

Original article

Race-ethnicity, crime, and other factors associated with adherence to inhaled corticosteroids

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Background: Previous studies have shown differences in adherence to inhaled corticosteroids (ICSs) by race-ethnicity, yet little is known about factors that contribute to adherence within these groups. Environmental stressors, such as crime exposure, which has been associated with asthma morbidity, might also predict ICS adherence.

Objective: We sought to identify factors associated with ICS adherence among patients with asthma and among African American patients and white patients separately.

Methods: Study patients with asthma were aged 18 to 50 years and were enrolled in a large southeast Michigan health maintenance organization between January 1, 1999, and December 31, 2001. The primary outcome, ICS adherence, was calculated by linking prescription-fill data with dosage information. Predictor variables included age, sex, race-ethnicity, measures of socioeconomic status (SES), average ICS copay, existing comorbidities, and crime rate in area of residence.

Results: Adherence information was available for 176 patients. ICS adherence was lower among African American patients ($n = 75$) when compared with white patients ($n = 94$; 40% vs 58%, respectively; $P = .002$). Among white patients, adherence was significantly lower for women when compared with men. Among African American patients, age and residential crime

rates were positively and negatively associated with ICS adherence, respectively. Area crime remained a predictor of adherence in African American patients, even after adjusting for multiple measures of SES.

Conclusions: This study suggests that an environmental stressor, area crime, provides additional predictive insight into ICS-adherent behavior beyond typical SES factors.

Clinical implications: Better understanding of environmental factors that influence ICS adherence might aid in efforts to improve it. (*J Allergy Clin Immunol* ■■■■;■■■:■■■-■■■.)

Key words: Adherence, inhaled corticosteroids, asthma, race-ethnicity, crime

We have previously shown nonadherence to inhaled corticosteroids (ICSs) to be associated with a number of poor asthma outcomes, including the number of asthma-related emergency department visits, asthma-related hospitalizations, and use of systemic steroids.¹ Although medication nonadherence is considered common for most chronic conditions,² it can be particularly low for pulmonary diseases.³ Average reported ICS adherence has been shown to vary by study but is typically in the range of 50% to 60%.^{1,4} Medication adherence has been reported to be lower among African American patients when compared with white patients,⁵⁻⁹ and this includes the use of inhaled steroids.¹⁰ This difference in ICS adherence might contribute to the racial disparities observed for poor asthma outcomes, such as emergency department visits, hospitalizations, and deaths.^{11,12} Unfortunately, little is known about the factors specific to ICS adherence among African American patients and white patients, and most factors examined to date, including measures of socioeconomic status (SES), have not been able to account for observed differences in adherence.¹³

One intriguing consideration is the role of environmental stressors in ICS adherence¹⁴ because these exposures might be more predictive of health and behavior than socioeconomic factors alone.¹⁵ Exposure to crime has been shown to be associated with poor asthma outcomes, and this relationship appears to be mediated, in part, through an effect on medication adherence.¹⁶

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Abbreviations used

CMA: Continuous, multiple-interval measure of medication availability
 CMSA: Consolidated metropolitan statistical area
 HMO: Health maintenance organization
 ICS: Inhaled corticosteroid
 SES: Socioeconomic status

Using a previously described cohort of insured individuals with asthma, we first examine whether ICS adherence differs by race-ethnicity. We next look for potential predictors of ICS adherence, such as area crime rates, among our entire study population and among African American patients and white patients separately.

METHODS**Study setting and patient population**

This study was approved by the Institutional Review Board at Henry Ford Health System and was in compliance with its Health Insurance Portability and Accountability Act policy. The study setting and patient selection criteria have been previously described.¹ In brief, patients were both members of a large health maintenance organization (HMO) in southeast Michigan, and they received their care from a large multispecialty medical group. Medical care claims data were used to retrospectively identify individuals aged 18 to 50 years with asthma during an index year (1999). Study patients were also required to be continuously enrolled in the HMO between January 1, 1999, and December 31, 2001, and have both medical and pharmacy benefit coverage during this time. Patients were excluded if they had a diagnosis of chronic obstructive pulmonary disease or congestive heart failure at any time between January 1, 1999, and December 31, 2001.

Information on patient characteristics, including age, sex, and race-ethnicity, were available from electronic data sources maintained by the health system. Average out-of-pocket medication expenses (ie, copay) for ICSs were calculated from pharmacy claims. We used an adaptation of the Charlson comorbidity index to estimate concomitant comorbidity from both diagnosis and procedural codes.¹⁷ To estimate median household income and other SES variables, we used a commercial package assembled by Mapping Solutions, LLC (Lansing, Mich). The components included MapInfo Professional and MapMarker (MapInfo Corp, Troy, NY) bundled with Allocate/Solocast (SRC LLC, Orange, Calif). MapMarker geocoding software assigned longitude and latitude coordinates to the address record, which was then mapped to the census block using MapInfo Professional. Allocate/Solocast are data retrieval and reporting engines, which then linked census block-level demographic information to the mapped address. Individuals' household income was taken as the median household income for their census block by using year 2000 data from the US Census Bureau. Census-block data were also used to determine the percentage of area residents with less than a high school education, the percentage of residents living below the federal poverty level, the proportion of owner-occupied homes in the area of residence, and the proportion of residences vacant.

Crime rates

Crime statistics for each patient's area of residence in 2001 were obtained from the Uniform Crime Report from the Michigan State Police Criminal Justice Information Center (http://www.michigan.gov/documents/2001_UCR_Annual_Report_49321_7.pdf), the Center for

Urban Studies at Wayne State University, and the Detroit Police Department's Crime Analysis Unit. The 62 residents of the city of Detroit were partitioned into their respective police scout-car areas (average of 1.3 study individuals per scout-car area), and individuals living in the surrounding Detroit consolidated metropolitan statistical area (CMSA) were assigned a crime rate for their area of residence (average of 1.9 individuals per area). The index crime rate was calculated as the number of part I offenses (less arson) for an area in 2001 divided by its population size. As part of its Uniform Crime Reporting Program, the Federal Bureau of Investigation defines the following serious felonies as part I offenses: criminal homicide, forcible rape, robbery, aggravated assault, burglary, larceny-theft, motor vehicle theft, and arson. Because arson statistics were not available by scout-car area in the city of Detroit, we excluded arson statistics in all calculations of the index crime rate.

Calculating ICS adherence

We adapted the methods of Steiner and Prochazka¹⁸ to measure adherence to inhaled medications.¹ In short, the medical records of all individuals fulfilling study criteria for asthma were abstracted by accredited medical record abstractors for ICS use and dosage information. These data were linked with prescription-fill information from pharmacy claims data. The number of days that a given fill of an ICS would last (ie, days supplied) was calculated by dividing the canister size (ie, puffs per canister) as derived from National Drug Codes in pharmacy claims by the dosage information (ie, puffs per day) obtained in medical records. The calculated days' supply was then used to estimate a continuous measure of medication adherence, otherwise known as a continuous, multiple-interval measure of medication availability (CMA),¹⁸ where CMA is calculated as the cumulative days' supplied divided by the total number of days between refills. To avoid overestimating adherence for prescriptions that extended beyond the study period, we calculated adherence for each patient for the time period beginning with the first fill of an ICS and ending with the last fill within the time period of January 1, 2000, through December 31, 2001. Therefore ICS adherence was only calculated for individuals with at least 2 fills of an ICS. Our calculations also accounted for switches that occurred within the same drug class (ie, the use of different ICS inhalers), changes in medication dosage, and times in which the provider stopped or discontinued the medication.

Statistical analysis

The primary outcome measure was the continuous measure of medication adherence, or CMA, in 2000-2001. Differences in patient characteristics by race-ethnicity were assessed by using a χ^2 test for categorical variables and a nonparametric Mann-Whitney 2-sample test for continuous variables. We calculated the prescribed number of ICS fills (ie, the number of fills that would have occurred with perfect adherence) by dividing the actual number of ICS fills by CMA during that time period. The distribution of the dependent variable, CMA, was approximately normal; therefore linear regression models were fit to identify those characteristics associated with adherence. The variables for index crime rate, median household income, the percentage of area residents with less than a high school education, the percentage of residents living below the federal poverty level, the proportion of owner-occupied homes in the area of residence, and the proportion of residences vacant were log₁₀ transformed so as to normalize their distribution, as well as to minimize the effect of extreme outliers. Multivariable linear regression models included adjustment for all available variables considered to be potentially associated with medication adherence; these included the patient's age, sex, race-ethnicity, median household income (and other SES variables), average copayment for inhaled steroids in 2000-2001, a measure of concomitant comorbidities (ie, the adapted Charlson comorbidity index), and the index crime rate in the area

TABLE I. Characteristics of study population with adherence information stratified by race-ethnicity, 2000-2001 (n = 169)

	All patients (n = 169)	African American patients (n = 75)	White patients (n = 94)	P value*
Age (y; mean $\pm$ SD)	40.8 $\pm$ 7.7	41.0 $\pm$ 7.3	40.6 $\pm$ 8.0	.834
Female sex (%)	115 (68.1)	49 (65.3)	66 (70.2)	.512
Race-ethnicity (%)				
African American	75 (44.4)	—	—	—
White	94 (55.6)	—	—	—
Estimated household income (\$; mean $\pm$ SD)	52,701 $\pm$ 20,824	44,976 $\pm$ 19,925	58,865 $\pm$ 19,517	.001
Index crime rate in area of residence (events per 1000 population) [†]	65 $\pm$ 55	83 $\pm$ 37	49 $\pm$ 63	.001
Charlson comorbidity index (mean $\pm$ SD)	1.4 $\pm$ 1.1	1.4 $\pm$ 1.1	1.5 $\pm$ 1.2	.725
Health care use in 2000-2001				
Mean $\pm$ SD no. of asthma-related outpatient visits per person	5.9 $\pm$ 4.8	5.6 $\pm$ 4.5	6.0 $\pm$ 5.1	.629
Mean $\pm$ SD no. of asthma-related emergency department visits per person	0.6 $\pm$ 1.4	0.9 $\pm$ 1.9	0.4 $\pm$ 0.9	.421
Mean $\pm$ SD no. of asthma-related hospitalizations per person	0.3 $\pm$ 1.0	0.5 $\pm$ 1.3	0.1 $\pm$ 0.3	.055
Average copay amount for corticosteroid inhaler (\$)	4.5 $\pm$ 4.5	3.7 $\pm$ 3.2	5.3 $\pm$ 5.3	.098
Mean $\pm$ SD no. of oral steroid fills per person	2.4 $\pm$ 3.6	2.7 $\pm$ 3.5	2.3 $\pm$ 3.6	.485
Mean $\pm$ SD no. of days of oral steroid use per person	32.3 $\pm$ 68.7	32.1 $\pm$ 56.7	32.4 $\pm$ 77.3	.585
Mean $\pm$ SD no. of β -agonist fills per person	13.4 $\pm$ 10.8	11.8 $\pm$ 10.2	14.8 $\pm$ 11.1	.060
Mean $\pm$ SD no. of ICS fills per person	7.5 $\pm$ 5.7	5.8 $\pm$ 3.9	9.0 $\pm$ 6.6	.004
Mean $\pm$ SD no. of prescribed ICS fills per person	18.3 $\pm$ 12.8	18.5 $\pm$ 15.8	18.1 $\pm$ 10.0	.635
Adherence to ICSs	0.50 $\pm$ 0.37	0.40 $\pm$ 0.26	0.58 $\pm$ 0.42	.002

*For the comparison of African American patients with white patients.

[†]Index crime rate for the year 2001. The index crime rate is calculated as the sum total of criminal homicides, forcible rapes, robberies, aggravated assaults, burglaries, larcenies-thefts, and motor vehicle thefts for a city or precinct divided by the population size.

of residence. Because we could not adjust for all SES variables simultaneously because of limited sample size, we examined measures of SES separately to see whether each diminished the relationship between crime and ICS adherence. Coefficient values from these linear regression models were direct estimates of the absolute percentage change in adherence. Statistical analyses were performed with SAS version 8.0 (SAS Institute Inc, Cary, NC).¹⁹

RESULTS

Study population

Four hundred sixty-one adults met our inclusion criteria in that they were given diagnoses of asthma in 1999, were continuously enrolled in the HMO for the subsequent 2 years, had both medical and pharmacy benefits in 2000 and 2001, and had their care provided by a medical group physician. We excluded 56 patients because they had concomitant diagnoses that could have been mistaken for asthma (ie, chronic obstructive pulmonary disease or congestive heart failure). Of the remaining 405 patients, medication adherence could be calculated for 176 patients by virtue of these patients having at least 2 fills of an ICS in the years of 2000 and 2001. We have previously shown that individuals with adherence information had greater use of β -agonist inhalers, greater use of oral corticosteroids, and more frequent asthma-related hospitalizations when compared with those without adherence information (ie, those with <2 fills of an ICS in the years 2000 and 2001).¹ For this article, we limit our discussion to just African American patients (n = 75) and white patients

(n = 94) because only 7 (4%) of the study individuals were of another race-ethnicity.

Table I presents the characteristics of these remaining 169 individuals stratified by race. Adherence to ICSs was 50% overall; however, African American patients had lower ICS adherence when compared with white patients (40% vs 58%, respectively; $P = .002$). Although African American patients had significantly lower ICS prescription fills ($P = .004$), the number of prescribed ICS canisters was not significantly different between African American patients and white patients (18.5 vs 18.1, respectively; $P = .635$). African American patients and white patients also differed significantly in their median household income (\$44,976 vs \$58,865, respectively) and in the index crime rate in their area of residence (83 events per 1000 population vs 49 events per 1000 population, respectively). Fifty-two (69.3%) of the 75 African American patients resided within Detroit city proper (referred to here as “urban”), and the remaining 23 (30.7%) lived in the surrounding Detroit CMSA (referred to here as the “suburbs” or “suburban”). In contrast, only 7 (7.4%) of the 94 white patients lived within urban Detroit; 86 (91.5%) lived in the surrounding Detroit suburbs, and 1 (1.1%) lived outside the Detroit CMSA.

Difference in ICS adherence by race-ethnicity

Differences in median household income could not fully account for difference in ICS adherence by race-ethnicity (Fig 1). ICS adherence among African American patients was lower at all income tertiles when compared with that

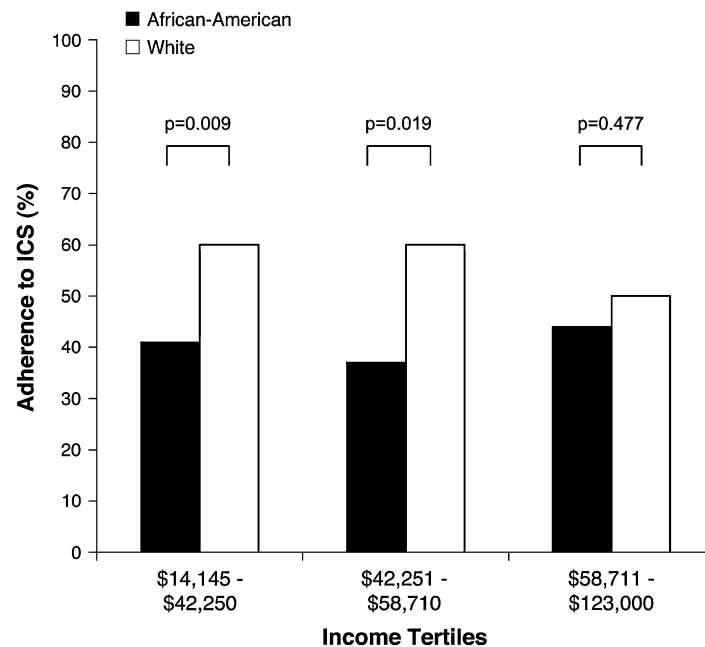


FIG 1. Differences in adherence to ICSs between African American patients and white patients stratified by tertiles of household income.

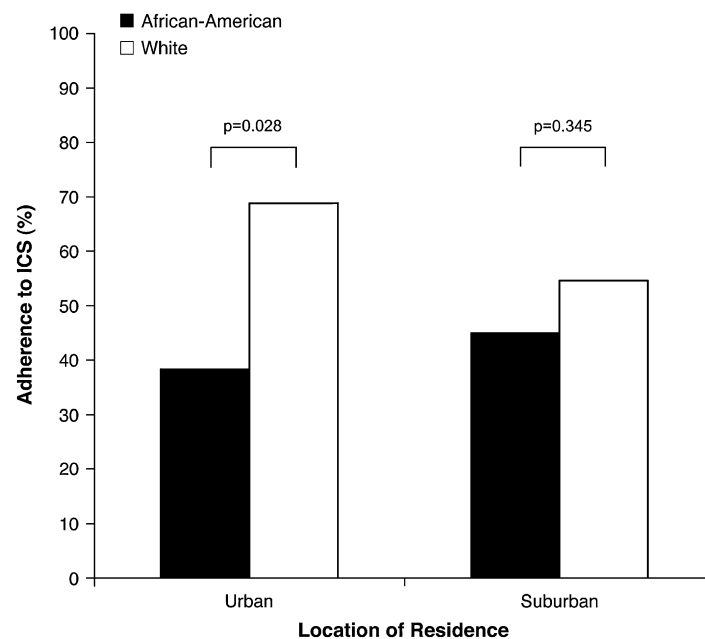


FIG 2. Differences in adherence to ICSs between African American patients and white patients stratified by location of residence.

of white patients, although this difference did not reach statistical significance at the highest income tertile. Similarly, location of residence, categorized as urban or suburban, could not fully explain the differences in ICS adherence by race (Fig 2). Adherence to inhaled steroids was higher for white patients when compared with that for African American patients for those residing in both Detroit and the surrounding suburbs, although differences

only reached statistical significance for those residing in urban Detroit.

The adjusted relationships between sociodemographic characteristics (ie, age, sex, race, and income), medication expenses, existing comorbidities, and residential factors (ie, crime) and adherence to ICSs are shown in Table II. These models show the percentage change in adherence per increase in each of the listed factors; positive values

TABLE II. Adjusted analysis of factors associated with adherence to ICSs*

Variable	All patients		African American patients		White patients	
	Change in adherence ± SE (%)†	P value	Change in adherence ± SE (%)†	P value	Change in adherence ± SE (%)†	P value
Age‡	4.1 ± 4.0	.307	9.3 ± 4.3	.034	−2.2 ± 6.3	.728
Female sex	−12.5 ± 6.4	.051	1.9 ± 6.8	.778	−28.6 ± 10.4	.008
African American race§	−20.8 ± 6.6	.002	—	—	—	—
Median household income	−19.7 ± 19.3	.311	−11.2 ± 19.1	.561	−46.2 ± 34.9	.191
Average copay amount for corticosteroid inhaler	−3.4 ± 9.5	.723	8.6 ± 12.0	.477	−12.5 ± 13.7	.368
Charlson comorbidity index	−2.5 ± 2.4	.285	0.3 ± 2.6	.918	−1.2 ± 3.8	.760
Index crime rate in area of residence	5.2 ± 10.9	.633	−27.3 ± 13.2	.042	23.9 ± 16.0	.140

*Adherence is measured as a continuous multiple interval of measure of medication availability, which is equal to the cumulative days' supply of inhaled steroids divided by the total number of days between refills for the time period from January 1, 2000, through December 31, 2001.

†Adjusted for all other variables listed.

‡Per 10-year increase.

§Compared with white patients.

||Values are log₁₀ transformed. Therefore changes in adherence represent the change per 10-fold increase in these variables.

correspond to an increase in adherence, and negative values correspond to a decrease. Only race-ethnicity remained significantly associated with ICS adherence after adjusting for the other variables listed ($P = .002$); differences by sex were of borderline statistical significance ($P = .051$). Adherence to ICS medication was estimated to be 20.8% lower for African American patients when compared with that of white patients after accounting for age, household income, average ICS copay amount, existing comorbidities, and the crime rate in the area of residence. Differences in ICS adherence by race-ethnicity were essentially unchanged by separately substituting other residential socioeconomic variables for median household income; these other variables included percentage of area residents with less than a high school education, percentage of residents living below the federal poverty level, proportion of owner-occupied homes in the area of residence, and proportion of residences vacant (data not shown).

Factors specific for ICS adherence among African American patients and white patients

Because predictors of ICS adherence might differ for African American patients and white patients, we looked for interactions between the factors listed in Table II and race-ethnicity. We observed a statistically significant interaction between race-ethnicity and crime ($P = .006$), suggesting that the effect of crime on ICS adherence differed between African American patients and white patients. The other factors, including household income, did not show a significant interaction with race-ethnicity on ICS adherence. However, because of the significant interaction between crime and race-ethnicity, we repeated the analyses for African American patients and white patients separately (Table II). Among African American patients, adherence to ICS medication was positively associated with age (9.3% increase in adherence per 10-year increase in age, $P = .034$) but negatively associated with the crime rate in the area of residence (27.3%

decrease in adherence per 10-fold increase in the crime rate, $P = .042$). Entering and removing household income from this model did not substantively alter the relationship between crime rate and adherence, suggesting that crime was not confounded by median household income; we also did not observe a significant interaction between crime rate and household income (data not shown). Separating the area crime rate into violent crimes (ie, criminal homicide, forcible rape, robbery, and aggravated assault) and property crimes (ie, burglary, larceny-theft, and motor vehicle theft) showed that both were associated with adherence in African American patients (see Tables E1 and E2 in the Online Repository at www.jacionline.org). Among white patients, adherence was significantly lower for women when compared with men (−28.6%, $P = .008$).

In African American patients the crime rate in the area of residence was consistently associated with ICS adherence after separately adjusting for other SES variables (Table III). A 10-fold increase in the crime rate was associated with a −26.3% change ($P = .037$) in ICS adherence after adjusting for the percentage of area residents with less than a high school degree (model 1), a −26.5% change ($P = .085$) in ICS adherence after adjusting for the percentage living below the federal poverty level (model 2), a −23.4% change ($P = .059$) in ICS adherence after adjusting for the proportion of owner-occupied homes in the area of residence (model 3), and a −25.0% change ($P = .037$) in ICS adherence after adjusting for the proportion of residences vacant (model 4). None of these other SES variables were independently associated with ICS adherence after adjusting for area crime rates. Together, these findings suggest that among African American patients in our study, area crime rate was a strong and independent predictor of ICS adherence.

Because of general differences in location of residence (ie, urban vs suburban) between African American and white patients in this study, we examined whether the

TABLE III. Adjusted analysis of factors associated with adherence to ICSs among African American patients*

	Model 1		Model 2		Model 3		Model 4	
	Change in adherence ± SE (%)	P value	Change in adherence ± SE (%)	P value	Change in adherence ± SE (%)	P value	Change in adherence ± SE (%)	P value
Age†	9.1 ± 4.3	.039	9.4 ± 4.4	.035	9.1 ± 4.4	.040	9.0 ± 4.3	.039
Female sex	2.1 ± 6.7	.762	2.2 ± 6.8	.751	2.5 ± 6.7	.717	2.7 ± 6.7	.691
Average copay amount for corticosteroid inhaler‡	9.2 ± 11.9	.441	9.4 ± 11.9	.436	9.4 ± 12.0	.435	9.6 ± 11.9	.422
Charlson comorbidity index	0.3 ± 2.6	.914	0.2 ± 2.6	.950	0.2 ± 2.7	.945	0.1 ± 2.6	.976
Index crime rate in area of residence‡	−26.3 ± 12.3	.037	−26.5 ± 15.2	.085	−23.4 ± 12.2	.059	−25.0 ± 11.7	.037
Percentage of area residents with less than high school education‡	7.4 ± 12.2	.545	—	—	—	—	—	—
Percentage of area residents living below the federal poverty level‡	—	—	2.7 ± 8.8	.763	—	—	—	—
Proportion of homes that are owner occupied in area of residence‡	—	—	—	—	0.4 ± 11.6	.972	—	—
Proportion of residences vacant in area of residence‡	—	—	—	—	—	—	3.5 ± 6.1	.561

*Adherence is measured as a continuous multiple interval of measure of medication availability, which is equal to the cumulative days' supply of inhaled steroids divided by the total number of days between refills for the time period from January 1, 2000, through December 31, 2001. Models are adjusted for all other variables listed.

†Per 10-year increase.

‡Values are log₁₀ transformed. Therefore changes in adherence represent the change per 10-fold increase in these variables.

association between crime and adherence reflected location of residence. Including a variable for location of residence in the multivariable model did not alter the magnitude of the crime variable (see Table E3 in the Online Repository at www.jacionline.org). Moreover, this variable was not independently associated with adherence (see Tables E3 and E4 in the Online Repository at www.jacionline.org).

DISCUSSION

In this study poor adherence to ICSs was pervasive and did not appear to be limited to any one particular group. However, despite poor overall ICS adherence, we did observe differences in adherence by race-ethnicity, with African American patients having lower levels when compared with white patients.

As others have observed,¹³ we found race-ethnicity to be persistently associated with adherence, even after adjusting for many other factors, such as demographic differences, socioeconomic and residential factors, pharmaceutical costs, and existing comorbidities. However, within race-ethnic groups we found different factors associated with ICS adherence. Among African American patients, age and residential crime rates were positively and negatively associated with ICS adherence, respectively. In contrast, among white patients, women were less likely to be adherent to inhaled steroids when compared with men. Although age and sex have been previously associated

with medication adherence,^{5,20,21} to our knowledge, this is the first study to demonstrate a significant relationship between crime rates and ICS adherence.

In a study by Wright et al¹⁶ of children with asthma residing in the inner city, increasing exposure to neighborhood violence was positively associated with asthma symptom days. This relationship was not substantively affected by adjusting for other sociodemographic factors, which included household income, caretaker education, and race-ethnicity. However, caretaker-reported skipping of medications did attenuate the relationship between violence exposure and symptom days. In other words, the relationship between exposure to violence and increasing asthma symptoms was probably mediated in part by poorer medication adherence in those so exposed.

This study suggests that among African American patients, residential crime rates might be a stronger predictor of ICS adherence than other socioeconomic factors. Because socioeconomic measures are not necessarily interchangeable,²² we adjusted our models using multiple measures of SES derived from census data. These measures included median household income and percentage living below the federal poverty level for income, percentage of high school graduates in area of residence for education, percentage of area owner-occupied homes for wealth, and other neighborhood characteristics, such as the percentage of residences vacant. Despite adjusting for these variables, area crime rate remained a consistent predictor of ICS adherence. According to Taylor et al,¹⁵ SES and race might provide the context

for understanding the more proximal effects of environment on health. Therefore the relationship between area crime rates and adherence suggests that crime explains a component of the environment that is relevant to health behavior but that is not readily captured by more typical measures of SES.

Residing in a high crime area might result in chronic stress, which in turn results in perceptions of helplessness and a lack of control over one's health.^{14,15} However, when present, strong social or community support might mitigate this stress.²³ Both locus of control (ie, perception of control over one's health) and social support have been associated with adherence to prescribed therapies,²⁴⁻²⁶ and therefore both might mediate or modify the relationship between exposure to crime and ICS adherence. Because Detroit is one of the most segregated cities in the United States,^{27,28} with African American patients comprising 77% of the city's population but only 7% of the surrounding population,²⁷ it is tempting to speculate that African American patients and white patients have different levels of social support, depending on their area of residence. Yet the relationship between crime and adherence was similar after adjusting for location of residence, and location of residence (ie, urban vs suburban) itself did not appear to be an independent predictor of adherence. Therefore these broad categories of residence did not explain the observed differences between exposure to crime and medication adherence among African American patients and white patients. However, it is still possible that more local measures of social or community support could account for these differences. In addition, it is possible that we had insufficient power to detect a relationship between crime and adherence in white patients because of lower overall crime exposure.

It is also important to note that although we saw differences in the number of ICS prescriptions filled between African American patients and white patients, we did not observe differences in the number of ICS inhalers prescribed. Although this suggests that providers were not biased in the prescribing of these controller medications, we cannot comment on the appropriateness of ICS use. It is possible that the number of ICS inhalers prescribed was inappropriately low for the severity of the underlying asthma. We also cannot exclude the possibility that other elements of the patient-provider relationship contributed to the differences in ICS adherence by race-ethnicity. Characteristics of the patient-provider relationship that have been associated with anti-inflammatory medication use include the patients' ease in communicating with their clinicians,¹⁰ the providers' willingness to listen and spend time with their patients,^{21,29} and the level of concern shown by the providers.³⁰ Physicians' perceptions of and affiliations with patients might differ by race,³¹ and how this contributes to differences in patient adherence deserves further study.

This study must be interpreted in light of its limitations. First, the study population consisted of patients with health insurance and pharmaceutical coverage. Although

possession of commercial insurance has been strongly associated with ICS adherence,¹³ we still observed differences in adherence and the factors predicting adherence by race-ethnicity.

Second, socioeconomic variables were derived from census data and therefore might be more reflective of the environment in which our study subjects lived than individual characteristics. This might have resulted in us underestimating the effect of individual income, education, and wealth on adherence but does not detract from our conclusion that crime appears to be a relevant environmental exposure. Being an observational study, we could not discern whether the effect of crime on adherence was mediated by being a victim or witness of crime, through the stress associated with living in high crime areas, or through some other environmental exposure associated with crime rates. However, we can say that crime did not appear to be a proxy for other SES measures examined. Because we did not have detailed information on underlying asthma severity, we cannot exclude the possibility that differences in adherence were the result of less severe asthma and hence less perceived ICS need among African American patients. However, we did not see significant differences in the patterns of health care use, such as asthma-related emergency department visits, hospitalizations, β -agonist use, or oral steroid use, to suggest that this was the case.

Lastly, we used pharmacy claims data to estimate adherence. Claims-based estimates of adherence have their limitations, such as their inability to assess either patterns of daily ICS use or appropriate inhaler technique. Yet to our knowledge, these adherence measures are the only ones shown to be predictive of multiple asthma outcomes associated with poor disease control.¹

In conclusion, we found differences in adherence to ICS by race-ethnicity. These differences could not be completely explained by any of the variables that we examined. However, given the multiple behavioral, social, and economic factors that contribute to ICS adherence,³² it is highly unlikely that any single factor will explain these differences. Among African American patients, however, we did find that area crime rates were negatively associated with ICS adherence and that this residential exposure was a stronger predictor of prescribed use than other measures of SES examined. This suggests that environmental factors beyond those typically associated with SES contribute to medication adherence. Differences in the relationship between crime exposure and adherence among African American patients and white patients suggest effect modification by additional unmeasured factors, which should be the subject of further research. Given the overall disappointing results of interventions to improve adherence to date,³³⁻³⁵ it is important to more fully understand the social and environmental barriers that transcend issues of access and knowledge; this article represents a step in that direction.

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