Longitudinal Patterns of Mexican and Puerto Rican Children's Asthma Controller Medication Adherence and Acute Healthcare Use

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Abstract

Rationale: Researchers tend to study Latinos as a single group, but recent asthma research confirmed differences among Latino subgroups. Variations in controller medication adherence may be a factor in the observed health disparities between Mexican and Puerto Rican children. Adherence is not a stable phenomenon; however, there is a paucity of data on patterns of adherence, sociodemographic predictors of patterns, and variations in asthma-related acute healthcare use by adherence pattern among Latino subgroups.

Objectives: To identify patterns of inhaled corticosteroid medication adherence over 12 months among Mexican and Puerto Rican children with persistent asthma, to examine sociodemographic predictors of adherence patterns by ethnicity, and to investigate asthma-related acute healthcare use based on these patterns.

Methods: We analyzed controller medication Doser data from Mexican and Puerto Rican children ($n = 123$; ages 5–12 yr) with persistent asthma who participated with their caregivers in a longitudinal nonintervention study (Phoenix, AZ, and Bronx, NY). Interview and medical record data were collected at enrollment and at 3, 6, 9, and 12 months after enrollment.

Results: Forty-seven to fifty-three percent of children had poor adherence (<50%) over each of the follow-up periods (cross-sectional). Children with lowest adherence were Puerto

Rican, from nonpoor families, or female. Longitudinal latent class analysis yielded four adherence classes: poor, moderate, decreasing adherence, and increasing adherence. Puerto Rican children had significantly higher odds of “decreasing” (odds ratio [OR], 2.86; 95% confidence interval [CI], 0.40 to 20.50) and “poor” (OR, 5.62; 95% CI, 1.44 to 21.90) adherence than Mexican children. Females had significantly greater odds of “decreasing” (OR, 4.80; 95% CI, 0.73 to 31.74) and “poor” (OR, 5.20; 95% CI, 1.77 to 15.30) adherence group membership than males. The “decreasing” adherence group was comprised of only poor children. Children in the “poor” adherence class had the highest mean number of acute visits and emergency department visits/hospitalizations across all assessment periods.

Conclusions: This study demonstrated that unique ethnicity within Latino populations may be associated with different risk levels for suboptimal controller medication adherence, which may be a factor in the observed asthma health disparities between Mexican and Puerto Rican children. Increased understanding of and attention to children's controller medication adherence patterns will provide evidence needed to identify children at highest risk for acute healthcare use and offer more-intensive intervention using less-intensive approaches for those at low risk.

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Keywords: medication adherence; asthma; healthcare disparities

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Despite evidence-based guidelines for asthma management and control (1), low asthma controller medication adherence in children persists, with minority children at greater risk of nonadherence and poor outcomes than nonminority children (2–6). Adherence to controller medications is critical and can significantly reduce exacerbations and improve asthma control (2, 7, 8). Researchers have tended to study Latinos as a single group, but recent descriptive asthma research has confirmed significant heterogeneity among Latino subgroups (particularly between Mexicans and Puerto Ricans) regarding prevalence, mortality and morbidity, illness beliefs, and asthma healthcare practices (9–13). Puerto Rican children exhibit the highest rates of asthma prevalence and mortality among all ethnic groups, whereas Mexican children have the lowest rates (9, 12). Genetic, environmental, healthcare system, and provider factors (13–15) cannot totally explain the differences between these two groups.

There is growing evidence on factors leading to nonadherence and interventions focused on improving adherence. Although an evidence-based cutoff value for good adherence (16) has not been established, rates greater than 80% are traditionally considered acceptable (16, 17). The majority of adherence interventions primarily target children with controller medication adherence less than 80%, assuming that children with greater than 80% adherence at initial assessment will remain adherent. There is evidence that adherence is not a stable phenomenon (17–20), although there is a paucity of data on patterns of adherence among individuals with asthma and none within subgroups of Latino children (21). Souverein and colleagues (17) examined longitudinal patterns of inhaled corticosteroid (ICS) medication initiation (21) among a sample of long-term care patients ($N = 13,922$). The results identified periods of nonadherence alternating with periods of regular ICS use. Laforest and colleagues (20) examined ICS adherence over 12 months among children and adults selectively recruited for high initial

adherence. The investigators noted fragmented episodes of ICS use that typically lasted several months, even though all individuals were adherent at baseline (20). A better understanding of controller medication adherence patterns in children will provide evidence needed to identify individuals at highest risk for nonadherence and acute healthcare use and offer a more-intensive intervention while using less-intensive approaches for those at low risk, preventing waste of precious healthcare resources.

A literature review revealed no studies directly examining controller medication adherence between Mexican and Puerto Rican children; thus, these analyses fill a critical gap in knowledge and offer insights into factors leading to asthma health disparities between these Latino subgroups. The objectives of these secondary analyses were to 1) identify patterns of children's ICS medication adherence over a 12-month assessment period in a sample of Mexican and Puerto Rican children with persistent asthma, 2) examine sociodemographic and seasonal predictors of adherence patterns, and 3) investigate asthma-related acute healthcare use based on these patterns. To the best of our knowledge, this is the first study to examine objectively measured longitudinal patterns of ICS medication adherence in children, explore heterogeneity in adherence patterns within a sample of Latino children, and link those patterns to clinical outcomes.

Methods

We analyzed ICS medication data from a sample of Mexican and Puerto Rican children (ages 5–12 yr) with persistent asthma requiring daily controller medications who participated with their caregivers in a longitudinal nonintervention study (Phoenix, AZ, and Bronx, NY). The main study tested an explanatory, integrated multifactorial model investigating the interaction of individual characteristics, cultural and experiential and healthcare system factors, and social-environmental context that lead to disparities between these

two Latino subgroups. Children and caregivers were recruited from two school-based health clinics and the Breathmobile in Phoenix, Arizona, and two inner-city hospital asthma clinics in Bronx, New York. A total of 267 child-caregiver dyads were enrolled in the main study. Structured interviews were administered to caregivers and shorter interviews and spirometry assessments conducted with children at enrollment and 3, 6, 9, and 12 months after enrollment. A retrospective review of children's medical records was completed. Objective measures of children's ICS medication adherence were assessed by Doser devices (MediTrack Products) attached to the top of the ICS canister at baseline. Data were downloaded at each follow-up visit, yielding 12 months of adherence measures. Owing to differences in treatment regimen adherence between inhaled and oral and combination ICS/long-acting β_2 -agonist controller medications, all children with use of oral and/or combination ICS/long-acting β_2 -agonist medications were excluded ($n = 73$) from these analyses. Two children had no record of controller or quick-relief medication prescriptions. We had Doser data on a subsample of 123 of 192 children (64.1%) prescribed ICS. The study was approved by the institutional review boards of Arizona State University, Phoenix Children's Hospital, Scottsdale Healthcare, and Albert Einstein College of Medicine.

Sociodemographic Characteristics

All enrolled participants self-identified as Mexican or Puerto Rican. We obtained each child's sex, age, and asthma duration (number of months since diagnosis); each family's perception of poverty; each caregiver's marital status and education; and the season in which the interview was conducted. Owing to the sociolegal climate in Phoenix, we did not ask for annual income, demonstrating sensitivity to the challenges these families were facing. To assess caregivers' perceptions of poverty, a measure adapted by Gore and colleagues (22) asked, "What best describes your family's standard of living?"

Response choices ranged from 1 = very well off to 6 = poor and was dichotomized as poor = nearly poor or poor. All enrolled children–caregiver dyads were Medicaid/Medicaid-eligible and received their asthma medications free of charge from the participating clinics.

Seasonality

Using each interview date, we recorded the season in which baseline and follow-up interviews were conducted, adherence data were captured, and acute asthma-related healthcare use occurred. Seasons were defined as spring = March–May; summer = June–August; fall = September–November; and winter = December–February.

Clinician-rated Asthma Severity

Clinician ratings of children's asthma severity were conducted per clinical guidelines (1). The ratings were based on clinicians' assessment of impairment given the caregivers' and children's responses to structured questions regarding daytime and nocturnal symptoms, activity limitations, short-acting β_2 -agonist use for the 2–4-week period before the interview, spirometry, and risk of adverse events. All ratings were completed by pediatric pulmonologists.

Adherence

Doser devices were attached to the child's ICS canister at the baseline visit. Doser data were downloaded at each assessment period (M3 = baseline to month 3; M6 = month 3 to month 6; M9 = month 6 to month 9; and M12 = month 9 to month 12), yielding 12 months of adherence data. The Doser devices recorded the number of actuations each day for the prior 30 days. For medications for which we could not attach the Doser because of built-in counters, we captured the counter data at each visit. Adherence data were cleaned per procedures outlined by McQuaid and colleagues (23). Adherence was calculated as the number of doses taken per day divided by the prescribed doses per day, multiplied by 100. Daily adherence was truncated to 100% to account for accidental actuations (e.g., bumping inside a backpack) or intentional actuations due to trying to make up for doses missed on the previous day. Average adherence and adherence categories were created (<50% = poor; 50–80% = moderate; >80% = good) at each time period (24).

Acute Healthcare Use

Children's medical records from the recruitment site were reviewed for 12 months before enrollment and for the 12-month study period to obtain counts of acute and emergency department (ED) asthma visits and hospitalizations. Asthma-related ED visits and hospitalizations were combined because of their low frequency. Because asthma-related healthcare visits may have occurred outside the child's medical home, caregiver reports were checked against the medical record based on visit date (± 1 mo to account for recall errors). In cases in which the medical record and caregiver dates were congruent, medical record data were used. When there was a caregiver report but no medical record visit for that date, caregiver report was used. If a visit was recorded in the medical record but not reported by the caregiver, medical record data were used.

Statistical Analyses

Only data for children prescribed an ICS medication and who had at least two adherence data points were analyzed. Cross-sectional descriptive chi-square analyses examined adherence by ethnicity, child sex and age, poverty, and season. Structural equation modeling and longitudinal latent class analysis (LLCA) explored patterns of adherence over time and acute healthcare use by adherence class. The LLCA also examined sociodemographic characteristics (ethnicity; marital status; poverty; caregiver education; child's age, sex, and asthma duration; and number of family members with asthma) to identify predictors of class membership. Interaction effects for ethnicity with caregiver marital status, education, poverty, and child sex were examined. Reference groups were Puerto Rican, female, nonpoor, summer, and "moderate" adherence group. Model selection was based on the log likelihood, Bayesian information criterion, and entropy. Models specifying two, three, and four classes were run, and fit statistics were compared to determine the best-fitting model (25, 26). Statistical significance was set at $P < 0.10$, the convention for structural equation modeling and LLCA.

Results

A total of 267 child–caregiver dyads enrolled and completed baseline measures and

assessments. We had adherence data for 123 of 192 children prescribed noncombination ICS medications (64.1%). Analyses were conducted (data not shown) to examine whether children who were missing adherence data were different from those who had adherence data based on ethnicity; recruitment site; number of family members with asthma; caregivers' marital status, education, perception of poverty, reported use of controller medication in the past month, age, and sex; and child's sex, age, and asthma duration and severity. Children who were missing adherence data were more likely not to have used controller medications in the past month, had mild or severe persistent asthma, and had caregivers who were older and high school graduates. There were no differences by ethnicity.

Table 1 presents the sample characteristics by ethnic group. Puerto Rican caregivers were less likely to be married or poor and more likely to have graduated from high school. Puerto Rican children were younger, had higher clinician ratings of severe persistent asthma, and had lower likelihood of caregiver-reported controller medication use in the past month than Mexican children.

Cross-Sectional Analyses

Figure 1 illustrates cross-sectional adherence by time. Good adherence (>80%) at each time period was low (14–23%), with the largest proportion of children demonstrating poor adherence (47–53%). Puerto Rican children had the highest proportion of poor adherence at each time period (63–80%) compared with Mexican children (40–49%) (see Figure E1A in the online supplement). Although a higher proportion of Mexican (19–23%) than Puerto Rican children (0–21%) had good adherence, overall, these proportions are quite low. Because all of the Puerto Rican children were enrolled at the Bronx hospital clinics, we conducted additional analyses to investigate whether adherence differences were due to ethnicity or to clinic setting. A subgroup analysis was conducted comparing adherence for Mexican and Puerto Rican children enrolled at the Bronx hospital clinic sites. More Puerto Rican children in the hospital clinics had poor adherence at every time period (71–80%) compared with Mexican children from the same clinic (33–63%). In addition, we examined adherence by site to determine whether adherence was lowest at the

Table 1. Sample baseline characteristics (N = 123)

Variable	Mexican (n = 89)	Puerto Rican (n = 34)
Recruitment site, n (%)		
Hospital clinic (New York)	17 (19.10)	34 (100)
Breathmobile (Arizona)	61 (68.54)	0
School-based health center (Arizona)	11 (12.36)	0
Season of baseline interview, n (%)		
Summer	25 (28.09)	8 (23.53)
Fall	21 (23.60)	12 (35.29)
Winter	26 (29.21)	8 (23.53)
Spring	17 (19.10)	6 (17.65)
Child		
Child sex, % female	31 (34.8)	15 (44.1)
Clinician-rated asthma severity, n (%)		
Mild intermittent	9 (10.34)	3 (9.68)
Mild persistent	27 (31.03)	5 (16.13)
Moderate persistent	47 (54.02)	18 (58.06)
Severe persistent	4 (4.06)	5 (16.13)
Any controller medication use in the past month, % yes, n (%)	78 (87.64)	27 (79.41)
Study child's age, yr, mean (SD)	9.53 (2.14)	8.64 (1.97)
Asthma duration, mo since diagnosis, mean (SD)	68.28 (36.22)	82.21 (33.21)
% Adherent: month 3	47.51 (30.05)	35.65 (28.91)
% Adherent: month 6	53.47 (31.47)	35.44 (37.86)
% Adherent: month 9	51.27 (28.68)	29.94 (27.57)
% Adherent: month 12	53.09 (29.39)	26.41 (29.29)
Caregiver, n (%)		
Married, % yes	45 (50.56)	9 (26.47)
Poor, % yes	59 (66.29)	10 (29.41)
High school graduate, % yes	34 (38.20)	19 (55.88)
Sex, % female	85 (95.51)	32 (94.12)
Age, mean (SD)	34.57 (6.41)	36.00 (9.39)
Number of family members with asthma, mean (SD)	1.17 (0.73)	0.82 (1.11)

Definition of abbreviation: SD = standard deviation.

hospital-based clinics in the Bronx compared with the other sites. The school-based health centers in Phoenix actually had the lowest adherence across all assessment periods (range, 10–31%) followed by the

hospital-based clinics (range, 34–38%), with the Breathmobile consistently having the highest adherence (range, 50–56%). These findings support our conclusion of ethnic differences unrelated to clinic site. Good

Figure 1. Categorical cross-sectional adherence.

adherence was low for both sexes, ranging from 5% to 23% (see Figure E1B). Across all time periods, females demonstrated the highest proportions of poor adherence (55–77%). At M3 and M6, more nonpoor children than poor children demonstrated poor adherence. These differences dissipated over time (see Figure E2A). There were no seasonal differences in adherence at any time period (see Figure E2B). Similar adherence proportions were observed for younger and older children, with the majority having poor adherence across all time periods (data not shown).

LLCA

We tested two-, three-, and four-class models examining adherence patterns from baseline through 12 months. Multiple imputation was used to impute missing data for the 123 children who had adherence data for at least two time periods. The LLCA revealed that the four-class solution was the best of the three models tested. These classes of adherence are poor (47%), moderate (31%), decreasing adherence (good or moderate adherence transitioning to poor adherence) (7%), and increasing adherence (poor adherence shifting to moderate or good adherence) (15%) (Figure 2). Table 2 presents the results for significant predictors of adherence class membership: ethnicity, child sex, and poverty. No differences were observed for marital status, caregiver's education level, child's age, asthma duration, or number of family members with asthma. Puerto Rican children had significantly higher odds than Mexican children of being in the "decreasing" and "poor" adherence groups. Females had significantly greater odds than males of being in the "decreasing" and "poor" adherence groups; no females were in the "improving" adherence class. The "decreasing" adherence class was comprised of only poor children, and these children also had lower odds of being in the "improving" adherence class. No interaction effects of ethnicity with caregiver marital status, education, poverty, or child sex were observed (data not shown).

Differences in asthma-related healthcare use (i.e., acute care visits and ED visits/hospitalizations) were examined by adherence class and modeled by assessment period across 12 months. These results are presented as forest plots (Figures 3 and 4, respectively) in which the x-axis represents the mean difference and I^2 is a measure of

Figure 2. Longitudinal latent class analysis: four-class solution.

heterogeneity between the groups. For these analyses, $I^2 > 50\%$ is considered statistically significant. Because of small class sizes and low frequency of healthcare visits, we examined effect sizes to ascertain clinically

meaningful (effect size, ≥ 0.20) differences between classes for acute care visits and ED visits/hospitalizations in addition to statistically significant differences. For acute visits, statistically significant heterogeneity

was observed among the different adherence classes (excluding month 9), as evidenced by I^2 values ranging from 63% to 78%. With the exception of month 9, small to moderate clinically meaningful differences were also noted over time (effect sizes ranging from 0.22 to 0.55), although there was no discernible pattern to these differences. Figure E3A plots the mean number of acute visits at each assessment period by adherence class. The “moderate” adherence class had the lowest acute visits through M9 but demonstrated a large increase from M9 to M12. The “decreasing” adherence class initially had the highest acute visits, which decreased through M9 and plateaued at M12. At M3, the “increasing” adherence class had low acute visits, which peaked at M6 and then declined through M9 and M12. With the exception of M9, the “poor” adherence class had the highest acute visits.

A different pattern emerged for ED visits/hospitalizations. Statistically significant heterogeneity between adherence classes was observed only at month 6 and month 9 ($I^2 = 80\%$ and 73% , respectively). However, only the difference between the poor and moderate adherence classes was clinically meaningful (effect size, 0.23). At M3, all four classes had equivalent ED visits/hospitalizations. At M6, the “poor” adherence class had significantly greater ED visits/hospitalizations than the remaining classes, a finding that held across M9 and M12 (Figure E3B). The “moderate” adherence class had the lowest ED visits/hospitalizations at M6 but demonstrated steadily increasing visits through M9 and M12. The “increasing” adherence class exhibited steady declines in ED visits/hospitalizations from baseline through M9, which then dramatically increased at M12. The “decreasing” adherence class had relatively stable ED visits/hospitalizations across the 12-month assessment period. Examination of the between-class differences revealed clinically meaningful differences for almost all contrasts (excluding M6 increasing vs. decreasing adherence and M12 increasing vs. poor adherence) from M3 through M12.

Table 2. Sociodemographic predictors of controller medication adherence class membership

Variable	Model χ^2	OR (95% CI)
Ethnicity	9.15	
Improving adherence		Referent*
Mexican		0.73 (0.05–11.86)
Puerto Rican		Referent*
Decreasing adherence		2.86 (0.40–20.50)
Mexican		Referent*
Puerto Rican		5.62 (1.44–21.90)
Poor adherence		Referent*
Mexican		5.62 (1.44–21.90)
Puerto Rican		Referent*
Child sex	85.07	
Improving adherence		Referent*
Male		0
Female		Referent*
Decreasing adherence		4.80 (0.73–31.74)
Male		Referent*
Female		5.20 (1.77–15.30)
Poor adherence		Referent*
Male		0
Female		Referent*
Poverty	99.49	
Improving adherence		Referent*
Nonpoor		0.41 (0.07–2.34)
Poor		Referent*
Decreasing adherence		0
Nonpoor		Referent*
Poor		0.74 (0.25–2.13)
Poor adherence		Referent*
Nonpoor		0.74 (0.25–2.13)
Poor		Referent*

Definition of abbreviations: CI = confidence interval; OR = odds ratio.

*Moderate adherence is the referent group.

Discussion

These results add to emerging evidence on patterns of ICS medication adherence in

Figure 3. Forest plot of longitudinal acute healthcare visits, by adherence class. CI = confidence interval; D+L = DerSimonian and Laird (random effects) model; ES = effect size; I-V = inverse variance weighted fixed effects model.

children. Notably, in our cross-sectional analyses, few children had adherence rates consistently above 80% and less than one-third were classified as having moderate adherence (50–80%). Our LLCA identified four classes of adherence, with the majority (78%) classified as poor or moderate. This

finding supports the tendency to focus interventions on individuals with adherence less than 80% using a risk–benefit approach. These results revealed that acute healthcare use differed by adherence class over time. Children in the “poor” adherence class had the highest use across the entire 12-month

period, but there was an unexplained drop in acute visits between M6 and M9 that was not explained by season. The “decreasing” adherence group had steadily declining acute visits and relatively stable ED visits/hospitalizations over the 12-month assessment period, which may be due to

Figure 4. Forest plot of longitudinal emergency department visits/hospitalizations, by adherence class. CI = confidence interval; D+L = DerSimonian and Laird (random effects) model; ED = emergency department; ES = effect size; I-V = inverse variance weighted fixed effects model.

caregivers stepping down therapy or stopping therapy when the child was asymptomatic for a period of time. Several studies have reported that caregivers have a strong desire for their children to be medication free and thus discontinue using

controller medications when the child no longer “has asthma” (27, 28). As we anticipated, children in the “moderate” adherence group also had the lowest number of acute visits through M9. An unexpected finding was a dramatic increase

in acute visits between M9 and M12, similar to what we observed for the poor adherence class. Again, this was not due to seasonal effects. When the “improving” adherence class emerged, given that this was not an intervention study, we hypothesized that

possibly an ED visit or hospitalization was the “trigger” for getting back on track with the prescribed regimen, and this group of caregivers intervened early enough to prevent ED visits and hospitalizations. There is some support for this, as evidenced by declining acute visits from M3 through M12 and slightly declining ED visits/hospitalizations through M9. However, this group had a substantial increase in ED visits/hospitalizations from M9 to M12 almost equaling the poor adherence class. Once more, this increase was not associated with season.

It is worth noting that evidence from prior research suggests that adherence in Latino children is strongly affected by children’s and caregivers’ symptom perceptions, which are not highly accurate (29–31), and differ between Puerto Rican and other Latino subgroups (32, 33); cultural beliefs about asthma and medication use (27, 28, 34); and other socioeconomic factors. This suggests the need for close clinical monitoring of ICS medication use and development of targeted interventions to address inaccurate symptom perception and suboptimal treatment patterns in this at-risk population. Given that pediatric adherence is heavily influenced by parental involvement, effective intervention may require tailoring to specific cultural needs at both adult (parent, grandparent) and child levels.

Our study also is the first study showing that unique ethnic identity within Latino populations may be associated with different risk levels and highlights the role of socioeconomic factors. We demonstrated that Puerto Rican children were at substantially greater risk of poor adherence than Mexican children and that poor adherence led to the highest acute healthcare use across time. This supports our notion that adherence patterns may be a factor in Latino children’s asthma health disparities. Our findings are pertinent in addressing the differences in asthma burden between Mexican and Puerto Rican children. Puerto

Rican children, on average, were half as adherent as Mexican children. Lack of adherence to ICS medications in our study highlights the role of these medications in the lack of bronchodilator responsiveness observed to a higher extent among Puerto Rican than among Mexican children (35). It is unsurprising that poverty adversely affects adherence. Lack of adherence to medications in poor families is likely multifactorial. For many of these families lacking sufficient resources, purchasing controller medications may be a lower priority when there are competing demands for limited resources. Although Puerto Ricans perceived themselves as less poor than Mexicans and all study children received their ICS medications for free, they had lower adherence, suggesting that factors other than poverty contributed to their lack of adherence. Higher asthma burden has been reported among female than among male children (4, 36), and our findings confirm that, with females exhibiting greater odds of decreasing and poor adherence. One explanation may be that as girls get older, there is social pressure to look and act a certain way, and using an inhaler may make them feel “different.”

Limitations

There are several important limitations. Objective measures of adherence were based on Doser tracking devices attached to the child’s ICS canister. The devices we used were capable of storing only the most recent 30 days of usage. Thus, we were unable to examine adherence continuously across the 12-month assessment period. Only 64% of the children had valid adherence data; thus, poor medication adherence may actually be underestimated because this subsample may represent those individuals who were reliable enough to bring the medications to the visits. In addition, several of the class sizes were small, and thus we may not have had adequate statistical power to assess longitudinal between-adherence-class differences. Last, we did not have pharmacy

fill/refill data to compute the medication possession ratio or controller/total medication ratio as additional measures of adherence.

Implications and Future Research

Our findings suggest that medication adherence is a major contributor to disease burden and acute healthcare use among urban Latino children. To the best of our knowledge, this is the first study to characterize longitudinal patterns of children’s asthma ICS medication adherence and to demonstrate differing risk levels for nonadherence based on ethnicity within the Latino population. Future research should further explore these patterns and risk factors among more heterogeneous Latino samples to inform targeted adherence intervention strategies. Health technology and wearable sensors that can seamlessly upload data through wireless connectivity and smartphone apps are transforming the ability to monitor adherence beyond simply counting device actuations to assessing inhaler technique and capturing clinically meaningful data such as exhaled nitrous oxide, cough rate, and respiration patterns (37). Given that a significant proportion of children did not have adherence data and that our Dosers could not continuously monitor adherence, future studies should incorporate these monitoring devices to more precisely examine the intra- and interperson variability longitudinally and minimize missing adherence data. This technology could support adherence interventions that can be tailored to different ethnic subgroups. ■

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