

# BMJ Open Role of social deprivation on asthma care quality among a cohort of children in US community health centres

Jennifer A Lucas ,<sup>1</sup> Miguel Marino,<sup>1,2</sup> Katie Fankhauser,<sup>1</sup> Andrew Bazemore,<sup>3</sup> Sophia Giebultowicz,<sup>4</sup> Stuart Cowburn,<sup>4</sup> Jorge Kaufmann,<sup>1</sup> David Ezekiel-Herrera,<sup>1</sup> John Heintzman<sup>1,4</sup>

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<sup>1</sup>Family Medicine, Oregon Health & Science University, Portland, Oregon, USA

<sup>2</sup>School of Public Health, Oregon Health & Science University, Portland, Oregon, USA

<sup>3</sup>American Board of Family Medicine, Lexington, Kentucky, USA

<sup>4</sup>OCHIN, Portland, Oregon, USA

## Correspondence to

Dr Jennifer A Lucas;  
[lucasje@ohsu.edu](mailto:lucasje@ohsu.edu)

## ABSTRACT

**Objective** Social deprivation is associated with worse asthma outcomes. The Social Deprivation Index is a composite measure of social determinants of health used to identify neighbourhood-level disadvantage in healthcare. Our objective was to determine if higher neighbourhood-level social deprivation is associated with documented asthma care quality measures among children treated at community health centres (CHCs).

**Methods (setting, participants, outcome measures)** We used data from CHCs in 15 states in the Accelerating Data Value Across a National Community Health Center Network (ADVANCE). The sample included 34 266 children with asthma from 2008 to 2017, aged 3–17 living in neighbourhoods with differing levels of social deprivation measured using quartiles of the Social Deprivation Index score. We conducted logistic regression to examine the odds of problem list documentation of asthma and asthma severity, and negative binomial regression for rates of albuterol, inhaled steroid and oral steroid prescription adjusted for patient-level covariates.

**Results** Children from the most deprived neighbourhoods had increased rates of albuterol (rate ratio (RR)=1.22, 95% CI 1.13 to 1.32) compared with those in the least deprived neighbourhoods, while the point estimate for inhaled steroids was higher, but fell just short of significance at the alpha=0.05 level (RR=1.16, 95% CI 0.99 to 1.34). We did not observe community-level differences in problem list documentation of asthma or asthma severity.

**Conclusions** Higher neighbourhood-level social deprivation was associated with more albuterol and inhaled steroid prescriptions among children with asthma, while problem list documentation of asthma and asthma severity varied little across neighbourhoods with differing deprivation scores. While the homogeneity of the CHC safety net setting studied may mitigate variation in diagnosis and documentation of asthma, enhanced clinician awareness of differences in community risk could help target paediatric patients at risk of lower quality asthma care.

## INTRODUCTION

Social determinants of health influence the quality of health outcomes and healthcare access for people with asthma.<sup>1–4</sup> Increased asthma morbidity has been associated with

## Strengths and limitations of this study

- This study uses electronic health record data from a multistate community health centre network linked with geocoded community-level data to examine the effect of neighbourhood social deprivation on asthma care quality.
- The Social Deprivation Index, a composite measure of 10 variables, was used to examine social deprivation among neighbourhoods.
- The data in this study were obtained from primary care clinics; therefore, we may have missed medication orders prescribed in the emergency department.
- We were not able to examine differences between specific Latino subgroups, as the data did not include subgroup information.

poor housing quality,<sup>1 5</sup> single-parent households<sup>6</sup> and low socioeconomic status,<sup>3 7</sup> all factors that contribute to social deprivation.<sup>8</sup>

The Social Deprivation Index (SDI) is a composite measure of neighbourhood-level social determinants of health, and can be used to measure disadvantages in healthcare access/outcomes across small geographical areas.<sup>9</sup> The SDI has been used to identify where at-risk patients are located and explains more variability in health outcomes than poverty alone.<sup>9 10</sup> Social deprivation has been linked to worse asthma outcomes and increased hospitalisation,<sup>7 11–14</sup> yet these associations have not been studied at the patient level in the USA using geographically widespread longitudinal electronic health record (EHR) data linked in the context of community data. Community health centres (CHCs) receive federal funding to provide primary/preventive care regardless of insurance status or ability to pay.<sup>15</sup> They serve disproportionate numbers of patients in or near poverty and racial/ethnic minorities.<sup>16</sup> This context is crucial in understanding the utility



of indices such as the SDI in clinical settings serving the underserved. It helps illuminate at which point in the care of a chronic disease such as asthma social deprivation may play a role, and existing research with the SDI has not included this setting.

The objective of this study was to use patient-level data linked with geocoded community-level data over time to examine associations between neighbourhood social deprivation and asthma diagnosis documentation and care measures among children seeking care at CHCs. Previous associations between social deprivation and asthma exist,<sup>3 7 11</sup> but do not directly correlate social deprivation with provision of asthma care. Because of the association with disease burden, we hypothesised that children living in areas with high levels of social deprivation would also have more asthma diagnoses documented on problem lists and more medications ordered than those living in less deprived areas.

## METHODS

We used data from the Accelerating Data Value Across a National Community Health Center Network (ADVANCE) Clinical Research Network, a national network of CHCs.<sup>17</sup> Our analysis includes EHR data from the OCHIN (not an acronym, formerly Oregon Community Health Information Network, until other states joined) network in 15 states. The majority of clinics were in California (33%), Oregon (29%), Ohio (13%) and Massachusetts (12%), with the rest in Alaska, Georgia, Indiana, Minnesota, Montana, North Carolina, Nevada, New Mexico, Texas, Washington and Wisconsin.

### Inclusion criteria

Included in the study were children with asthma aged 3–17 who had  $\geq 1$  ambulatory visit in study clinics between 2008 and 2017, and who had an address that, when geocoded, allowed identification of the census tract in which the patient resided. Non-Hispanic white, non-Hispanic black and Latino children were included in this analysis. We identified asthma in this population when  $\geq 1$  International Classification of Diseases (ICD)-9 code of 493\* or ICD-10 codes of J45\* were captured in any encounter between 2008 and 2017. The majority of children in our sample (65.8%) had  $\geq 2$  asthma diagnoses during the study period. While there is currently no standard in defining asthma cases epidemiologically, ICD codes have been found to be valuable in research using EHR data.<sup>18–20</sup>

### Outcomes

The outcome variables were binary indicators of (1) asthma documented on the problem list ever, and (2) having asthma severity documented on the problem list ever. Our intent *was not to measure asthma prevalence* (ie, not merely which children were ever noted to have asthma anywhere in the record), but to measure the care for asthma as a chronic illness. Problem list documentation

was our proxy for documenting asthma as a chronic condition, as research has shown that use of the problem list is associated with higher quality clinical care,<sup>21 22</sup> and use of a problem list is a feature of commonly recommended care for chronic conditions, as well as being a quality measure for the use of EHR.<sup>22–25</sup> Documenting asthma severity is necessary to determine appropriate medication prescription.<sup>26</sup> Asthma and asthma severity were determined using ICD-9 or ICD-10 codes (online supplemental appendix table 1). Additional outcome measures included rates of (1) albuterol prescription, (2) inhaled steroid prescription, and (3) oral steroid prescription. Prescriptions for asthma medications were based on ordered medications, and medications were identified by National Drug Codes, reviewed and cleaned by analysts and reviewed again for final categorisation by a practising clinician (online supplemental appendix table 1).

### Independent variables

The main independent variable was a categorical version of the SDI, a composite measure of deprivation from 10 variables in the following seven domains: income, education, employment, housing, household characteristics, transportation and demographics created by the Robert Graham Center (online supplemental appendix table 2). The SDI uses the 2011–2015 American Community Survey 5-year estimate.<sup>9 27</sup> Quartiles of the SDI score (unitless range of 0–100) were calculated based on the distribution of the score in our patient sample and used in the analysis as has been done in other studies<sup>5 10 28</sup> with the lowest quartile (Q1, SDI scores ranging from 0 to 56) representing the least deprived neighbourhoods at the census tract level, and the highest quartile (Q4, SDI scores ranging from 93 to 100) representing the neighbourhoods with the most deprivation at the census tract level. Q3 included SDI scores from 80 to 92, and Q2 included SDI scores ranging from 57 to 79. A patient's neighbourhood was determined at the census tract where, based on addresses recorded in the EHR, the patient resided for the longest cumulative duration during the study period. We also constructed a binary indicator that specified whether a patient ever reported an address change to a different census tract to serve as a covariate (referred to as 'neighborhood change').

Additional covariates included patient-level characteristics: age in years at first visit at a study clinic,<sup>3–17</sup> sex (female or male), rate of visits per year (<1, 1–2, 3–4,  $\geq 5$ ), insurance during the study period recorded at each visit (never insured, private insurance used at  $\geq 1$  visit, public insurance used at  $\geq 1$  visit, a combination of public and private insurance) and race/ethnicity (Latino, non-Hispanic white and non-Hispanic black). While we generally use Latino/Latina because it is often preferred in populations similar to our study population, the actual ethnicity information collected by clinics is 'Hispanic' and 'non-Hispanic'. We included body mass index (BMI), denoted as never overweight/obese, overweight/obese at  $\geq 1$ , but not all clinic visits, or overweight/obese at every

clinic visit. Overweight/obese was defined as having a BMI  $\geq 85$ th percentile for one's respective age and sex, consistent with Centers for Disease Control and Prevention standards.<sup>29</sup> BMI and BMI percentile were calculated at the encounter level using the R package *childsds*.<sup>30</sup> We also included an indicator of family-level poverty (federal poverty level (FPL)) measured at each visit over the course of the study period (always  $\geq 138\%$  FPL, always  $< 138\%$  FPL, above and below  $138\%$  FPL and not documented at visits (to account for missing data)). Smoking exposure was also assessed in three groups: (1) never exposed, (2) ever exposed (this includes patients or parents who are current or ever smokers, and children exposed to second-hand smoke), and (3) unknown if exposed.

### Statistical analysis

Descriptive analyses were conducted to examine patient characteristics. For binary outcomes (ie, asthma and asthma severity documented in the problem list), we used generalised estimating equations logistic regression models as a function of SDI quartiles, adjusted for all covariates listed above. Models were fitted with a compound symmetry correlation structure and empirical sandwich variance estimator to obtain adjusted ORs and their corresponding 95% CIs, accounting for clustering of patients within CHCs. For the analyses evaluating prescription rates, we used negative binomial regression (due to overdispersion) to estimate adjusted rate ratios (RRs) of prescription separately for albuterol, inhaled steroids and oral steroids, also while accounting for clustering of patients by CHC.

R and Stata software were used to perform statistical analysis.<sup>31</sup> Two-sided statistical significance was set at  $p < 0.05$ . The data used in this study are collected during routine primary care and consent from patients to use data in research is obtained from clinics. The data are deidentified before transfer to the study team.

### Patient and public involvement

Our network has a panel of patients who review all research and reviewed our larger project on asthma disparities; patients were not directly involved in the design and conduct of this specific analysis.

## RESULTS

The sample included 34 266 children across 15 states. **Table 1** shows patient characteristics. The largest proportion of children were Latino (47.2%), followed by non-Hispanic white (27.8%), then non-Hispanic black (25.0%). More than half of the population was male (56.2%) and many patients first received care at a CHC at ages 3–5 years (44.6%) or ages 6–10 years (32.1%). Most patients had some public insurance (83.0%) and one to two ambulatory visits per year (43.2%). Overall, 33.6% of patients were overweight/obese at every visit and 37.4% were never overweight/obese. More than half of the population (53.6%) did not have a change in neighbourhood.

Most children lived in a household that was  $< 138\%$  FPL at every ambulatory visit (61.2%). The majority of the sample did not have documented tobacco smoke exposure, direct or indirect (70.3%). The majority of children living in neighbourhoods with the most community deprivation (top quartile, Q4) were Latino (53.6%) or non-Hispanic black (36.9%), had used public insurance at  $\geq 1$  clinic visit (90.7%) and more than one-third always had an overweight or obese BMI recorded at clinic visits (35.0%). Among the children living in the quartile with the least deprivation (lowest quartile, Q1), most were non-Hispanic white (53.7%) or Latino (35.0%), 71.6% used public insurance at  $\geq 1$  clinic visit and 30.4% always had an overweight or obese BMI recorded at clinic visits. Similar numbers of children in Q1 (44.9%) and Q4 (41.4%) had neighbourhood changes (**table 1**).

Across the study period, 75.4% of patients had asthma documented on their problem list and 21.2% had asthma severity documented on the problem list. Albuterol prescription was 1.88 prescriptions per year, on average. Inhaled steroids were prescribed an average of 0.52 times per year, and there was an average of 0.35 oral steroid prescriptions each year. Online supplemental appendix table 3 shows these unadjusted outcomes by SDI quartile. Children living in the areas with the most deprivation more often had asthma documented on their problem lists (80.1%) compared with children living in the areas with the least deprivation (70.7%). The same trend was observed for asthma severity documentation (25.8% vs 17.7%).

From **table 2**, the adjusted odds of having asthma recorded on the problem list were similar among children living in all quartiles. Non-Hispanic black children had 32% greater odds of having asthma on the problem list than non-Hispanic white children. As the number of visits increased, the odds of asthma on the problem list also increased (**table 2**).

Children with asthma had the same odds of having asthma severity documented on the problem list, regardless of where they lived. We observed increased odds of asthma severity documentation as number of visits increased (**table 2**). Children who moved to a different neighbourhood during the study period had lower odds of having asthma severity documented compared with those with no change in neighbourhood (OR=0.90, 95% CI 0.85 to 0.95).

Among children with asthma (**figure 1**, online supplemental appendix table 4), we observed a trend that as SDI increased, the rate of albuterol also increased by 8%, 15% and 22% (Q2: RR=1.08, 95% CI 1.02 to 1.14; Q3: RR=1.15, 95% CI 1.09 to 1.22; Q4: RR=1.22, 95% CI 1.13 to 1.32).

For inhaled steroid prescriptions, all quartiles had similar rates of inhaled steroid prescriptions as in Q1; however, rates trended upwards with increased deprivation, and the rates of those in Q4, compared with those in Q1, neared significance (RR=1.16, 95% CI 0.99 to 1.34).

Lastly, the rates of oral steroid prescription were similar between children living in any neighbourhood compared

**Table 1** Patient characteristics overall and by Social Deprivation Index score quartile\* (n=34 266)

	Overall n (%)	Quartile 1 (0–56) n (%)	Quartile 2 (57–79) n (%)	Quartile 3 (80–92) n (%)	Quartile 4 (93–100) n (%)
<b>Race/ethnicity</b>					
Latino	16 160 (47.2)	2523 (35.0)	3676 (45.2)	4368 (51.4)	5593 (53.6)
Non-Hispanic black	8571 (25.0)	815 (11.3)	1434 (17.6)	2475 (29.2)	3847 (36.9)
Non-Hispanic white	9535 (27.8)	3868 (53.7)	3019 (37.2)	1648 (19.4)	1000 (9.6)
<b>Age at first encounter† (years)</b>					
3–5	15 295 (44.6)	3019 (41.9)	3838 (47.2)	4010 (47.2)	4428 (42.4)
6–10	11 000 (32.1)	2374 (32.9)	2578 (31.7)	2585 (30.4)	3463 (33.2)
11–13	5007 (14.6)	1179 (16.4)	1096 (13.5)	1178 (13.9)	1554 (14.9)
14–17	2964 (8.7)	634 (8.8)	617 (7.6)	718 (8.5)	995 (9.5)
<b>Sex</b>					
Female	15 010 (43.8)	3203 (44.5)	3577 (44.0)	3642 (42.9)	4588 (44.0)
Male	19 256 (56.2)	4003 (55.6)	4552 (56.0)	4849 (57.1)	5852 (56.1)
<b>Insurance type</b>					
Never insured	830 (2.4)	245 (3.4)	224 (2.8)	188 (2.2)	173 (1.7)
Public insurance used at >1 clinic visit	28 451 (83.0)	5161 (71.6)	6514 (80.1)	7304 (86.0)	9472 (90.7)
Private insurance used at >1 clinic visit	2473 (7.2)	1067 (14.8)	680 (8.4)	422 (5.0)	304 (2.9)
Public and private insurance	2512 (7.3)	733 (10.2)	711 (8.8)	577 (6.8)	491 (4.7)
<b>Visits per year‡</b>					
<1	4878 (14.2)	1122 (15.6)	1232 (15.2)	1147 (13.5)	1377 (13.2)
1–2	14 803 (43.2)	3320 (46.1)	3671 (45.2)	3731 (43.9)	4081 (39.1)
3–4	7825 (22.8)	1608 (22.3)	1802 (22.2)	2003 (23.6)	2412 (23.1)
≥5	6760 (19.7)	1156 (16.0)	1424 (17.5)	1610 (19.0)	2570 (24.6)
<b>BMI category</b>					
Never overweight/obese	12 823 (37.4)	3009 (41.8)	2988 (36.8)	2991 (35.2)	3835 (36.7)
>1 visit with overweight/obese BMI	9941 (29.0)	2006 (27.8)	2506 (30.8)	2478 (29.2)	2951 (28.3)
Always overweight/obese	11 502 (33.6)	2191 (30.4)	2635 (32.4)	3022 (35.6)	3654 (35.0)
<b>Neighbourhood change</b>					
Yes	15 918 (46.5)	3236 (44.9)	4141 (50.9)	4220 (49.7)	4321 (41.4)
No	18 348 (53.6)	3970 (55.1)	3988 (49.1)	4271 (50.3)	6119 (58.6)
<b>% federal poverty level</b>					
Always ≥138	1967 (5.7)	709 (9.8)	614 (7.6)	387 (4.6)	257 (2.5)
Above and below 138	4489 (13.1)	1201 (16.7)	1384 (17.0)	1132 (13.3)	772 (7.4)
Always <138	20 955 (61.2)	3717 (51.6)	4595 (56.5)	5461 (64.3)	7182 (68.8)
Not documented	6855 (20.0)	1579 (21.9)	1536 (18.9)	1511 (17.8)	2229 (21.4)
<b>Smoking exposure</b>					
Never exposed	24 094 (70.3)	5193 (72.1)	5912 (72.7)	6128 (72.2)	6861 (65.7)
Ever exposed	4964 (14.5)	988 (13.7)	1113 (13.7)	1084 (12.8)	1779 (17.0)
Unknown if exposed	5208 (15.2)	1025 (14.2)	1104 (13.6)	1279 (15.1)	1800 (17.2)

\*Quartile 1 of the Social Deprivation Index score represents neighbourhoods with the least deprivation and quartile 4 represents neighbourhoods with the most deprivation.

†Children aged 3–5 are often in preschool/kindergarten, while those aged 6–10 are in elementary school. Children aged 11–13 are in middle school and those aged 14–17 are of high school age. We anticipated possible differences in experience based on age, as asthma changes over childhood, and age is also a proxy for utilisation.

‡Visits per year include all ambulatory visits.

BMI, body mass index.



**Table 2** Adjusted ORs of asthma and asthma severity documentation on the problem list (n=34 266)

	Adjusted OR of asthma documented on problem list OR (95% CI)	Adjusted OR of asthma severity documented on problem list OR (95% CI)
<b>Social Deprivation Index score*</b>		
Quartile 1	Ref	Ref
Quartile 2	1.01 (0.94 to 1.08)	1.04 (0.96 to 1.13)
Quartile 3	1.02 (0.95 to 1.09)	1.01 (0.92 to 1.09)
Quartile 4	1.00 (0.92 to 1.08)	1.02 (0.93 to 1.12)
<b>Race/ethnicity</b>		
Non-Hispanic white	Ref	Ref
Latino	1.05 (0.97 to 1.12)	1.00 (0.90 to 1.10)
Non-Hispanic black	1.32 (1.20 to 1.46)	1.08 (0.97 to 1.21)
<b>Age at first encounter (years)</b>		
3–5	Ref	Ref
6–10	1.32 (1.23 to 1.42)	1.15 (1.05 to 1.25)
11–13	1.19 (1.09 to 1.30)	1.14 (1.01 to 1.29)
14–17	0.99 (0.90 to 1.09)	1.44 (1.19 to 1.75)
<b>Sex</b>		
Female	Ref	Ref
Male	1.16 (1.08 to 1.21)	0.97 (0.92 to 1.02)
<b>Insurance type</b>		
Private insurance used at >1 clinic visit	Ref	Ref
Never insured	0.86 (0.73 to 1.01)	1.62 (1.33 to 1.97)
Public insurance used at >1 clinic visit	1.05 (0.96 to 1.15)	1.08 (0.96 to 1.22)
Public and private insurance	1.12 (0.99 to 1.27)	0.88 (0.77 to 1.00)
<b>Visits per year†</b>		
<1	Ref	Ref
1–2	1.18 (1.10 to 1.26)	2.04 (1.80 to 2.30)
3–4	1.41 (1.28 to 1.55)	2.94 (2.57 to 3.37)
≥5	1.50 (1.34 to 1.67)	4.17 (3.60 to 4.83)
<b>BMI category</b>		
Never overweight/obese	Ref	Ref
≥1 visit with overweight/obese BMI	1.19 (1.12 to 1.26)	0.91 (0.84 to 0.98)
Always overweight/obese	1.14 (1.08 to 1.20)	0.96 (0.90 to 1.02)
<b>% federal poverty level</b>		
Always ≥138	Ref	Ref
Above and below 138	1.13 (0.99 to 1.28)	0.81 (0.70 to 0.93)
Always <138	1.10 (0.99 to 1.21)	0.92 (0.82 to 1.03)
Not documented	1.00 (0.88 to 1.13)	0.93 (0.80 to 1.08)
<b>Neighbourhood change</b>		
No	Ref	Ref
Yes	1.04 (1.00 to 1.09)	0.90 (0.85 to 0.95)
<b>Smoking exposure</b>		
Never exposed	Ref	Ref
Ever exposed	1.13 (1.05 to 1.21)	0.98 (0.90 to 1.08)
Unknown if exposed	1.01 (0.93 to 1.10)	0.90 (0.80 to 1.02)

Continued

Table 2 Continued

	Adjusted OR of asthma documented on problem list OR (95% CI)	Adjusted OR of asthma severity documented on problem list OR (95% CI)
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\*Quartile 1 of the Social Deprivation Index (SDI) score represents neighbourhoods with the least deprivation and quartile 4 represents neighbourhoods with the most deprivation. The SDI is a composite measure of deprivation from 10 variables in the following seven domains: income, education, employment, housing, household characteristics, transportation and demographics created by the Robert Graham Center using 2011–2015 American Community Survey 5-year estimates.

†Visits per year include all ambulatory visits.

BMI, body mass index.

with those living in neighbourhoods in Q1. For all medications, non-Hispanic black children had higher rates of prescriptions than did non-Hispanic white children. The rates of albuterol and oral steroid prescriptions were also greater for Latino children compared with non-Hispanic white children (online supplemental appendix table 4).

## DISCUSSION

This study is the first of which we are aware that links geocoded patient-level EHR data and an ecological measure of social deprivation to determine the relationship between area deprivation and documented asthma care and prescribing in a national primary care cohort. We found similar odds of asthma or asthma severity documented on the problem list between the four SDI quartiles when adjusted for relevant covariates. This suggests that this step in chronic asthma care appears to be equal for children receiving care in CHCs, regardless of the socioeconomic status of the neighbourhoods in which they reside. Moreover, among these children with diagnosed asthma, Latino and non-Hispanic black children also had higher odds of documentation of asthma on their problem lists than did non-Hispanic white children, suggesting that children with increased risks associated with asthma are receiving quality care from CHCs. These

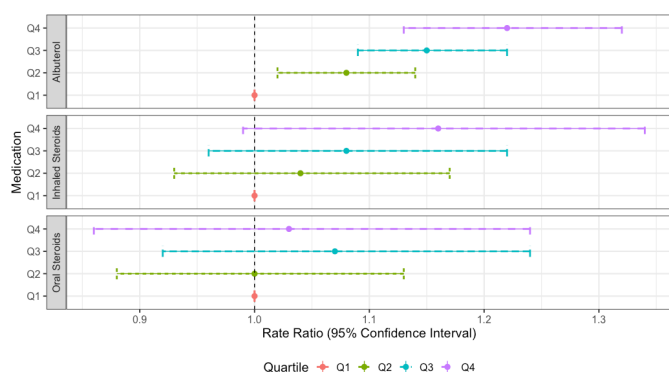
findings are consistent with previous research, which has shown that CHCs may be a factor in mitigating racial/ethnic disparities, as well as in lessening disparities related to the access and utilisation of care.<sup>32–34</sup>

The adjusted rate of albuterol prescription increased as neighbourhood deprivation increased, indicating that more emergency medication was prescribed in neighbourhoods with greater deprivation. Albuterol prescription may be an indicator of asthma symptoms, and asthma symptoms might increase as community deprivation increases.<sup>12 14</sup>

The adjusted rate of inhaled steroids trended higher and approached significance in the most deprived quartile compared with the least deprived quartile, again possibly indicating that asthma symptoms are worse in communities with more deprivation. The adjusted rate of oral steroid prescription did not differ between quartiles. This could be because oral steroids are often prescribed for exacerbations in emergency situations instead of at primary care visits, and may not have been captured as much as albuterol or inhaled steroid, both frequently prescribed in the primary care setting.

Understanding that social deprivation was associated with greater medication prescription, with other important factors held constant, may be of practical value to the healthcare providers and policymakers. Clinics and other health authorities can use social deprivation data to plan for elevated medication (or other care) needs in more deprived areas. In delivering care to underserved patients who use CHCs, neighbourhood social deprivation level may be a better indicator of care need over the patient's documented asthma severity. This may involve in-clinic social determinants of health screening, neighbourhood assessments or other tools to more proactively estimate asthma needs and to provide close follow-up on medication effectiveness, adherence and other aspects of disease management.

Children who were never insured were more likely than those who were privately insured to have asthma severity documented on the problem list. This is a surprising finding, but demonstrates that CHCs deliver quality chronic disease care to those with the least resources. Classifying asthma severity is one of the first steps in long-term asthma management to improve control and prevent exacerbations that can lead to increased hospitalisation or use of emergency/urgent care.<sup>26</sup> Our



**Figure 1** Rate ratios of asthma medication prescriptions (n=34 266). All models adjusted for race/ethnicity, age, sex, insurance type, visits/year, body mass index (BMI), neighbourhood change, % federal poverty level (FPL) and smoking exposure. Quartile 1 (Q1) of the Social Deprivation Index (SDI) score represents neighbourhoods with the least deprivation and quartile 4 (Q4) represents neighbourhoods with the most deprivation. Reference group is Q1.

findings underscore that while children living in more deprived areas *may* require more asthma medications, they do receive the required care (or at least have it ordered) in CHCs, reinforcing the vital link that these health centres play in deprived communities. Our study provides evidence that these centres and the populations they serve require important resources, and that CHC-served populations are targets for asthma intervention. Finally, children who moved residence also had lower odds of documentation of asthma and asthma severity on their problem lists than children who stayed in the same area. This may be a concrete demonstration of the health-care disruption that may be associated with residential mobility or transience. This needs further research, but providers and clinics can be attuned to children with changing addresses, and consider devoting resources towards outreach to those children to ensure there is no interruption in care.

This study had several limitations. Our data came from primary care clinics, so it is possible that we did not account for oral steroids prescribed in emergency departments. Additionally, primary care clinics in the USA often do not do comprehensive allergy testing so our data do not contain history of atopy and IgE laboratory results in a consistent manner. Children with severe asthma and allergies are commonly referred to allergy and immunology specialists. Furthermore, we did not have access to pharmacy data, so we did not know if prescriptions were filled, only that they were ordered. Further research using pharmacy data for asthma medications in this population may be needed. We also were not able to study differences between specific Latino subgroups, as our data did not include subgroup information. We were not able to include Asian children, as the sample was too small (~3%) for meaningful analysis. Future research can examine these phenomena in both of those sets of patients. We were not able to determine if asthma was the primary diagnosis at each visit, but, given our long study period, could measure whether these care measures *ever* occurred, which is consistent with clinical practice guidelines. Lastly, we were not able to include urban versus rural environment in our models because more than 98% of our population visited clinics in urban environments.

## CONCLUSION

Social determinants of health influence the care of patients with asthma seen in primary care settings, yet there is not a standardised way to understand these data in the context of a clinical care setting. We have used community data linked with clinical data via patient address to determine that social deprivation is associated with increased medication prescription despite similar documentation of asthma and asthma severity among these clinics; these findings reinforce the role CHCs play in communities with barriers to health and indirectly demonstrate the burden of disease in these communities. Proactive, risk-based asthma care across communities

could be obtained if health systems were provided with regular access to administrative deprivation data such as the SDI to then inform locally targeted policies and interventions to improve asthma management and education at a community level.

**Twitter** Miguel Marino @MmMiguelmM

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## ORCID iD

Jennifer A Lucas <http://orcid.org/0000-0002-2895-9809>

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<b>Appendix Table 1. Variable definitions</b>	
<b>Metric</b>	<b>Method</b>
<b>Asthma diagnosis at an encounter</b>	Asthma diagnosis was determined by having $\geq 1$ International Classification of Disease (ICD)-9 codes of 493* or ICD-10 codes of J45* documented at an encounter during the study period. Only diagnoses provided in a healthcare context were used to eliminate bias from self-reported asthma
<b>Asthma on Problem List</b>	Asthma on problem list was determined by having $\geq 1$ ICD-9 codes of 493* or ICD-10 codes of J45* documented on the patient's problem list during the study period. Asthma on the problem list is our proxy for documentation of asthma as a chronic condition. Only diagnoses provided in a healthcare context were used to eliminate self-reported asthma
<b>Asthma Severity on Problem List</b>	Asthma severity on problem list was determined by having a problem list documented with $\geq 1$ of the following ICD-10 codes in 4 categories: 1) Mild intermittent asthma, uncomplicated (J45.20), with (acute) exacerbation (J45.21), with status asthmaticus (J45.22); 2) Mild persistent asthma, uncomplicated (J45.30), with (acute) exacerbation (J45.31), with status asthmaticus (J45.32); 3) Moderate persistent asthma, uncomplicated (J45.40), with (acute) exacerbation (J45.41), with status asthmaticus (J45.42); 4) Severe persistent asthma, uncomplicated (J45.50), with (acute) exacerbation (J45.51), with status asthmaticus (J45.52)
<b>Body mass index (BMI) assessment</b>	BMI and BMI percentile were calculated at the encounter level using the `chiltds` package in R based on age, sex, weight, and height. Overweight was defined as BMI over the 85 <sup>th</sup> percentile at a given encounter and obese was defined as over the 95 <sup>th</sup> percentile at a given encounter. Biologically implausible values were flagged as 8 standard deviations over or 4 under the mean BMI. To measure at the patient level, encounter-level data was reduced to never, sometimes, or always mutually exclusive categories for both overweight and obese.
<b>Medication Administration</b>	Type of administration was first categorized based on prescription unit where: chewable tablet, disintegrating tablet, extended release capsule, extended release tablet, oral capsule, oral tablet, oral solution, oral strip, oral suspension, and granules corresponded to "swallowed;" injectable solution, injectable suspension, and prefilled syringe corresponded to "injected;" inhalant powder, metered dose inhaler, oral powder, and oral spray corresponded to "inhaled;" and nasal corresponded to "nasal." If a route of administration was not determined in the first round, a text search was performed connecting the keywords: tablets, capsules, and granules to "swallowed;" suspension, injection, and syringe to "injected;" inhaler, nebulizer, and spray to "inhaled;" and nasal to "nasal."
<b>Medication Category</b>	Medication names were reduced by removing common words shorter than 5 characters after cleaning the most frequent abbreviations, and the remaining medication keyword combinations were reviewed by the PI physician and categorized into one of seven categories: 1) albuterol/rescue inhaler, 2) inhaled corticosteroid, 3) oral steroid, 4) other inhaler, 5) other non-inhaler, 6) peak air meter, and 7) remove. The medications included in this study were oral steroids (dexamethasone, methylprednisolone, prednisolone, and prednisone), inhaled corticosteroids (beclomethasone, betamethasone, budesonide, ciclesonide, dexamethasone, flunisolide, fluticasone, mometasone, prednisolone, and triamcinolone), and albuterol/rescue inhalers (albuterol, levalbuterol, formoterol, metaproterenol, and pirbuterol).
<b>Social Deprivation Index (SDI) Score</b>	The SDI is a composite measure of deprivation using information about income, education, employment, housing, household characteristics, transportation, and demographics from the 2011-2015 American Community Survey. The SDI score is a standardized measure of the SDI that allows comparison across different areas. The SDI score is available from the Robert Graham Center for census tracts. Thus, each patient was assigned a census tract where, based on addresses recorded in the EHR, the patient resided cumulatively, over one or more address(es), for the longest duration during the study period. Patients were then linked to the SDI score for their respective census tract. The SDI score distribution in the study population was categorized into quartiles. (Appendix Table 3)

**Appendix Table 2. Composition of the Social Deprivation Index\***

<b>Domain</b>	<b>Variable</b>
Income	Percent population less than 100% FPL (income in past 12 months)
Education	Percent population $\geq 25$ years of age with less than 12 years of education
Employment	Percent non-employed (not seeking employment)
Employment	Percent unemployed (actively seeking employment)
Housing	Percent population living in renter-occupied housing units
Housing	Percent population living in crowded housing (occupants per room $> 1.01$ to 1.50 occupants per room)
Household Characteristics	Percent single-parent households with dependents $< 18$ years old
Transportation	Percent population with no car
Demographics	Percent population black
Demographics	Percent high needs population ( $< 5$ years and $\geq 65$ years and over)

\*Data from The Robert Graham Center <https://www.graham-center.org/rgc/maps-data-tools/sdi/social-deprivation-index.html>

**Appendix Table 3. Unadjusted Asthma Diagnosis and Care Outcomes Overall and by Social Deprivation Index Score Quartile\* (N=34,266)**

	Overall (N%)	Quartile 1 (0-56) (N%)	Quartile 2 (57-79) (N%)	Quartile 3 (80-92) (N%)	Quartile 4 (93-100) (N%)
<b>Asthma on problem list</b>					
Yes	25,844 (75.4)	5,100 (70.7)	5,954 (73.2)	6,432 (75.7)	8,358 (80.1)
No	8,422 (24.6)	2,106 (29.2)	2,175 (26.8)	2,059 (24.3)	2,082 (19.9)
<b>Asthma severity on problem list</b>					
Yes	7,254 (21.2)	1,273 (17.7)	1,555 (19.1)	1,735 (20.4)	2,691 (25.8)
No	27,012 (78.8)	5,933 (82.3)	6,574 (80.9)	6,756 (79.6)	7,749 (74.2)
<b>Prescriptions per year</b>					
	Overall (mean/95%CI)	Quartile 1 (0-56) (mean/95%CI)	Quartile 2 (57-79) (mean/95%CI)	Quartile 3 (80-92) (mean/95%CI)	Quartile 4 (93-100) (mean/95%CI)
Albuterol	1.88 (1.75-2.00)	1.43 (1.15-1.70)	1.83 (1.58-2.08)	1.90 (1.70-2.12)	2.19 (1.95-2.43)
Inhaled steroids	0.52 (0.48-0.56)	0.36 (0.32-0.40)	0.50 (0.40-0.59)	0.51 (0.46-0.57)	0.65 (0.56-0.74)
Oral steroids	0.35 (0.30-0.39)	0.28 (0.19-0.37)	0.35 (0.25-0.45)	0.40 (0.29-0.51)	0.34 (0.27-0.42)

\*Quartile 1 of the social deprivation index score represents neighborhoods with the least deprivation and Quartile 4 represents neighborhoods with the most deprivation

<b>Appendix Table 4. Adjusted Rates of Asthma Medication Prescription (N=34,266)</b>			
	Albuterol Prescription Adjusted IRR (95% CI)	Inhaled Steroid Prescription Adjusted IRR (95% CI)	Oral Steroid Prescription Adjusted IRR (95% CI)
<b>Social Deprivation Index Score*</b>			
Quartile 1	Ref	Ref	Ref
Quartile 2	1.08 (1.02-1.14)	1.04 (0.93-1.17)	1.00 (0.88-1.13)
Quartile 3	1.15 (1.09-1.22)	1.08 (0.96-1.22)	1.07 (0.92-1.24)
Quartile 4	1.22 (1.13-1.32)	1.16 (0.99-1.34)	1.03 (0.86-1.24)
<b>Ethnicity</b>			
Non-Hispanic White	Ref	Ref	Ref
Latino	1.18 (1.09-1.28)	1.13 (0.97-1.31)	1.37 (1.21-1.56)
Non-Hispanic Black	1.55 (1.44-1.67)	1.62 (1.46-1.80)	1.46 (1.21-1.76)
<b>Age at first encounter</b>			
3-5 years	Ref	Ref	Ref
6-10 years	0.73 (0.70-0.77)	0.79 (0.71-0.88)	0.46 (0.42-0.51)
11-13 years	0.70 (0.66-0.74)	0.73 (0.65-0.83)	0.35 (0.30-0.41)
14-17 years	0.68 (0.62-0.73)	0.61 (0.52-0.72)	0.29 (0.23-0.38)
<b>Sex</b>			
Female	Ref	Ref	Ref
Male	1.13 (1.11-1.16)	1.16 (1.11-1.22)	1.25 (1.18-1.33)
<b>Insurance Type</b>			
Private insurance used at ≥1 clinic visit	Ref	Ref	Ref
Never insured	1.16 (1.01-1.32)	1.00 (0.80-1.25)	1.08 (0.83-1.41)
Public insurance used at ≥1 clinic visit	1.19 (1.11-1.28)	1.08 (0.97-1.20)	0.91 (0.79-1.06)
Public and private insurance	0.93 (0.86-1.01)	0.83 (0.73-0.94)	0.75 (0.64-0.88)
<b>Visits per Year</b>			
Less than 1	Ref	Ref	Ref
1 to 2	1.80 (1.73-1.89)	2.07 (1.90-2.25)	1.90 (1.71-2.11)
3 to 4	2.80 (2.65-2.97)	3.98 (3.59-4.42)	3.92 (3.41-4.52)
5 or more	5.00 (4.61-5.42)	8.11 (7.10-9.27)	8.69 (7.25-10.41)
<b>BMI Category</b>			
Never overweight/obese	Ref	Ref	Ref
≥1 visit with overweight/obese BMI	0.89 (0.86-0.93)	0.86 (0.81-0.92)	0.89 (0.83-0.97)
Always overweight/obese	0.95 (0.92-0.98)	0.96 (0.90-1.03)	0.96 (0.90-1.04)
<b>Percent Federal Poverty Level</b>			
Always ≥138	Ref	Ref	Ref
Above & below 138	0.76 (0.70-0.82)	0.74 (0.65-0.84)	0.68 (0.58-0.81)
Always <138	0.87 (0.81-0.94)	0.85 (0.74-0.97)	0.79 (0.67-0.94)
Not documented	1.03 (0.91-1.18)	0.99 (0.84-1.17)	1.09 (0.85-1.39)
<b>Neighborhood Change</b>			
No	Ref	Ref	Ref
Yes	0.97 (0.93-1.01)	0.97 (0.92-1.04)	0.91 (0.84-0.98)
<b>Smoking exposure</b>			
Never exposed	Ref	Ref	Ref
Ever exposed	1.05 (0.98-1.12)	1.10 (0.99-1.22)	0.97 (0.87-1.08)
Unknown if exposed	1.05 (0.98-1.13)	1.06 (0.95-1.18)	0.90 (0.79-1.03)

\*Quartile 1 of the social deprivation index score represents neighborhoods with the least deprivation and Quartile 4 represents neighborhoods with the most deprivation