scheduled to run out (i.e. date of last prescription + days of supply + 30-day grace period), provided the child was still enrolled in Medicaid/Medicaid-expansion CHIP at that time.

Independent variables were obtained from NHIS data and hence, pertain to the time that the respondent participated in NHIS. The only exception was age, which was categorized at the time of the child's first preventive asthma medication claim. Independent variables included age (2–4, 5–11, 12–17 years, based on age groups used in the National Asthma Education and Prevention Program [NAEPP] Expert Panel Report Guidelines [3]), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and all other non-Hispanic races), health status (excellent/very good, good, or fair/poor), limitation due to other chronic conditions besides asthma (yes/no), healthcare delayed or not sought in the past year due to cost (yes/no), presence of a regular primary physician for routine care (yes/no), highest level of school completed by any family member (<12th grade, high school diploma, or some college or above), urbanicity (central-city metropolitan statistical area [MSA], MSA but not in central-city, not in MSA),

US census region (Northeast, Midwest, South, or West), and family structure (a single-adult and 1–2 children, a single-adult and ≥ 3 children, multiple adults and 1–2 children, or multiple adults and ≥ 3 children). Also, we examined the effect of four categories of preventive asthma medication regimens recommended by the NAEPP [3] (i.e. only ICS, only leukotriene modifiers, both ICS and leukotriene modifiers, or preventive asthma medications other than ICS or leukotriene modifiers) as regimen may affect adherence [20]. Due to small sample sizes, we did not analyze separately Asians/Pacific Islanders, American Indians/Alaska Natives, non-Hispanic multiracial subgroups, or exclusive use of long-acting β_2 -agonists, mast cell stabilizers, or monoclonal antibodies.

We considered including imputed family income and the need for referrals before accessing subspecialists as covariates, but these were highly correlated to highest educational attainment in the family and the presence of a regular primary physician for routine care, respectively. Model fit using the Partial Likelihood Ratio Tests was improved with the latter set of variables, so these were chosen for our model.

Finally, for a sensitivity analysis discussed below, we identified a subgroup of children with more severe underlying asthma as defined by Health Employer Data Information System (HEDIS) [31] criteria, using a claims-based algorithm created by the US National Committee for Quality Assurance. Children were classified as having persistent asthma if they fulfilled any of the following criteria during two consecutive years: (1) ≥ 1 hospitalizations for asthma; (2) ≥ 1 emergency-department visits for asthma; (3) ≥ 4 medication claims for asthma; or (4) ≥ 4 outpatient visits for asthma along with ≥ 2 asthma medication claims [31].

Statistical analysis

We conducted survival analysis measuring length of continuous preventive asthma medications usage prior to discontinuation. The cohort was right-censored at 18 years old, upon disenrollment from Medicaid or Medicaid-expansion CHIP, upon enrollment in a managed care program, or if they reached the end of 2008 in a continuous medication regimen.

Sensitivity analyses were conducted that changed the definition of discontinuation by varying the additional 30-day window allowed after the previous prescription ran out to 15 d and 60 d. However, our results were essentially unchanged and these data are not presented. We also restricted the study to the subgroup of children aged 5–17 years with results largely unchanged from the analysis that includes children 2–4 years of age. Similarly, to examine the role of asthma severity in discontinuation and the accuracy of time-dependent covariate values, we conducted two sensitivity analyses. The first included only children who met the HEDIS criteria for persistent asthma and the second included only children whose first claim took place within 2 years from the date of NHIS interview. Although some people meet the HEDIS criteria for persistent asthma by having more PAM claims, and hence, by definition have a longer time to discontinuation, the analysis of children with HEDIS-defined persistent asthma was used to examine whether the relationships between covariates and time-to-discontinuation within this more severe group of children were consistent with the findings for the entire study population.

To obtain nationally representative estimates, NHIS sample weights were used. NHIS weights were also adjusted to account for linkage-eligibility using a model-based calibration approach in SUDAAN (WTADJUST procedures) to preserve correct population totals within race/ethnicity, age, and sex cross-stratifications [26–28]. Analyses were performed with SAS version 9.3 software (SAS Institute Inc., Cary, NC) [32] and SUDAAN software version 10.0 (Research Triangle Institute, Research Triangle Park, NC) [33] to account for the complex survey design of the NHIS.

We used the Kaplan–Meier method to plot our primary outcome, the overall univariate time-to-preventive asthma medication discontinuation survival curve. This univariate estimate examines time-to-discontinuation and not how it relates to any other independent variable. Next, we conducted bivariate and multivariate Cox proportional-hazards models. Multivariate models were adjusted for the covariates discussed above using the Breslow method for ties. We also attempted using the Efron method of addressing ties, and the

results were essentially identical with only very small changes in estimates and no changes in significance.

Covariates were chosen that have been found in other research to be predictive of discontinuation: age at first preventive asthma medication claim, sex [9,34–40], race/ethnicity [4,9,10,21,38,41], urbanicity [41], geographic location [9], reported highest educational attainment by any family member [35,37,39,42], family structure [39,40,43], reported health status [9], presence of chronic conditions besides asthma [7,35], healthcare out-of-pocket costs [12], presence of a primary care provider [5,6], and preventive asthma medication regimen [7,20,36].

Results

Weighted results showed that the sample was 56% male, 50% 5–11 years old, and 46% non-Hispanic white (Table 1). The median time of continuous enrollment was 1218 d or about 3 and 1/3 years. Only 5% of the sample had less than a 90-day enrollment period. Examining the survival curve for preventive asthma medication usage, a decline in usage began after 30 d of follow-up due to the grace period included in the definition of discontinuation (Figure 2). That is, discontinuation is widely observed at 60 d because most children (55%) had 30 d of supply and never obtained a refill. Additionally, 63% had discontinued after 90 d of follow-up from the start of the first prescription. After 190 d, just 15% had not yet discontinued their regimen. Among those that had not discontinued by 190 d, two-thirds continued usage until the 2-year mark. Discontinuation after 2 years occurred less rapidly, with only another 2.5% of children discontinuing preventive asthma medications between 2 and 3 years (Figure 2).

Results were similar for adjusted Hazard ratios [aHRs] and unadjusted HRs for preventive asthma medication discontinuation, therefore, only aHRs are reported here (Table 2). Adolescents 12–17 years old and toddlers 2–4 years old had slightly higher hazards of discontinuation (aHR, 1.13; 95% CI, 1.05–1.23; and 1.12; 1.03–1.21, respectively) versus 5–11 year olds, as did Hispanics (aHR, 1.24; 1.13–1.35) and non-Hispanic blacks (aHR, 1.17; 1.07–1.28) versus non-Hispanic whites, children in households with one adult and ≥ 3 children (aHR, 1.17; 1.05–1.30) versus multiple adults and ≤ 2 children, and children with caregivers who had an educational attainment ≤ 12 th grade (aHR, 1.11; 1.02–1.20) versus caregivers with some college or above. Compared to regimens including both ICS and leukotriene modifiers, discontinuation was greater for those on ICS without leukotriene modifiers or on other preventive asthma medications (aHR, 1.67; 1.56–1.80; and 2.23; 1.78–2.80, respectively). No significant associations with discontinuation were detected for sex, reported health status, limitations due to chronic conditions besides asthma, delay of healthcare due to cost, presence of a primary physician for routine care, US region, or urbanicity.

After exclusion of children 2–4 years of age, the Kaplan–Meier curve showed a slight increase in the compliance length after eliminating children 2–4 years of age (as is suggested by the Cox model, showing faster discontinuation within that group). Although confidence intervals for the two curves were

Table 1. Characteristics of children ($n = 4262$) who filled at least one Medicaid preventive asthma medication fee-for-service claim from 1999 to 2008.

Characteristics	Unweighted			Weighted	
	Censored	Non-compliant	Total	Percent	SE
	($n = 660$)	($n = 3602$)	($n = 4262$)	(%)	(%)
Sex					
Males	373	2068	2441	56.0	0.9
Females	287	1534	1821	44.0	0.9
Age at first preventive asthma medication fee-for-service claim (years)					
2–4	125	844	969	23.0	0.8
5–11	346	1783	2129	49.2	0.9
12–17	189	975	1164	27.8	0.8
Race/ethnicity					
Non-Hispanic white	228	1334	1562	45.9	1.4
Non-Hispanic black	161	963	1124	27.3	1.3
Hispanic	250	1230	1480	23.4	1.3
All other non-Hispanic races	21	75	96	3.4	0.6
Preventive asthma medication regimen					
Any inhaled corticosteroid ^a	289	1270	1559	37.2	1.0
Leukotriene modifiers ^b	145	786	931	21.7	0.7
Both ^c	205	1447	1652	38.5	0.9
Neither of the above ^d	21	99	120	2.6	0.3
HEDIS criteria for persistent asthma					
Yes	243	1486	1729	41.8	0.8
No	417	2116	2533	58.2	0.8
Reported health status					
Excellent/very good	404	2111	2515	59.8	0.9
Good	185	1058	1243	28.6	0.8
Fair/poor	70	428	498	11.5	0.6
Limited due to chronic conditions (besides asthma)					
Yes	35	297	332	8.5	0.5
No	625	3305	3930	91.6	0.5
Healthcare delayed or not sought (past 12 mo) due to cost					
Yes	59	254	313	8.2	0.6
No	601	3348	3949	91.8	0.6
Has a regular primary physician for routine care					
Yes	206	1001	1207	29.3	1.0
No	454	2601	3055	70.7	1.0
Adult with the highest education in the family					
≤ 12th grade	144	945	1089	22.6	0.9
High school diploma	166	994	1160	27.3	0.9
Some college or above	330	1586	1916	47.8	1.1
Family structure					
Only 1 adult and 1-2 children	125	610	735	18.1	0.7
Only 1 adult and 3+ children	57	459	516	11.5	0.7
Multiple adults and 1-2 children	230	1115	1345	32.7	1.0
Multiple adults and 3+ children	242	1390	1632	36.5	1.0
Metropolitan statistical area					
In central city MSA	272	1241	1513	30.4	1.4
In MSA but not in central city	235	1144	1379	33.4	1.4
Not in MSA	153	1217	1370	36.2	1.6
United States region					
Northeast	88	481	569	13.2	0.9
Midwest	128	578	706	18.9	1.1
South	344	2227	2571	59.4	1.4
West	100	316	416	8.5	0.7

HEDIS, Healthcare Effectiveness Data & Information Set; MAX, Medicaid Analytic eXtract; MSA, Metropolitan statistical area; NHIS, National Health Interview Survey; SE, percentage standard error.

^aInhaled corticosteroids (ICS): beclomethasone, budesonide, ciclesonide, flunisolide, fluticasone, mometasone, triamcinolone, budesonide-formoterol, fluticasone-salmeterol, or mometasone-formoterol.

^bLeukotriene modifiers: montelukast, zafirlukast, or zileuton.

^cPreventive asthma regimen consist of both ICS and leukotriene modifiers.

^dPreventive asthma regimen consist of either long-acting β_2 -agonist bronchodilators (i.e. formoterol or salmeterol), mast cell stabilizers (i.e. cromolyn or nedocromil), or a monoclonal antibody (i.e. omalizumab).

overlapping at every time-point, the 5–17-year group had a greater percent of the group compliant at every time-point by 1 to 2 percentage points. When the unadjusted and adjusted Cox proportional Hazards models were compared for the 5–17 group and the 2–17 group, point estimates were largely similar

in all cases. However, some estimates gained significance, while one estimate lost significance. Specifically, estimates that gained significance were: Leukotriene modifiers (unadjusted HR = 1.12 (1.02–1.23), adjusted HR = 1.14 (1.04–1.25)); unadjusted results for living in a family with 1 adult

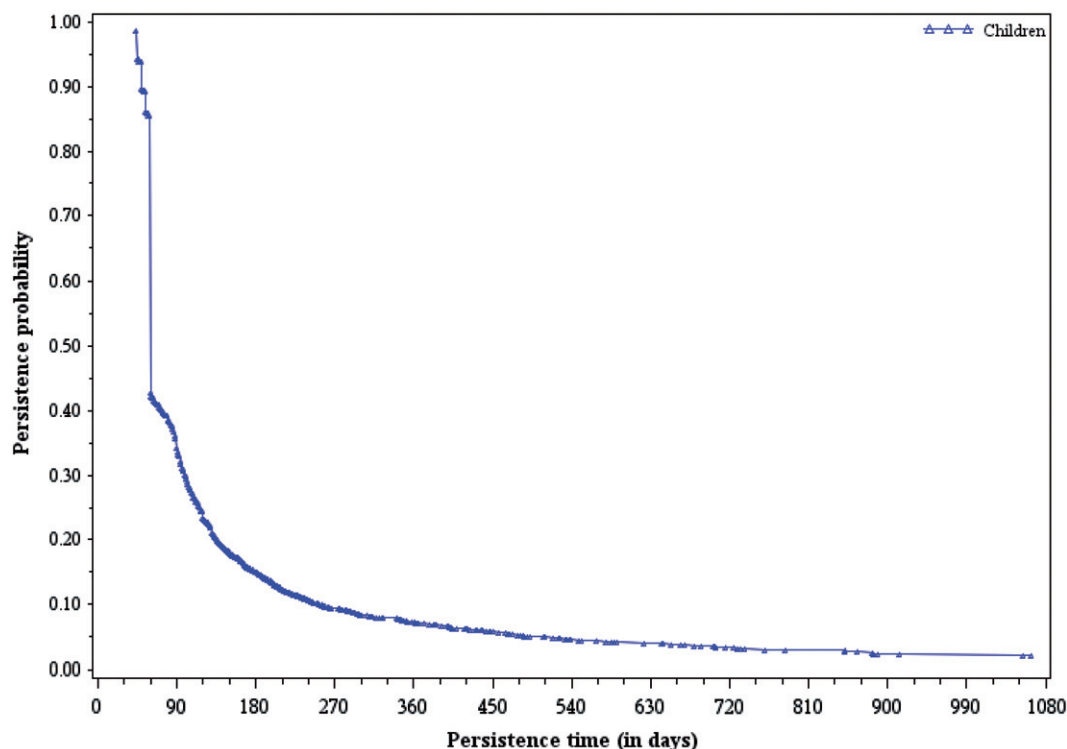


Figure 2. Kaplan-Meier plot function for the length of preventive asthma medication time-to-discontinuation for children (2–17 years old) surveyed by the NHIS and with Medicaid/Medicaid-expansion CHIP claims from 1999 to 2008 within their longest period of fee-for-service enrollment. *Abbreviations:* NHIS, National Health Interview Survey. Note: Preventive asthma medications include inhaled corticosteroids, long-acting β_2 -agonists, leukotriene modifiers, mast cell stabilizers, or monoclonal antibodies.

and 1–2 children (unadjusted HR = 1.12 (1.02–1.23)); living in family with multiple adults and 3+ children (unadjusted HR = 1.14 (1.04–1.25), adjusted HR = 1.09 (1.00–1.19)); and unadjusted estimates for living in the West (unadjusted HR = 1.16 (1.00–1.34)). Only adjusted estimates of having a highest level of education in the family of <12th grade lost significance (adjusted HR = 1.08 (0.99–1.17)).

Similarly, after exclusion of children whose first preventive asthma medication claim was >2 years after their NHIS interview, the direction and significance were unchanged, with the exception that the aHR associated with being non-Hispanic black or being a toddler lost significance. In additional sensitivity analyses among children with persistent asthma, the direction and significance also remained unchanged except for the aHR for reporting “good” versus “excellent/very good” health status gained significance and having a single-parent and ≥ 3 children lost significance (Supplementary Table 2). We suspect that these losses of significance were likely due to smaller sample sizes.

Discussion

Our findings support previous literature identifying high preventive asthma medication discontinuation among children enrolled in Medicaid [9,11–21]. More than half of children did not have even one refill claim for their preventive asthma medication and only 37% of the entire sample showed continued utilization on the 90th day of follow-up. Yet, for the residual 15% of children with continued usage after 190 d, the discontinuation curve flattened considerably. This might indicate a potential 6-month threshold after which discontinuation decreases.

The NAEPP Guidelines recommend preventive asthma care visits at least every 6 months [3,44], but it has been uncertain how time-to-preventive asthma medication discontinuation in children enrolled in Medicaid/CHIP compares to this time frame. Our results suggest over 80% of children will have discontinued preventive asthma medications by this time, and earlier follow-up would be necessary to assess the effects of preventive asthma medications on asthma symptoms and potentially help to prevent discontinuation. Indeed, scheduling regular visits for asthma has previously been associated with improved ICS use [45].

Previous regional and state-specific research has identified substantial preventive asthma medication underuse among children enrolled in Medicaid [6,7,11–19]. This may be explained in part by the short duration of usage that we measured here, although low initiation of preventive asthma medications may also be a factor. Consistent with other studies [9,34–40], our results indicate that usage falls among adolescents, typically within an age range when children assume responsibility for taking their own medications.

Our results indicate that non-Hispanic black and Hispanic children have higher hazards of preventive asthma medication discontinuation. This could reflect a number of potential barriers. Some studies suggest that barriers to optimal preventive care among publicly insured children may be, in part, related to cultural and traditional health beliefs [10,13,37]. Indeed, it may be illustrative that racial/ethnic differences persist within the Medicaid/Medicaid-expansion CHIP population which is more socio-economically homogenous than the general population. Similar to previous research [37,39,46], we also found that caregivers’

Table 2. Weighted crude and adjusted hazard ratios for preventive asthma medication discontinuation among children ($n=4262$) who filled 1+ Medicaid PAM fee-for-service claims from 1999 to 2008.

Characteristics	Unadjusted		Fully adjusted model*	
	HR	(95% CI)	aHR	(95% CI)
Sex				
Males		1.00		1.00
Females	1.04	(0.98–1.11)	1.03	(0.97–1.10)
Age at first preventive asthma medication fee-for-service claim (years)				
2–4	1.12	(1.02–1.22)	1.12	(1.03–1.21)
5–11		1.00		1.00
12–17	1.19	(1.10–1.29)	1.13	(1.05–1.23)
Race/ethnicity				
Non-Hispanic white		1.00		1.00
Non-Hispanic black	1.20	(1.10–1.30)	1.17	(1.07–1.28)
Hispanic	1.27	(1.18–1.37)	1.24	(1.13–1.35)
All other non-Hispanic races	1.06	(0.86–1.31)	0.93	(0.75–1.16)
Preventive asthma medication regimen				
Any inhaled corticosteroid ^a	1.65	(1.53–1.77)	1.67	(1.56–1.80)
Leukotriene modifiers ^b	1.05	(0.95–1.15)	1.07	(0.98–1.18)
Both ^c		1.00		1.00
Neither of the above ^d	2.25	(1.85–2.74)	2.23	(1.78–2.80)
HEDIS criteria for persistent asthma				
Yes		1.00		NA
No	1.62	(1.51–1.74)		NA
Reported health status				
Excellent/Very good		1.00		1.00
Good	0.98	(0.91–1.07)	0.95	(0.88–1.03)
Fair/Poor	1.03	(0.94–1.14)	1.04	(0.94–1.15)
Limited due to chronic conditions (besides asthma)				
Yes		1.00		1.00
No	1.00	(0.88–1.14)	1.04	(0.89–1.20)
Healthcare delayed or not sought (past 12 mo) due to cost				
Yes	1.00	(0.89–1.12)	1.03	(0.91–1.16)
No		1.00		1.00
Has a regular primary physician for routine care				
Yes		1.00		1.00
No	1.00	(0.92–1.08)	1.00	(0.93–1.08)
Adult with the highest education in the family				
≤ 12th grade	1.15	(1.07–1.25)	1.11	(1.02–1.20)
High school diploma	1.05	(0.97–1.14)	1.04	(0.96–1.12)
Some college or above		1.00		1.00
Family structure				
Only 1 adult and 1–2 children	1.06	(0.97–1.17)	0.99	(0.90–1.09)
Only 1 adult and 3+ children	1.23	(1.11–1.37)	1.17	(1.05–1.30)
Multiple adults and 1–2 children		1.00		1.00
Multiple adults and 3+ children	1.08	(0.99–1.18)	1.06	(0.97–1.15)
Metropolitan statistical area				
In central city MSA	1.09	(1.00–1.18)	1.02	(0.94–1.11)
In MSA, but not in central city		1.00		1.00
Not in MSA	1.03	(0.95–1.12)	1.06	(0.98–1.15)
United States region				
Northeast	1.13	(1.00–1.27)	1.07	(0.94–1.22)
Midwest		1.00		1.00
South	1.05	(0.96–1.15)	1.07	(0.98–1.18)
West	1.06	(0.93–1.20)	1.01	(0.89–1.15)

^aHR, adjusted weighted hazard ratio; CI, weighted confidence interval; HR, weighted hazard ratio; HEDIS, Healthcare Effectiveness Data & Information Set; MAX, Medicaid Analytic eXtract; MSA, Metropolitan statistical area; NA, not applicable; NHIS, National Health Interview Survey.

*Fully adjusted model is adjusted for sex, age (in years) at first fee-for-service claim, race, ethnicity, type of preventive asthma medication regimen, reported health status, limitations due to other chronic conditions besides asthma, healthcare delayed or not sought in the past year due to cost, presence of a regular primary physician for routine care, adult with the highest educational attainment in the family, household distribution, MSA and US region.

^aInhaled corticosteroids (ICS): beclomethasone, budesonide, ciclesonide, flunisolide, fluticasone, mometasone, triamcinolone, budesonide-formoterol, fluticasone-salmeterol, or mometasone-formoterol.

^bLeukotriene modifiers: montelukast, zafirlukast, or zileuton.

^cPreventive asthma regimen consist of both ICS and leukotriene modifiers.

^dPreventive asthma regimen consist of either long-acting β_2 -agonist bronchodilators (i.e. formoterol or salmeterol), mast cell stabilizers (i.e. cromolyn or nedocromil), or a monoclonal antibody (i.e. omalizumab).

Numbers of participants may not sum to total due to missing data.

educational attainment may be related to children's discontinuation. Most children are dependent upon their parents' health knowledge and behaviors, and, thus, their socioeconomic and domestic environment could be critical in their asthma management. Also, children living in a household with a single-adult and ≥ 3 children had increased hazards of discontinuation. This finding is consistent with prior research suggesting that discontinuation is greater in families lacking adequate social support and in those without strong routines, instruction, and supervision [47,48].

Consistent with other studies [30,41–43], in this study a leukotriene modifier combined with ICS was associated with lower hazards of discontinuation when compared to inhalational therapies alone (i.e. ICS, long-acting β_2 -agonists, or mast cell stabilizers). However, the combined regimen might indicate more severe disease, which may be the motivating factor for usage.

Although significant differences in the discontinuation curves were found between demographic groups, differences in terms of days prior to discontinuation were not large. Indeed, at the 75th percentile of the discontinuation curve for each group, the differential in terms of days prior to discontinuation averaged approximately 1 month (ranging between 11 and 72 d). For example, at the 75th percentile of the discontinuation curve, medication discontinuation for Hispanics and non-Hispanic blacks occurred 32 d and 21 d before non-Hispanic whites, respectively.

Our study has several strengths. All socio-demographic data were obtained from an in-home survey performed by trained interviewers, as opposed to administrative records. Medicaid/Medicaid-expansion CHIP claims allow us to capture a very large, population-based longitudinal cohort of children with prescriptions for preventive asthma medications.

Limitations include the inability to: evaluate how gaps in Medicaid coverage affect discontinuation patterns; evaluate whether observed discontinuation patterns also apply to children with commercial insurance coverage, those enrolled in Medicaid managed care plans or those in CHIP programs administered separately from Medicaid; assess whether linkage-eligible and non-eligible NHIS respondents were similar in terms of discontinuation of asthma medications, emergency asthma visits, or hospitalizations; and rule out utilization claims coding errors. Also, it is unknown whether filled prescriptions were actually used and whether they were administered properly. Therefore, prescriptions filled indicate only an upper bound for the discontinuation curve. Similarly, we were unable to determine whether failure to refill prescriptions was due to physicians failing to renew prescriptions, patients failing to fill provided prescriptions, or other barriers to preventive care. It is possible that some children received a short course of preventive asthma medication for an acute asthma exacerbation, or that their physician would step-down medications after clinical improvement or due to side effects. However, use of preventive asthma medications for short courses for asthma exacerbations is not recommended by NAEPP guidelines. Also, only prescriptions paid for by Medicaid or Medicaid-expansion CHIP were recorded in our data. Other medication sources, such as physician samples or prescriptions provided to respondents before our study period, were not included.

Considerable variation was identified in the sample sizes of the different regions. However, this population variation largely reflects the regional distribution of children enrolled in Medicaid/CHIP in the US, as identified by the NHIS. Our study sample may over-represent the South and under-represent the West, as 59.4% and 8.5% of our sample were from the South and West, respectively, compared to 42.5% and 19.6% of children from the South and West respectively enrolled in Medicaid/CHIP in the 2004 NHIS overall. While asthma prevalence may account for some differences between our sample and the distribution of children in Medicaid, another major factor is likely the penetration of managed care versus fee-for-service in different areas.

Copays for medications and other access issues may create barriers to preventive asthma medication usage among Medicaid/CHIP enrollees. In our study, the presence of a primary care physician and whether cost may have delayed care were not found to be significant predictors of discontinuation and, after controlling for these factors, the differences in discontinuation by socio-demographic indicators persisted. Still, improved measurement of out-of-pocket costs and other access issues may have identified barriers that we were unable to perceive in this study.

Conclusions and key findings

This analysis showed that among children enrolled in Medicaid or Medicaid-expansion CHIP in the US, only 37% of those using preventive asthma medications continue to take those medicines for more than 3-months. Socio-demographic factors (i.e. age, and race/ethnicity), family factors (structure and caregivers' level of educational attainment), and the type of preventive asthma regimen may explain some of the observed variance in time-to-discontinuation. Understanding the factors associated with preventive asthma medication discontinuation may help to inform current pediatric asthma care and future NAEPP guidelines.

Declaration of interest

The authors declare no conflicts of interests. The authors alone are responsible for the content and writing of this article.

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SUPPLEMENTARY TABLE 1 (Online only).

Title: Unweighted frequencies of children (2-17 years-old) surveyed by 1997-2005 NHIS and eligible for linkage to the Medicaid Analytic eXtract (MAX) files from 1999-2008.

NHIS characteristics	Total NHIS children		MAX Linkage eligible children	
	Frequency (n=220 685)	Percent (%)	Frequency (n=116 805)	Percent (%)
Sex				
Males	113 163	51.3	60 022	51.4
Females	107 522	48.7	56 783	48.6
Age (years)				
2-4	40 822	18.5	21 829	18.7
5-11	98 917	44.8	52 195	44.7
12-17	80 946	36.7	42 781	36.6
Race/Ethnicity				
Non-Hispanic white	110 512	50.1	63 696	54.5
Non-Hispanic black	36 475	16.5	18 237	15.6
Hispanic	64 598	29.3	30 666	26.3
All other non-Hispanic races	9100	4.1	4206	3.6
Reported health insurance coverage				
Medicaid or CHIP	51 377	23.3	29 170	25.0
Private	129 677	58.8	69 369	59.4
Other	39 631	18.0	18 266	15.6
Reported health status				
Excellent/Very good	175 643	79.6	94 394	80.8
Good	39 529	17.9	19 654	16.8
Fair/Poor	4760	2.2	2612	2.2
Limited due to asthma/breathing condition lasting 3+ months				
Yes	14 679	6.7	8412	7.2
No	206 006	93.3	108 393	92.8
Limited due to chronic conditions (besides asthma)				
Yes	8082	3.7	4994	4.3
No	212 603	96.3	111 811	95.7
Healthcare delayed or not sought (past 12mo) due to cost				
Yes	10 313	4.7	5726	4.9
No	210 372	95.3	111 079	95.1
Has a regular primary physician for routine care				
Yes	22 800	10.3	13 278	11.4
No	197 885	89.7	103 527	88.6
Referrals required for specialist care				
Yes	26 241	11.9	15 163	13.0
No	194 444	88.1	101 642	87.0
Adult with the highest education in the family				
≤ 12th grade	34 993	15.9	17 067	14.6
High school diploma	46 039	20.9	23 980	20.5
Some college or above	112 714	51.1	63 086	54.0

Family structure

Only 1 adult and 1-2 children	23 782	10.8	13 189	11.3
Only 1 adult and 3+ children	14 909	6.8	8426	7.2
Multiple adults and 1-2 children	89 462	40.5	47 484	40.7
Multiple adults and 3+ children	92 532	41.9	47 706	40.8

Metropolitan Statistical Area

In central city MSA	71 057	32.2	35 329	30.2
In MSA, but not in central city	110 356	50.0	57 218	49.0
Not in MSA	39 272	17.8	24 258	20.8

United States region

Northeast	36 984	16.8	19 841	17.0
Midwest	46 564	21.1	26 832	23.0
South	77 333	35.0	43 478	37.2
West	59 804	27.1	26 654	22.8

Abbreviations: CHIP , Children's Health Insurance Program; MAX, Medicaid Analytic eXtract; MSA, Metropolitan Statistical Area; NHIS, National Health Interview Survey.

Note: Numbers of participants may not sum to total due to missing data.

SUPPLEMENTARY TABLE 2 (Online only).

Title: Adjusted hazard ratios for preventive asthma medication non-compliance among children (n=1729) with persistent asthma according to HEDIS criteria who filled 1+ Medicaid preventive asthma medication fee-for-service claim from 1999-2008.

Characteristics	Total			Censored	Noncompl	Adjusted model†	
	Unwgted (n=1729)	Wgted Pct (%)	SE (%)	Unwgted (n=243)	Unwgted (n=1486)	Weighted aHR	(95% CI)
Sex							
Males	1009	57.8	1.3	132	877	1.00	
Females	720	42.2	1.3	111	609	1.02	(0.92-1.13)
Age at first preventive asthma medication fee-for-service claim (years)							
2-4	489	28.4	1.3	60	429	1.12‡	(1.00-1.25)
5-11	901	51.9	1.5	141	760	1.00	
12-17	339	19.7	1.2	42	297	1.20	(1.05-1.38)
Race/Ethnicity							
Non-Hispanic white	626	44.6	1.9	90	536	1.00	
Non-Hispanic black	537	31.2	1.6	55	482	1.34	(1.17-1.54)
Hispanic	526	20.9	1.4	89	437	1.28	(1.11-1.48)
All other non-Hispanic races	40	3.4	0.8	9	31	1.16	(0.81-1.67)
Preventive asthma medication regimen							
Any inhaled corticosteroid ^a	424	24.4	1.3	79	345	1.53	(1.35-1.72)
Leukotriene modifiers ^b	209	12.8	1.0	32	177	0.83	(0.71-0.97)
Both ^c	1079	61.9	1.4	132	947	1.00	
Neither ^d	17	1.0	0.3	0	17	*	
HEDIS criteria for persistent asthma							
Yes	1729	100.0	0.0	243	1486	NA	
No	0	0.0	0.0	0	0	NA	
Reported hlth status							
Excel/Very good	933	54.4	1.3	130	803	1.00	
Good	526	30.7	1.3	77	449	0.86	(0.76-0.98)
Fair/Poor	269	14.9	1.0	35	234	1.01	(0.87-1.17)
Limited due to chronic conditions (besides asthma)							
Yes	160	10.0	0.8	16	144	1.00	
No	1569	90.0	0.8	227	1342	1.16	(0.93-1.44)
Healthcare delayed or not sought (past 12mo) due to cost							
Yes	106	6.6	0.8	12	94	1.14	(0.92-1.41)
No	1623	93.4	0.8	231	1392	1.00	
Has a regular primary physician for routine care							
Yes	561	33.0	1.4	102	459	1.00	
No	1168	67.0	1.4	141	1027	1.04	(0.93-1.17)
Adult with highest education in family							
≤ 12th grade	431	22.9	1.2	65	366	1.05	(0.92-1.19)

High school diploma	487	27.7	1.3	58	429	1.06	(0.93-1.20)
Some college or above	775	47.3	1.6	114	661	1.00	
Family structure							
Only 1 adult & 1-2 children	328	19.5	1.2	56	272	1.02	(0.87-1.18)
Only 1 adult & 3+ children	223	11.9	1.0	23	200	1.12	(0.93-1.34)
Multiple adults & 1-2 children	545	32.6	1.4	87	458	1.00	
Multiple adults & 3+ children	618	35.0	1.5	75	543	1.02	(0.88-1.18)
Metropolitan Statistical Area							
In MSA central city	660	33.0	1.7	104	556	1.10	(0.96-1.27)
In MSA not in central city	543	33.1	1.8	95	448	1.00	
Not in MSA	526	33.9	1.8	44	482	1.07	(0.92-1.23)
United States region							
Northeast	257	14.0	1.1	41	216	1.13	(0.92-1.40)
Midwest	313	20.0	1.3	55	258	1.00	
South	1014	58.9	1.7	118	896	1.13	(0.98-1.31)
West	145	7.1	0.9	29	116	1.14	(0.93-1.40)

Abbreviations: aHR, adjusted hazard ratio; HEDIS, Healthcare Effectiveness Data & Information Set; MAX, Medicaid Analytic eXtract; MSA, Metropolitan statistical area; NA, not applicable; NHIS, National Health Interview Survey; Noncompl, non-compliant; Pct, percentage; SE, weighted percentage standard error; Unwgted, unweighted; Wgted, weighted.

† Fully adjusted model is adjusted for sex, age (in years) at first preventive asthma medication fee-for-service claim, race, ethnicity, type of preventive asthma medication regimen, reported health status, limitation due to other chronic conditions besides asthma, healthcare delayed or not sought in the past year due to cost, presence of a regular primary physician for routine care, adult with the highest education in the family, household distribution, MSA and US region.

‡ The observed difference for the association with 2-4 years old at first preventive asthma medication fee-for-service claim is statistically significant at the 5% level, because the interval does not embrace an aHR of one.

* Estimate is unreliable due to fewer than 30 observations.

^a Inhaled corticosteroids (ICS): beclomethasone, budesonide, ciclesonide, flunisolide, fluticasone, mometasone, triamcinolone, budesonide-formoterol, fluticasone-salmeterol, or mometasone-formoterol.

^b Leukotriene modifiers: montelukast, zafirlukast, or zileuton.

^c Preventive asthma regimen consist of both ICS and leukotriene modifiers.

^d Preventive asthma regimen consist of either long-acting β_2 -agonist bronchodilators (i.e., formoterol or salmeterol), mast cell stabilizers (i.e., cromolyn or nedocromil), or a monoclonal antibody (i.e., omalizumab).

Note: Numbers of participants may not sum to total due to missing data.