BMJ Open Respiratory Research

Childhood adversity and asthma prevalence: evidence from 10 US states (2009–2011)

Nandita Bhan,[1] M Maria Glymour,[2] Ichiro Kawachi,[3] S V Subramanian[3]

To cite: Bhan N, Glymour MM, Kawachi I, *et al*. Childhood adversity and asthma prevalence: evidence from 10 US states (2009–2011). *BMJ Open Resp Res* 2014;**1**:e000016. doi:10.1136/bmjresp-2013-000016

► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/bmjresp-2013-000016)

Received 31 October 2013
Revised 4 February 2014
Accepted 6 February 2014

[1]South Asia Network for Chronic Diseases, Public Health Foundation of India, New Delhi, India
[2]Department of Epidemiology & Biostatistics, UCSF School of Medicine, San Francisco, California, USA
[3]Department of Social & Behavioral Sciences, Harvard School of Public Health, Boston, Massachusetts, USA

Correspondence to
Professor S V Subramanian; svsubram@hsph.harvard.edu

ABSTRACT

Background: Existing evidence on stress and asthma prevalence has disproportionately focused on pregnancy and postpregnancy early life stressors, largely ignoring the role of childhood adversity as a risk factor. Childhood adversity (neglect, stressful living conditions and maltreatment) may influence asthma prevalence through mechanisms on the hypothalamic-pituitary axis.

Methods: Data from the Center for Disease Control's (CDC's) Behavioral Risk Factor Surveillance System (BRFSS) surveys were used to examine cross-sectional associations of adverse childhood experiences (ACE) with lifetime and current asthma prevalence. Information on childhood adversity was available from 84 786 adult respondents in 10 US states. Poisson regression models (with robust SE) were used to estimate prevalence ratios (PRs) relating overall ACE score and dimensions of exposure ACE to asthma prevalence, adjusting for socioeconomic status.

Results: Greater ACE was associated with a higher prevalence of asthma (adjusted $PR_{cat\ 4}$=1.78 (95% CI 1.69 to 1.87), adjusted $PR_{cat\ 1}$=1.21 (95% CI 1.16 to 1.27)). Reported experiences of sexual abuse (adjusted PR=1.48* (1.42 to 1.55)) and physical abuse (adjusted PR=1.38* (1.33 to 1.43)) were associated with a higher asthma prevalence. No clear socioeconomic gradient was noted, but those reporting lowest education and income levels reported high rates of asthma and adversity. Sensitivity analyses indicated that ACE exposures were interrelated.

Conclusions: Report of childhood adversity predicts asthma prevalence among US adults. Frameworks for asthma prevention need to recognise and integrate aspects related to childhood adversity. Further investigation into specific time periods of exposure would provide meaningful inferences for interventions.

Strengths and limitations of this study

- Greater adversity in childhood associated with increased risk of current and lifetime asthma prevalence.
- Dimensions of adversity (parental discord, stressful living conditions, verbal, physical and sexual abuse) were, singularly and in combinations, associated with increased asthma risks.
- Lowest SES groups at higher risks of adversity, but unclear socioeconomic gradients.

INTRODUCTION

The majority of research linking stress with asthma has focused on pregnancy and postpregnancy early life stressors, with little investigation into childhood adversity and its long-term impacts. Three sets of epidemiological studies have dominated the discussion. First, studies examining in utero effects of stress during pregnancy and immediate postpregnancy risk factors have assessed evidence for programming of respiratory health.[1–4] Second, studies have drawn associations between reported or measured parental stress as predictors of wheezing among children.[5–7] Third, associations between mental distress and asthma have been examined.[5 8–11]

Assessing the role of childhood adversity investigates and relates to the research around physiological mechanisms for stress and asthma research. Evidence from stress biology finds links to asthma (along with bronchial hypersensitivity, eczema and wheezing) through immune and inflammatory responses, acting through the hypothalamic-pituitary axis.[1 12–14] For instance, extreme stress and emotional states such as trauma have been associated with asthma through immune dysregulation as well as nervous system hyper-responsiveness. The role of such mechanisms may be more pronounced in childhood compared to pregnancy and postpregnancy. Further, hormones and inflammation (eg, interleukin (IL)-4, IL-5 and IL-13) related to stress can lead to contractions of smooth muscle and excess of mucus production, heightening risks for asthma morbidity.[14] Hormonal mechanisms influencing weight gain and obesity have also been associated with stress and asthma.[15 16]

Research on childhood adversity may also address some limitations in the current

epidemiological research on stress and asthma. Childhood adversity, often reported, examines the qualitative nature of experiencing stress in social interactions instead of focusing on stress biomarkers. In previous epidemiological studies, household or parental measures of stress were equated to the individual's own stress. This ignores the role of factors such as personality, resilience and the interactions between individual-social environments.

Childhood adversity has been operationalised by adverse childhood experiences (ACE), a multi-domain marker measuring diverse aspects of adversity including neglect, stressful living conditions, maltreatment and abuse. A number of studies have examined associations between ACE and health behaviours (including smoking, alcohol and drug initiation), suicide ideation and mental health outcomes.[17–27] A handful of studies relating separate aspects of adversity to asthma outcomes have highlighted the potential for this relationship. For instance, a prospective follow-up of African-American women showed higher incidence rate ratios (IRRs) for physician-diagnosed asthma associated with any childhood abuse (IRR=1.24 (95% CI 1.06 to 1.45) and any adolescent abuse (IRR =1.10 (95% CI 0.88 to 1.36).[28] Respondent's child protection agency history (a proxy for a stressful home environment or parental discord) was associated with higher elevated odds of lifetime asthma (adjusted OR=2.26, 95% CI 1.33 to 3.83); the association did not hold, however, for self-reported measures for the same exposure.[29] Hyland *et al*[30] showed that reported insults and physical punishment during childhood was associated with a higher likelihood of asthma (RR: 1.6).

In the context of these gaps, this study examined the relationships between overall ACE as well as independent ACE dimensions with asthma prevalence, using data from 10 US states between 2009 and 2011. We hypothesised positive relationships between adversity (measured through ACE) and asthma prevalence, even as relationships with markers of socioeconomic status (SES) may be variable for adversity and asthma.

MATERIALS AND METHODS

Data and sample

Behavioral Risk Factor Surveillance System (BRFSS) is a nationally representative annual telephone health survey designed and administered by the Center for Disease Control (CDC) that collects data on health risk behaviours, preventive health practices and access to healthcare across US states.[31] As a repeated cross-sectional survey, it was designed to help in tracking preventive health goals and for highlighting emerging issues.

Information on self-reported physician-diagnosed asthma prevalence was available for 1 384 116 respondents across the USA between 2009 and 2011; however, information on childhood adversity measures was available for 84 796 respondents (2009: 12 088, 2010: 24 334 and 2011: 48 364). Hence, the total sample 'n' for this study was 84 796 (men: 40.1%, women: 59.9%) from 10 US states, representing all geographic regions: Arkansas, District of Columbia (DC), Hawaii, Louisiana, Minnesota, Montana, Nevada, Vermont, Washington and Wisconsin.

Variables

The main *outcomes* analysed in the study were self-reported physician-diagnosed asthma prevalence among adults (measured by lifetime and current asthma). Respondents in the survey were asked: "(Ever told) by a doctor, nurse or other health professional that you had asthma" followed by "Do you still have asthma?". These outcomes have not been systematically tested for outcome reliability and validity. A review on self-reported asthma has estimated a mean sensitivity of 68% (range 48–100%) and a mean specificity of 94% (range 78–100%), with an increase if physician-diagnosis was reported.[32]

The main *exposure* of interest was childhood adversity operationalised as an ACE score. The analysis used both overall ACE score (categorised by adversity type) and five separate dimensions of ACE. Eleven questions from a submodule administered in 10 states gathered data from respondents regarding ACE (details in online supplementary table S2). Five separate dimensions were considered and represented inter-related aspects of experience of stress before age 18 years (details discussed in online supplementary table S2). These included: (1) parental marital discord, (2) stressful living conditions, (3) experience of verbal abuse, (4) experience of physical abuse and (5) experience of sexual abuse. ACE questions used in the BRFSS have been tested previously for reliability.[21] Weighted-κ for individual questions and accumulated dimensions ranged from 0.52 to 0.86 with the reliability estimate for overall ACE being 0.64 (0.36 to 0.6).[21] The interrelatedness of ACE dimensions has also been tested previously, with 81–98% of respondents reporting more than one dimension of ACE.[33] The type of adversity measured by ACE was categorised into an exploratory gradient. The categories considered included: 'none' (category 0), 'parental marital discord or verbal abuse' (category 1), 'discord, verbal abuse and stressful living conditions' (category 2), 'discord, verbal abuse, stressful living conditions and physical abuse' (category 3) and 'discord, verbal abuse, stressful living conditions, physical and sexual abuse, and sexual abuse only' (category 4; see online supplementary table S1).

Other covariates in the analysis included respondent household income and education, age, sex, race, survey year and state of residence. Respondents did not provide data on parents, and hence their self-reported education and income were used as controls and proxies for lifetime SES. Household income was categorised into six categories (less than US$15 000, US$15 000–35 000, US $35 000–50 000, US$50 000–75 000, >US$75 000 and not

reported or refused) and education was categorised as 'Less than high school', 'Finished high school', 'Some college' and 'College or more'. Respondent self-reports of race/ethnicity were categorised as Non-Hispanic White (NHW), Non-Hispanic Black (NHB), Hispanic and Other (including multiracial).

Analysis

The study estimated prevalence rates for lifetime and current asthma, along with dimensions of childhood adversity in the sample. Bivariate associations (along with χ^2 tests) were estimated for asthma prevalence and ACE (overall and dimensions) with socioeconomic covariates of interest. Multivariable Poisson regression models with robust SE were used to estimate prevalence ratios (PRs) for asthma by ACE, adjusted for SES. PRs were preferred as risk ratio estimates over ORs due to the high prevalence of asthma in several categories.[34 35] Regression models included unadjusted models (M1); models adjusted for age, sex, race and survey year (M2); models adjusted for age, sex, race, survey year and SES (M3) and models adjusted for age, sex, race, survey year, SES and state (M4). All analyses were conducted using STATAV.12.

RESULTS

Prevalence rates for ACE and asthma

Table 1 shows the differences in asthma prevalence (lifetime and current) by socioeconomic and demographic

Table 1 Sample characteristics and associations between asthma prevalence and socioeconomic and demographic variables

	Sample (%)	Lifetime asthma prevalence*	Current asthma prevalence*
Sex			
Male	34 003 (40.1)	10.72	6.83
Female	50 783 (59.9)	14.84	11.07
Age			
18–24	3133 (3.7)	17.71	10.95
25–44	17 750 (20.94)	14.79	10.009
45–64	36 727 (43.32)	13.19	9.48
>65	26 524 (31.28)	11.62	8.54
Income			
<US$15 000	7092 (8.36)	19.75	15.62
US$15 000–US$35 000	22 322 (26.33)	14.29	10.62
US$35 000–US$50 000	11 864 (13.99)	12.46	8.63
US$50 000–US$75 000	12 702 (14.98)	11.99	8.12
>US$75 000	20 832 (24.57)	11.05	7.10
Education			
<High school	5790 (6.83)	16.7	13.26
Finished high school	23 639 (27.88)	12.58	9.41
Some college	23 480 (27.69)	13.79	9.67
College+	31 742 (37.44)	12.56	8.41
Race/ethnicity			
Non-Hispanic White	68 485 (80.77)	12.49	8.97
Non-Hispanic Black	5351 (6.31)	15.7	11.67
Hispanic	2561 (3.02)	13.67	8.81
Others (including multiracial)	7523 (8.87)	17.4	11.57
Survey year			
2009	12 088 (14.26)	11.01	7.47
2010	24 334 (28.7)	15.1	10.17
2011	48 364 (57.04	12.77	9.45
State			
Arkansas	3676 (4.34)	11.86	8.59
DC	3683 (4.34)	15.56	10.22
Hawaii	6232 (7.35)	16.5	10.01
Louisiana	8412 (9.92)	10.64	6.98
Minnesota	13 928 (16.43)	10.73	7.81
Montana	9297 (10.97)	12.94	9.55
Nevada	3605 (4.25)	14.23	9.53
Vermont	13 331 (15.72)	14.73	10.90
Washington	13 901 (16.4)	14.16	10.22
Wisconsin	8721 (10.29)	12.7	9.77

*Differences were statistically significant with p<0.0001.

covariates, including age, sex, race/ethnicity, income and education levels. Higher asthma prevalence was seen among women, those in the lower age groups, among NHW populations and those reporting lower income and education levels. Stressful living conditions was the most commonly reported dimension of ACE (34.46%) followed by any verbal abuse (32.62%) and parental marital discord (20.67%; table 2). Nearly 12.29% reported any experience of sexual abuse.

Exposure to experiences of adversity was associated with higher asthma prevalence. Experiencing parental marital discord and living in stressful conditions were respectively associated with higher lifetime asthma prevalence (parental marital discord: 16.77% vs 12.2%; p<0.0001, and stressful living conditions: 17.14% vs 11.12%; p<0.0001). Asthma prevalence was higher among those reporting an experience of verbal abuse (16.77% vs 11.46%: p<0.0001), any physical abuse (17.7% vs 11.87%: p<0.0001) or any sexual abuse (20.34% vs 12.16%: p<0.0001), compared to those with no experience of the specific adversity.

ACE and asthma prevalence

High adversity in childhood was associated with greater asthma prevalence, with evidence for a stepwise gradient (table 3). Each ACE category was seen to be positively related to asthma current and lifetime prevalence. Small differences in the asthma PRs were noted for this exploratory gradient between respondents reporting categories 2 and 3 adversity. Highest risks for asthma prevalence were seen among respondents reporting highest ACE compared to those reporting no adversity (PR=2.03 (95% CI 1.94 to 2.14)). Adjusting for race/ethnicity, SES, demographic covariates and state of residence led to proportionally greater attenuations in asthma prevalence (~30%) among those who reported all dimensions of ACE (adjusted PR (APR)=1.78 (95% CI 1.69 to 1.87) compared to lower categories of ACE. Similar patterns were noted for current asthma with unadjusted PR=2.23 (95% CI 2.09 to 2.36) reducing on covariate adjustment to APR=1.88 (1.77 to 2.006).

Analyses for separate ACE dimensions showed positive relationships between childhood adversity and asthma prevalence, adjusted for covariates (table 4). Respondents who reported parental marital discord showed a 37% higher prevalence (PR=1.37, 95% CI 1.32 to 1.43). Adjusted for covariates, PRs reduced by 35%. For current asthma, parental discord was associated with a 40% high prevalence (APR=1.40 (95% CI 1.34 to 1.47). Respondents reporting stressful living conditions in childhood showed a 54% higher asthma prevalence (PR=1.54, 95% CI 1.49 to 1.59), which attenuated by 18% on covariate adjustment. Stressful living conditions were associated with a 47% higher prevalence of current asthma (APR=1.47 (95% CI 1.41 to 1.54)). Respondents reporting verbal or physical abuse showed 38% higher

Table 2 Dimensions of childhood adversity and prevalence of asthma

	Sample distribution of ACE dimensions	Asthma lifetime prevalence* (%)	Asthma current prevalence* (%)
Parental marital discord†			
No	66 118 (78.78)	8069 (12.20)	5596 (8.62)
Yes	17 350 (20.67)	2909 (16.77)	2063 (12.09)
Never married	457 (0.54)	90 (19.69)	65 (14.51)
Total	83 925 (100.00)		
Stressful living conditions‡			
No	55 290 (65.54)	6151 (11.12)	4209 (7.77)
Yes	29 076 (34.46)	4985 (17.14)	3560 (12.41)
Total	84 366 (100.00)		
Experience of verbal abuse			
No	55 966 (67.38)	6412 (11.46)	4425 (8.05)
Yes	27 096 (32.62)	4543 (16.77)	3210 (12.02)
Total	83 062 (100.00)		
Experiences of physical violence (on individual or parent)§			
No	64 880 (77.22)	7701 (11.87)	5267 (8.27)
Yes	19 143 (22.78)	3388 (17.70)	2469 (13.10)
Total	84 023 (100.00)		
Experiences of sexual abuse in childhood¶			
No	73 475 (87.71)	8936 (12.16)	6141 (8.51)
Yes	10 294 (12.29)	2094 (20.34)	1528 (15.28)
Total	83 769 (100.00)		

*Differences were statistically significant with p<0.0001.
†Marital status of parents: were they divorced/separated?
‡Lived with someone who was depressed, mentally ill, suicidal, alcoholic, illegal drug user or had served time in prison.
§Experienced violence in the household (verbal or physical).
¶Experience of sexual abuse.
ACE, adverse childhood experience.

Table 3 Prevalence ratios from Poisson regression models for lifetime asthma by overall ACE score

	Lifetime asthma prevalence				Current asthma prevalence			
	Unadjusted	Adjusted (age, sex, survey year)	Adjusted (age, sex, survey year, SES)	Adjusted (age, sex, survey year, SES and state)	Unadjusted	Adjusted (age, sex, survey year)	Adjusted (age, sex, survey year, SES)	Adjusted (age, sex, survey year, SES and state)
ACE Categories (Ref: None)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	1.24 (1.18 to 1.30)	1.23 (1.17 to 1.29)	1.22 (1.16 to 1.27)	1.21 (1.16 to 1.27)	1.26 (1.18 to 1.33)	1.25 (1.18 to 1.33)	1.24 (1.17 to 1.32)	1.24 (1.17 to 1.31)
2	1.52 (1.44 to 1.62)	1.46 (1.37 to 1.55)	1.44 (1.35 to 1.53)	1.44 (1.35 to 1.53)	1.54 (1.43 to 1.66)	1.50 (1.39 to 1.62)	1.48 (1.37 to 1.59)	1.47 (1.37 to 1.59)
3	1.54 (1.46 to 1.63)	1.52 (1.44 to 1.6)	1.46 (1.38 to 1.54)	1.46 (1.38 to 1.53)	1.62 (1.52 to 1.73)	1.63 (1.53 to 1.73)	1.54 (1.44 to 1.64)	1.54 (1.44 to 1.64)
4	2.03 (1.94 to 1.14)	1.89 (1..8 to 1.99)	1.79 (1.71 to 1.89)	1.78 (1.69 to 1.87)	2.23 (2.09 to 2.36)	2.03 (1.91 to 2.16)	1.89 (1.78 to 2.02)	1.88 (1.77 to 2.006)
Female		1.35 (1.3 to 1.4)	1.32 (1.27 to 1.37)	1.31 (1.26 to 1.36)		1.57 (1.49 to 1.65)	1.52 (1.46 to 1.60)	1.53 (1.45 to 1.60)
Age (in years)								
25–44		0.8 (0.74 to 0.87)	0.86 (0.79 to 0.93)	0.86 (0.79 to 0.93)		0.87 (0.78 to 0.97)	0.98 (0.88 to 1.09)	0.97 (0.87 to 1.09)
45–64		0.72 (0.67 to 0.78)	0.77 (0.71 to 0.84)	0.77 (0.71 to 0.83)		0.83 (0.75 to 0.93)	0.93 (0.84 to 1.04)	0.92 (0.83 to 1.02)
65+		0.68 (0.63 to 0.74)	0.69 (0.63 to 0.75)	0.67 (0.62 to 0.73)		0.82 (0.73 to 0.91)	0.83 (0.74 to 0.92)	0.81 (0.73 to 0.90)
Survey year								
2010		1.36 (1.29 to 1.44)	1.42 (1.34 to 1.51)	1.12 (1.003 to 1.25)		1.35 (1.26 to 1.46)	1.45 (1.35 to 1.57)	1.12 (0.97 to 1.30)
2011		1.15 (1.08 to 1.21)	1.19 (1.12 to 1.26)	1.04 (0.93 to 1.16)		1.26 (1.18 to 1.35)	1.34 (1.25 to 1.44)	1.13 (0.99 to 1.27)
Income								
US$15 000–US$35 000			0.77 (0.72 to 0.81)	0.77 (0.73 to 0.82)			0.73 (0.68 to 0.78)	0.74 (0.68 to 0.79)
US$35 000–US$50 000			0.67 (0.63 to 0.72)	0.67 (0.63 to 0.72)			0.61 (0.56 to 0.66)	0.61 (0.56 to 0.67)
US$50 000–US$75 000			0.64 (0.59 to 0.68)	0.64 (0.59 to 0.68)			0.57 (0.52 to 0.62)	0.57 (0.53 to 0.62)
>US$75 000			0.58 (0.54 to 0.62)	0.58 (0.54 to 0.62)			0.50 (0.46 to 0.54)	0.50 (0.57 to 0.55)
Do not know, refused			0.72 (0.67 to 0.77)	0.72 (0.67 to 0.77)			0.67 (0.61 to 0.73)	0.67 (0.62 to 0.73)
Education								
Finished high school			0.81 (0.76 to 0.87)	0.81 (0.76 to 0.87)			0.77 (0.71 to 0.83)	0.77 (0.71 to 0.84)
Some college			0.89 (0.83 to 0.95)	0.89 (0.83 to 0.95)			0.79 (0.74 to 0.86)	0.80 (0.74 to 0.87)
College or more			0.90 (0.84 to 0.97)	0.9 (0.84 to 0.96)			0.80 (0.74 to 0.87)	0.79 (0.73 to 0.87)
State								
DC				1.22 (1.11 to 1.35)				1.17 (1.02 to 1.34)
Hawaii				1.3 (1.19 to 1.41)				1.13 (0.99 to 1.28)
Louisiana				0.88 (0.79 to 0.97)				0.80 (0.71 to 0.92)
Minnesota				0.9 (0.83 to 0.97)				0.89 (0.81 to 0.97)
Montana				1.03 (0.95 to 1.12)				1.006 (0.87 to 1.16)
Nevada				1.07 (0.96 to 1.18)				1.19 (1.09 to 1.31)
Vermont				1.18 (1.10 to 1.27)				1.09 (1.01 to 1.18)
Washington				1.15 (1.06 to 1.24)				1.04 (0.95 to 1.15)

Baseline: age category 18–24 years, male, sampled in 2009, income <US$15 000, education less than high school, in Arkansas.
Category 1: Parental marital discord+experience of a verbal abuse; *Category 2:* parental marital discord+experience of a verbal abuse+stressful living conditions; *Category 3:* parental marital discord+experience of a verbal abuse+stressful living conditions+experience of physical abuse; *Category 4:* parental marital discord+experience of a verbal abuse+stressful living conditions +experience of physical abuse+sexual abuse.
ACE, adverse childhood experience; SES, socioeconomic status.

Table 4 Results from Poisson regression models (PRs and 95% CI) for lifetime asthma prevalence by independent ACE dimensions

	Lifetime asthma				Current asthma			
	Model 1: Unadjusted	Model 2: Adjusted for age, sex, race, survey year	Model 3: Adjusted for age, sex, race, survey year, income and education	Model 4: Adjusted for age, sex, race, survey year, income and education, and State	Model 1: Unadjusted	Model 2: Adjusted for age, sex, race, survey year	Model 3: Adjusted for age, sex, race, survey year, income and education	Model 4: Adjusted for age, sex, race, survey year, income and education, and State
Parental marital discord								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.37 (1.32 to 1.43)	1.3 (1.25 to 1.35)	1.26 (1.21 to 1.31)	1.24 (1.19 to 1.29)	1.40 (1.34 to 1.47)	1.37 (1.30 to 1.44)	1.28 (1.22 to 1.35)	1.27 (1.21 to 1.34)
Never married	1.63 (1.35 to 1.95)	1.39 (1.14 to 1.69)	1.31 (1.08 to 1.58)	1.33 (1.09 to 1.6)	1.68 (1.34 to 2.11)	1.58 (1.26 to 1.99)	1.37 (1.09 to 1.71)	1.40 (1.12 to 1.76)
Stressful living conditions before age 18								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.54 (1.49 to 1.59)	1.48 (1 to 43 to 1.54)	1.45 (1.39 to 1.5)	1.44 (1.39 to 1.49)	1.59 (1.53 to 1.66)	1.53 (1.47 to 1.60)	1.48 (1.42 to 1.54)	1.47 (1.41 to 1.54)
Reported experience of verbal abuse before age 18								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.46 (1.41 to 1.52)	1.42 (1.37 to 1.47)	1.38 (1.34 to 1.43)	1.38 (1.33 to 1.43)	1.49 (1.43 to 1.56)	1.45 (1.39 to 1.52)	1.41 (1.35 to 1.47)	1.41 (1.35 to 1.47)
Reported experience of physical violence before age 18								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.49 (1.44 to 1.55)	1.44 (1.39 to 1.50)	1.38 (1.33 to 1.44)	1.38 (1.33 to 1.43)	1.58 (1.51 to 1.66)	1.55 (1.48 to 1.62)	1.45 (1.39 to 1.52)	1.45 (1.39 to 1.52)
Reported experience of sexual abuse before age 18								
No	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.67 (1.59 to 1.74)	1.56 (1.49 to 1.63)	1.49 (1.43 to 1.56)	1.48 (1.42 to 1.55)	1.79 (1.70 to 1.89)	1.63 (1.55 to 1.72)	1.54 (1.46 to 1.63)	1.53 (1.45 to 1.62)

ACE, adverse childhood experience; PR, prevalence ratio.

Table 5 Results from Poisson regression models on combinations of adversity experiences

	Asthma prevalence		Current asthma	
	Adjusted for age, sex, survey year	Fully adjusted	Adjusted for age, sex, survey year	Fully adjusted
No adversity	1.00	1.00	1.00	1.00
Parental discord	1.17* (1.08 to 1.28)	1.13* (1.04 to 1.23)	1.24* (1.12 to 1.38)	1.18* (1.06 to 1.31)
Stressful living conditions	1.31* (1.23 to 1.40)	1.31* (1.23 to 1.41)	1.35* (1.24 to 1.46)	1.35* (1.24 to 1.46)
Verbal abuse	1.16* (1.08 to 1.26)	1.17* (1.08 to 1.27)	1.15* (1.05 to 1.27)	1.17* (1.06 to 1.28)
Physical abuse	1.03 (0.90 to 1.18)	1.01 (0.88 to 1.15)	1.08 (0.92 to 1.28)	1.04 (0.88 to 1.23)
Sexual abuse	1.34* (1.18 to 1.51)	1.32* (1.17 to 1.49)	1.38* (1.19 to 1.59)	1.37* (1.18 to 1.59)
Parental discord and stressful living conditions	1.50* (1.36 to 1.67)	1.46* (1.31 to 1.62)	1.58* (1.39 to 1.79)	1.50* (1.32 to 1.71)
Parental discord and Verbal abuse	1.24* (1.06 to 1.45)	1.22* (1.04 to 1.42)	1.26* (1.04 to 1.53)	1.23* (1.01 to 1.49)
Parental discord and physical abuse	1.14 (0.91 to 1.44)	1.08 (0.86 to 1.37)	1.32* (1.008 to 1.72)	1.22 (0.94 to 1.60)
Parental discord and sexual abuse	1.59* (1.24 to 2.06)	1.50* (1.17 to 1.93)	1.55* (1.13 to 2.13)	1.44* (1.04 to 1.97)
Stressful living Conditions and verbal abuse	1.47* (1.36 to 1.58)	1.46* (1.35 to 1.57)	1.49* (1.36 to 1.63)	1.47* (1.35 to 1.62)
Stressful living conditions and physical	1.46* (1.32 to 1.62)	1.40* (1.26 to 1.55)	1.58* (1.40 to 1.79)	1.49* (1.32 to 1.69)
Stressful living conditions and sexual abuse	1.54* (1.35 to 1.75)	1.50* (1.32 to 1.71)	1.64* (1.40 to 1.92)	1.59* (1.36 to 1.86)
Verbal and physical abuse	1.62* (1.53 to 1.71)	1.56* (1.47 to 1.65)	1.73* (1.62 to 1.86)	1.65* (1.54 to 1.76)
Verbal and sexual abuse	1.66* (1.49 to 1.83)	1.59* (1.44 to 1.77)	1.75* (1.54 to 1.98)	1.68* (1.48 to 1.90)
Physical and sexual abuse	2.20* (2.07 to 2.33)	2.03* (1.91 to 2.15)	2.41* (2.23 to 2.58)	2.15* (2.009 to 2.31)

*p<0.05.

adjusted risks for asthma prevalence (APR=1.38, 95% CI 1.33 to 1.43). Respondents reporting sexual abuse had a 67% higher asthma prevalence (PR=1.67, 95% CI 1.59 to 1.74); covariate adjustment moderately attenuated the estimated risk (APR=1.48, (95% CI 1.42 to 1.55)). Respondents reporting any experience of sexual abuse were noted to have a 53% higher prevalence of current asthma (APR=1.53 (95% CI 1.45 to 1.62)).

Additionally, combined experiences of adversity provided greater risks of asthma lifetime and current prevalence, particularly for respondents reporting physical and sexual abuse (APR=2.15 (95% CI 2.009 to 2.31)), verbal and sexual abuse (APR=1.68 (1.48 to 1.90)) and verbal and physical abuse (APR=1.65 (95% CI 1.54 to 1.76); table 5). Among the singular dimensions of asthma, adjusted for covariates and other dimensions of adversity, stressful living conditions and experience of sexual abuse in childhood predicted the highest risks of asthma prevalence (Stressful Living Conditions: APR=1.35 (95% CI 1.24 to 1.46); Sexual Abuse: APR=1.37 (95% CI 1.18 to 1.59)). The risks for asthma among those reporting parental marital discord only (APR=1.24 (95% CI 1.12 to 1.38)) and parental marital discord with verbal abuse (APR=1.26 (95% CI 1.04 to 1.53)) were similar.

Social determinants of adversity

Higher rates of parental marital discord (separation or divorce) were reported by racial/ethnic minorities (NHB: 36.88%, Hispanic: 28.48% vs NHW: 18.93%; table 6). Hispanics reported higher rates of adversity seen through rates of living in stressful conditions (38.5%) compared to NHW (34.6%) and NHB (32.8%) populations. Higher rates of verbal and physical abuse were also reported by Hispanics (verbal abuse: 36.3%, physical abuse: 34.24%) compared to NHW (verbal abuse: 32.7%, physical abuse: 21.4%) and NHB (verbal abuse: 26.4%, physical abuse: 26.08%). Hispanics reported higher rates of sexual abuse (14.26%) compared to NHB (12.1%) and NHW (12.05%) populations.

The lowest income and educational categories reported higher rates of adversity but a clear SES gradient could not be established (see online supplementary table S3). Respondents with less than high school education reported greater parental marital discord (29.28%) compared to college educated respondents (15.82%); similar rates were seen for any physical abuse (<high school education: 30.48% vs college educated: 18.97%). Respondents with lowest incomes (income<US$15 000) reported higher adversity, with small differences between the remaining groups. Lowest income respondents (<US$15 000) reported higher parental marital discord (29.27%) and stressful living conditions (42.6%) compared to respondents with income between US $15 000 and US$35 000 (parental marital discord: 22.78%, stressful living conditions: 35.52%). Those in the lowest income group also reported higher rates of sexual abuse (19.02%) compared to 10.77% in the highest income group.

DISCUSSION

Our study reports three major findings. *First*, we found a positive relationship between childhood adversity and

Table 6 Distribution of ACE dimensions by race/ethnicity, income and education in the BRFSS

	Parents separated or divorced	Parents never married	Reported stressful living conditions before age 18	Reported verbal abuse	Reported experience of physical violence before age 18	Reported experience of sexual abuse before age 18
Race/ethnicity						
Non-Hispanic White	12 836 (18.93)	182 (0.27)	23 564 (34.61)	21 936 (32.70)	14 518 (21.40)	8155 (12.05)
Non-Hispanic Black	1918 (36.88)	183 (3.52)	1735 (32.82)	1368 (26.42)	1367 (26.08)	632 (12.10)
Hispanic	716 (28.48)	25 (0.99)	979 (38.51)	909 (36.35)	865 (34.24)	359 (14.26)
Others	1679 (22.54)	60 (0.81)	2517 (33.61)	2610 (35.38)	2183 (29.28)	1029 (13.84)
Education						
Less than High school	1627 (29.28)	74 (1.33)	2134 (37.88)	1706 (30.95)	1703 (30.48)	796 (14.26)
Finished high school	5327 (23.00)	155 (0.67)	7925 (34.00)	6979 (30.46)	5512 (23.79)	2586 (11.20)
Some college	5258 (22.79)	135 (0.59)	8510 (36.71)	8070 (35.33)	5797 (25.09)	3225 (14.01)
College or more	4937 (15.82)	86 (0.28)	10 226 (32.69)	10 068 (32.60)	5921 (18.97)	3568 (11.46)
Income						
<US$15 000	2011 (29.27)	88 (1.28)	2960 (42.60)	2608 (38.27)	2256 (32.71)	1306 (19.02)
US$15 000–35 000	4972 (22.78)	157 (0.72)	7799 (35.52)	7067 (32.68)	5511 (25.21)	2927 (13.43)
US$35 000–US$50 000	2299 (19.66)	52 (0.44)	4009 (34.16)	3733 (32.29)	2677 (22.88)	1369 (11.73)
US$50 000–US$75 000	2405 (19.17)	43 (0.34)	4377 (34.80)	4203 (33.77)	2764 (22.00)	1466 (11.71)
>US$75 000	3686 (17.90)	48 (0.23)	7005 (33.93)	6805 (33.31)	4013 (19.48)	2213 (10.77)
Refused, missing or do not know	1776 (18.78)	62 (0.66)	2645 (27.72)	2407 (25.97)	1712 (18.10)	894 (9.48)

ACE, adverse childhood experience; BRFSS, Behavioral Risk Factor Surveillance System.

asthma prevalence that persisted after adjusting for covariates. *Second*, we observed increasing asthma by categories of adversity, which has not been investigated in previous research. Studies on childhood adversity need to investigate the scope and meaning of this observed gradient, including whether these relationships hold for other health outcomes. *Third*, separate dimensions of ACE were associated with asthma prevalence, with the strength of the relationship varying by exposure.

The linkages between childhood adversity and asthma may be explained by the physiological evidence on the role of sociobiological and neurobiological mechanisms from stress and adversity. These mechanisms go on to impact immune and inflammatory responses, muscular and nervous system mechanisms, and hormonal and obesity-related mechanisms, all of which relate to asthma.[12–15] Studies on asthma prevalence have also attributed some of the disease burden to environmental risk factors, including poor control of pollutants (toxins, dust and mites) in the household.[36–42] There is also some evidence on *clustering* or co-occurrence of risks of disadvantages (socioeconomic, adversity and environmental risks) within households.[14 36 43 44] Studies have, in the past, examined the relationships between stress during pregnancy and postpregnancy and asthma among children.[9] The scope for connecting pregnancy and early life exposures to childhood adversity was not available in the BRFSS surveys, and needs to be investigated in future analyses.

An aspect needing more examination in studies of adversity pertains to the interrelatedness of dimensions.[33] Previous assessments of adversity have shown high degrees of interconnectedness, with the presence of one dimension of adversity increasing the probability of additional ACE exposures (adjusted odds between 2 and 17.7 times, median 2.8).[33] In our study, 12% of the respondents reported having experienced all dimensions of adversity and 23% reported the lowest category of adversity—experiencing parental discord and verbal abuse (see online supplementary table S1). This co-occurrence of multiple ACE dimensions also varied by gender. In our study, the reported experience of the overall ACE score was higher among women compared to men (15.08% vs 6.5%), but when sexual abuse was excluded, men (16.2%) reported higher ACE compared to women (12.44%). Lower levels of adversity did not show gender differences.

In addition to understanding the level of co-occurrence of experiences of adversity, examining the role of combinations of adverse experiences may potentially be another area for research in the future. Research needs to examine the health effects of combinations of adversity, and whether certain experiences singularly or in consonance with others have greater impacts than others. Our additional analyses (table 5) showed that experiencing multiple types of abuse (verbal, physical and sexual) can magnify risks for asthma, beyond the experience of a singular adversity dimension.

We adjusted for race/ethnicity and SES in the relationships between childhood adversity and asthma prevalence. Several studies have shown the racial/ethnic and SES patterning of asthma prevalence rates in the

USA.[44–48] A review on maltreatment highlighted the potential role of parental poverty and low educational achievement.[49] Since we did not have data on parental SES or SES of the respondents during childhood, we adjusted for own SES as a proxy for the same. Those in the lowest income and education groups reported higher rates on all dimensions of ACE, but since this information does not necessarily correspond to childhood SES, the patterning of the adversity–asthma relationship by SES remains unclear. Associations of smoking with adversity and asthma may also be another aspect of relevance,[27 50] with smoking either being potentially driven by experiences of adversity, or as an independent predictor of asthma. Adjusting for smoking in the analyses (see online supplementary table S4) would only be relevant if the attempt was to disentangle the behavioural determinants from neuroendocrinal mechanisms.

Limitations

Findings from this study need interpretation in light of certain limitations. While data from the BRFSS surveys provide tremendous value in surveying major health conditions and behaviours in the USA, these surveys, based on self-reported data and recall, may be prone to several limitations. *First*, adversity measured through ACE in the BRFSS surveys was self-reported and based on recall. Information was unavailable in the surveys on the exact timing or duration of the exposure. Social desirability bias, limited duration of questioning and the sensitivity of ACE questions may lead to underestimation of the true burden of ACE in the population.[51] A study on self-reporting of abuse in surveys has shown that self-reported accounts can be underestimates or overestimates.[52] *Second*, our analysis is based on childhood adversity data available from a subsample of the BRFSS from 10 states over 3 years. No information was available on why these states were chosen. *Third*, the data were cross-sectional, and hence this analysis only examined associations and does not present a causal argument. Information on age at asthma diagnosis was available based on recall for a subset, but this could not be related to the timing of the experience of adversity. *Fourth*, BRFSS asthma questions have not been systematically examined for reliability and validity, and diagnostic assessments are needed to compare the strengths and limitations of self-reported physician-diagnosed asthma prevalence in population-level studies. Even as the questions in the surveys on asthma have asked respondents about physician diagnoses, careful assessment is needed on the validity of these questions. *Finally*, BRFSS did not provide data on parental SES. A key element for future research in the area linking adversity to asthma will pertain to the SES linkages, which may also be relevant from an intervention point of view.

Conclusion

We found positive relationships between retrospectively reported childhood adversity and current and lifetime asthma prevalence. The framework for asthma prevention needs to recognise the importance of childhood adversity as an important risk factor. Greater investigation is needed to understand the specific time periods in which this experience may have an enhanced effect on the risks for asthma, along with linking it to early life exposures.

Contributors NB, MMG, IK and SVS jointly conceptualised the study. NB led the data analysis, interpretation and writing of the manuscript. MMG, IK and SVS contributed to the interpretation and writing of the manuscript and provided overall supervision.

Funding This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests At the time of research, NB was a doctoral student at the Harvard School of Public Health and received the Presidential Scholarship at Harvard University (2009–2013). SVS is supported by the Robert Wood Johnson Investigator Award in Health Policy Research; he was also partially supported by the National Institutes of Health Career Development Award (NHLBI K25 HL081275) when the study was conducted.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. Wright RJ. Epidemiology of stress and asthma: from constricting communities and fragile families to epigenetics. *Immunol Allergy Clin North Am* 2011;31:19–39.
2. Wright RJ. Perinatal stress and early life programming of lung structure and function. *Biol Psychol* 2010;84:46–56.
3. Wright RJ, Brunst KJ. Programming of respiratory health in childhood: influence of outdoor air pollution. *Curr Opin Pediatr* 2013;25:232–9.
4. Wright RJ, Enlow MB. Maternal stress and perinatal programming in the expression of atopy. *Expert Rev Clin Immunol* 2008;4:535–8.
5. Milam J, McConnell R, Yao L, *et al*. Parental stress and childhood wheeze in a prospective cohort study. *J Asthma* 2008;45:319–23.
6. Shankardass K, McConnell R, Jerrett M, *et al*. Parental stress increases the effect of traffic-related air pollution on childhood asthma incidence. *Proc Natl Acad Sci USA* 2009;106:12406–11.
7. Wright RJ, Cohen S, Carey V, *et al*. Parental stress as a predictor of wheezing in infancy: a prospective birth-cohort study. *Am J Respir Crit Care Med* 2002;165:358–65.
8. Chun TH, Weitzen SH, Fritz GK. The asthma/mental health nexus in a population-based sample of the United States. *Chest* 2008;134:1176–82.
9. Cookson H, Granell R, Joinson C, *et al*. Mothers' anxiety during pregnancy is associated with asthma in their children. *J Allergy Clin Immunol* 2009;123:847–53.e11.
10. Jackson JS, Knight KM, Rafferty JA. Race and unhealthy behaviors: chronic stress, the HPA axis, and physical and mental health disparities over the life course. *Am J Public Health* 2010;100:933–9.
11. Weidner G, Kohlmann CW, Dotzauer E, *et al*. The effects of academic stress on health behaviors in young adults. *Anxiety Stress Coping* 1996;9:123–33.
12. O'Connor TM, O'Halloran DJ, Shanahan F. The stress response and the hypothalamic-pituitary-adrenal axis: from molecule to melancholia. *QJM* 2000;93:323–33.
13. Rietveld S, Everaerd W, Creer TL. Stress-induced asthma: a review of research and potential mechanisms. *Clin Exp Allergy* 2000;30:1058–66.
14. Wright RJ, Rodriguez M, Cohen S. Review of psychosocial stress and asthma: an integrated biopsychosocial approach. *Thorax* 1998;53:1066–74.
15. Lugogo NL, Bappanad D, Kraft M. Obesity, metabolic dysregulation and oxidative stress in asthma. *Biochim Biophys Acta* 2011;1810:1120–6.

16. Sismanopoulos N, Delivanis DA, Mavrommati D, *et al*. Do mast cells link obesity and asthma? *Allergy* 2013;68:8–15.
17. Anda RF, Butchart A, Felitti VJ, *et al*. Building a framework for global surveillance of the public health implications of adverse childhood experiences. *Am J Prev Med* 2010;39:93–8.
18. Anda RF, Brown DW, Dube SR, *et al*. Adverse childhood experiences and chronic obstructive pulmonary disease in adults. *Am J Prev Med* 2008;34:396–403.
19. Anda RF, Brown DW, Felitti VJ, *et al*. Adverse childhood experiences and prescribed psychotropic medications in adults. *Am J Prev Med* 2007;32:389–94.
20. Chapman DP, Liu Y, Presley-Cantrell LR, *et al*. Adverse childhood experiences and frequent insufficient sleep in 5 U.S. States, 2009: a retrospective cohort study. *BMC Public Health* 2013;13:3.
21. Dube SR, Williamson DF, Thompson T, *et al*. Assessing the reliability of retrospective reports of adverse childhood experiences among adult HMO members attending a primary care clinic. *Child Abuse Neglect* 2004;28:729–37.
22. Dube SR, Miller JW, Brown DW, *et al*. Adverse childhood experiences and the association with ever using alcohol and initiating alcohol use during adolescence. *J Adolesc Health* 2006;38:444.e1–10.
23. Felitti VJ, Anda RF, Nordenberg D, *et al*. Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: the adverse childhood experiences (ACE) study. *Am J Prev Med* 1998;14:245–58.
24. Foege WH. Adverse childhood experiences: a public health perspective. (Editorial). *Am J Prev Med* 1998;14:354–5.
25. Hillis SD, Anda RF, Dube SR, *et al*. The association between adverse childhood experiences and adolescent pregnancy, long-term psychosocial consequences, and fetal death. *Pediatrics* 2004;113:320–7.
26. Strine TW, Dube SR, Edwards VJ, *et al*. Associations between adverse childhood experiences, psychological distress, and adult alcohol problems. *Am J Health Behav* 2012;36:408–23.
27. Strine TW, Edwards VJ, Dube SR, *et al*. The mediating sex-specific effect of psychological distress on the relationship between adverse childhood experiences and current smoking among adults. *Subst Abuse Treat Prev Policy* 2012;7:30.
28. Coogan PF, Wise LA, O'Connor GT, *et al*. Abuse during childhood and adolescence and risk of adult-onset asthma in African-American women. *J Allergy Clin Immunol* 2013;131:1058–63.
29. Scott KM, Smith DA, Ellis PM. A population study of childhood maltreatment and asthma diagnosis: differential associations between child protection database versus retrospective self-reported data. *Psychosom Med* 2012;74:817–23.
30. Hyland ME, Alkhalaf AM, Whalley B. Beating and insulting children as a risk for adult cancer, cardiac disease and asthma. *J Behav Med* 2013;36:632–40.
31. Centers for Disease Control and Prevention (CDC). *Behavioral risk factor surveillance system survey data*. Atlanta, Georgia: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2009–2011.
32. Toren K, Brisman J, Jarvholm B. Asthma and asthma-like symptoms in adults assessed by questionnaires: a literature review. *Chest* 1993;104:600–8.
33. Dong M, Anda RF, Felitti VJ, *et al*. The interrelatedness of multiple forms of childhood abuse, neglect and household dysfunction. *Child Abuse Negl* 2004;28:771–84.
34. Barros AJD, Hirakata VN. Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. *BMC Med Res Methodol* 2003;3:21.
35. Coutinho LM, Scazufca M, Menezes PR. (2008) Methods for estimating prevalence ratios in cross-sectional studies. *Rev Saude Publica* 2008;42:992–8.
36. Eggleston PA. The environment and asthma in US inner cities. *Chest* 2007;132(Suppl 5):782S–8S.
37. Landrigan PJ, Schechter CB, Lipton JM, *et al*. Environmental pollutants and disease in American children: estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities. *Environ Health Perspect* 2002;110:721–8.
38. Landrigan PJ. Environmental hazards for children in USA. *Int J Occup Med Environ Health* 1998;11:189–94. Review
39. Mendell MJ. Indoor residential chemical emissions as risk factors for respiratory and allergic effects in children: a review. *Indoor Air* 2007;17:259–77.
40. Nachman KE, Parker JD. Exposures to fine particulate air pollution and respiratory outcomes in adults using two national datasets: a cross-sectional study. *Environ Health* 2012;11:25.
41. Office of the Surgeon General (US). Report of the Surgeon General's Workshop on Healthy Indoor Environment. January 12–13, 2005, National Institutes of Health, Bethesda, MD. Rockville (MD): Office of the Surgeon General (US); 2005. Introduction.
42. Wong GW, von Mutius E, Douwes J, *et al*. Environmental determinants associated with the development of asthma in childhood. *Int J Tuberc Lung Dis* 2006;10:242–51.
43. Sandel M, Wright RJ. When home is where the stress is: expanding the dimensions of housing that influence asthma morbidity. *Arch Dis Child* 2006;91:942–8.
44. Williams DR, Sternthal M, Wright RJ. Social determinants: taking the social context of asthma seriously. *Pediatrics* 2009;123: S174.
45. Boudreaux ED, Emond SD, Clark S, *et al*. Acute asthma among adults presenting to the emergency department: the role of race/ethnicity and socioeconomic status. *Chest* 2003;124:803–12.
46. Chandra D, Clark S, Camargo CA Jr. Race/ethnicity differences in the inpatient management of acute asthma in the United States. *Chest* 2009;135:1527–34.
47. Payne-Sturges D, Gee SC. National environmental health measures for minority and low-income populations: tracking social disparities in environmental health. *Environ Res* 2006;102:154–71.
48. Subramanian SV, Jun HJ, Kawachi I, *et al*. Contribution of race/ethnicity and country of origin to variations in lifetime reported asthma: evidence for a nativity advantage. *Am J Public Health* 2009;99:690–7.
49. Gilbert R, Widom CS, Browne K, *et al*. Burden and consequences of Child Maltreatment in high-income countries. Child Maltreatment 1. *Lancet* 2009;373:68–81.
50. Vander Weg MW. Adverse childhood experiences and cigarette smoking: the 2009 Arkansas and Louisiana Behavioral Risk Factor Surveillance Systems. *Nicotine Tob Res* 2011;13:616–22.
51. Edwards VJ, Anda RF, Nordenberg DF, *et al*. Bias assessment for child abuse survey: factors affecting probability of response to a survey about child abuse. *Child Abuse Negl* 2001;25:307–12.
52. Haugaard JJ, Emery RE. Methodological issues in child sexual abuse research. *Child Abuse Negl* 1989;13:89–100.