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Latent factors of adverse childhood experiences and adult-onset asthma

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Original Article

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Abstract

Asthma is a chronic respiratory disease with complex etiology. Adverse childhood experiences (ACEs) have been linked to asthma in adulthood. Underlying potential mechanisms for the ACE-asthma relationship include stress-induced inflammatory pathways and immune dysregulation. We conducted a cross-sectional secondary data analysis of the 2013 Alberta ACE Survey to explore the relationship between latent ACE factors and self-reported adult asthma. We evaluated the underlying correlation structure among eight different ACEs using exploratory factor analysis. We conducted a logistic regression model to evaluate whether ACE factors retained from the factor analysis predicted self-reported asthma in adulthood. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). We analyzed ACE survey results from 1207 participants. Factor analysis yielded four ACE latent factors: factor 1/relational violence, factor 2/negative home environment, factor 3/illness at home, and factor 4/sexual abuse. Results of the logistic regression showed that experiencing sexual abuse (OR: 3.23; 95% CI: 1.89, 5.23), relational violence (OR: 1.99; 95% CI: 1.17, 3.38), and being exposed to a negative home environment (OR: 1.86; 95% CI: 1.03, 3.35) were predictive of a diagnosis of asthma in adulthood, whereas living in a household with someone experiencing illness did not show an effect (OR: 1.38; 95% CI: 0.75, 2.56). Factor analysis provides an effectual approach to understand the long-term impact of ACEs on respiratory health. Our findings have important implications to understand the developmental origins of asthma in adulthood and inform interventions aimed at reducing the lasting negative impact of childhood adversities on future respiratory health.

Introduction

Asthma is a chronic respiratory disease characterized by recurring episodes of airway inflammation, shortness of breath, wheeze, cough, and chest tightness.[1] Asthma is one of the most common chronic illnesses in Canada affecting approximately 10.8% (3.8 million) of the total population, with an average of 443 new cases diagnosed every day.[2] Asthma poses significant burden to the health care system and substantial adverse effects on health-related quality of life. In 2010–2011, approximately 0.8 million medical visits in Canada were attributed to asthma, constituting a major cause of productivity loss and school absenteeism.[2]

The etiology and pathogenesis of asthma is complex and not completely understood.[1] Current scientific evidence implicates a complex interplay of prenatal and early-life exposures, genetic factors, and environmental hazards in asthma causation pathways.[1,3] A growing body of research has identified harmful effects of early-life environmental exposures on asthma including maternal atopy and smoking, preterm birth and bronchopulmonary dysplasia, infections, and malnutrition.[4] Among these early-life exposures, adverse childhood experiences (ACEs) such as physical or sexual abuse, emotional maltreatment, and witnessing chronic relational violence have been linked to an increased susceptibility to developing asthma in adulthood.[5–13] Childhood trauma is thought to leave a lifelong negative impact on respiratory health that is mediated through stress-induced inflammatory pathways and immune dysregulation.[5–14]

Evidence indicates that ACEs often occur in clusters.[12,13] Consequently, recent studies have analyzed the cumulative effect of exposure to multiple ACEs on asthma onset.[9–12,15] Exposure to multiple ACEs has consistently been reported to increase the risk of adult asthma in a dose–response manner.[9,12,13] These findings suggest that ACEs are multidomain constructs encompassing different and overlapping adverse experiences and that ACE combinations are likely to have a cumulative effect on asthma onset.[10,13,16]

As the number of ACE exposures increases, elucidating their conjoined effects on health outcomes poses some statistical challenges. For example, large sample sizes would be required

to estimate the effects of large numbers of potential ACE combinations (e.g., a total of 26 different combinations theoretically would exist when 5 ACEs are to be evaluated, whereas 247 combinations could potentially exist if 8 ACEs are studied), making statistical modeling intractable. An alternative approach is to identify latent factors/constructs underlying diverse ACEs. Using this approach, a large number of ACEs can be parsimoniously represented by a smaller number of underlying latent factors.[17] Latent factors are unobserved variables that are inferred through mathematical models from other variables and that substantially reduce data dimensionality,[17] while providing significant insights into the relationship between ACEs and future health.[18] To our knowledge, the use of latent factors of ACEs has not been explored as an alternative to evaluate the relationship between ACEs and adult-onset asthma. Understanding how ACE latent factors influence asthma development in adult life may provide valuable insights for the design of integrative preventive strategies targeting children from families with high vulnerability to ACEs and help to reduce the impact of ACEs on asthma burden.

Using data from the 2013 Alberta Adverse Childhood Experiences survey (ACE survey),[12,19] the present study evaluated relations among eight types of ACE to identify latent factors of ACEs and assess their association with the development of asthma in adulthood. Our study objectives were (1) to identify latent factors characterizing the correlation structure among ACEs and (2) to evaluate the effect of ACE latent factors on adult asthma development. We hypothesized that ACEs are highly correlated; they can be represented by latent factors and that ACE latent factors associate with asthma in adulthood.

Methods

Study design and data sources

We conducted a cross-sectional secondary data analysis of the 2013 Alberta ACE Survey conducted by the Alberta Centre for Child, Family and Community Research.[12,19] Briefly, the ACE survey was a computer-assisted telephone survey using a random sample of 1207 adults living in Alberta (response rate 20.9%) that gathered sociodemographic data, information about adversity during childhood (defined as <18 years of age), and poor health outcomes in adulthood, including asthma and other respiratory problems. The survey had eight questions about ACEs that assessed individual exposures to abuse, neglect, and household dysfunction during childhood. Detailed methods for the original survey study are described elsewhere.[12] Ethics approval for this secondary analysis was obtained from the University of Alberta's Health Research Ethics Board (Study ID: Pro00083997). A data access agreement was signed with the data custodian (PolicyWise for Children and Families) to protect confidentiality and privacy of the original study participants.

Exposure variables

We obtained data on the following eight individual ACEs from the Alberta ACE survey: verbal insults (frequently experienced verbal insults or threats from an adult or parent in the household), physical abuse (experienced physical injury or bruise caused by a parent or adult in household), sexual abuse (experienced inappropriate sexual advances or contact by an adult or someone older to them by 5 years or more), witnessing violence against mother, alcohol/drug use at home, living in a household with someone with depression/mental illness, living in a household with someone with chronic illness/physical disability, and parental separation/divorce. Data on ACEs occurring before the age of 18 years were self-reported and measured on a binary scale (absent/present). No information about duration and severity of ACE exposure was collected in the survey.[19]

Study outcome and covariates

Participants in the Alberta ACE survey were asked questions about adult health diagnostic indicators (i.e., "Have you been diagnosed with any of the following health problems as an adult?") and if they received treatment or not (i.e., "If Yes, did you receive treatment?"). The primary outcome of interest was a self-reported diagnosis of asthma as an adult (>18 years of age). We obtained data on characteristics of the study population including sex, age, area of residence in Alberta (Edmonton/Calgary/other), and country of birth (Canada/elsewhere).

Statistical analysis

We described the characteristics of the study population using frequencies and percentages for categorical variables and mean with standard deviations for continuous variables. We performed an exploratory factor analysis to evaluate the underlying correlation structure of the eight ACEs. We used the bivariate polychoric correlation matrix as input and applied the maximum likelihood method for extracting the factor solution. Correlation values were interpreted as very high (0.90–1.00), high (0.70–0.89), moderate (0.50–0.69), low (0.30–0.49), and negligible (0.00–0.29).[20] The adequacy of the sample for factor analysis was estimated using the Kaiser–Meyer–Olkin test.[21]

We first used a scree plot to generate a plausible range of factors and then Bayesian information criterion (BIC)[22] and Akaike's information criterion (AIC)[22] to determine the number of ACE latent factors to be retained for subsequent analysis.[22] We applied a varimax Kaiser normalization rotation to improve interpretability of results and to pursue orthogonality of factors.[21] Factor loading coefficients were interpreted as the correlation between individual ACEs and the extracted latent factors. We used a path flow diagram to visually represent the relationship among the eight types of ACE, the latent factors derived from the factor analysis, and how the underlying latent factors were associated with a diagnosis of asthma in adulthood. Predictive factor scores (a linear combination of factor loadings and original variables) were to be used in logistic regression models.

We built a logistic regression model using predictive factor scores for the ACE latent factors retained and calculated odds ratios (ORs) with 95% confidence intervals (CIs) having self-reported adult asthma (yes/no; the nonasthma group was chosen as the reference group in the calculation of the ORs) as the outcome variable and resulting latent factors as explanatory variables while adjusting for sex (1 = male/0 = female) and being born in Canada (1 = yes/0 = no). Model diagnostics were run to evaluate the goodness of fit of the regression model. We estimated the minimally detectable OR for the survey population ($n = 1207$) using the lowest prevalence of ACE exposure (physical abuse: 11%) and the prevalence of asthma in the absence of ACE (~7%) for a power of 80% according to formulas of power and sample size calculations for logistic models.[23] Our study sample had a statistical power of 80% to detect an OR of 2.17.

We followed the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for reporting study design

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Table 1. Sociodemographic characteristics and prevalence of adverse childhood experiences reported in the 2013 Alberta Adverse Childhood Experiences survey (*n* respondents = 1207)

Characteristics	*n* (%)
Sex	
Male	595 (49%)
Female	612 (51%)
Born in Canada	965 (80%)
Area of residence in Alberta	
Edmonton	404 (34%)
Calgary	402 (33%)
Other	401 (33%)
Alcohol/drugs use at home	256 (21%)
Depression/mental illness at home	245 (20%)
Chronic illness/physical disability at home	236 (20%)
Parental separation/divorce	213 (18%)
Experienced verbal insults in childhood	205 (17%)
Experienced sexual abuse in childhood	179 (15%)
Witnessing violence against mothers in childhood	160 (13%)
Experience physical abuse in childhood	133 (11%)

and results.[24] All statistical analyses were conducted using STATA Data Analysis and Statistical Software (Version SE 14.2; StataCorp LLC, College Station, Texas, USA).

Results

We analyzed ACE survey results from the 1207 completed interviews. The mean age of survey respondents was 51 years (range: 17–94 years). Female-to-male ratio was 1.03. The response rates for ACE questions were very high, ranging from 98.9% to 99.7%. About 80% of respondents were born in Canada, 67% resided in the two main metropolitan areas of Edmonton and Calgary, whereas 33% had residence elsewhere in Alberta. About 9% ($n = 106$) of the survey population reported being diagnosed with asthma in adulthood. Alcohol/drug abuse at home (21%) was the most commonly experienced ACE, and the least frequently reported ACE was physical abuse (11%). Table 1 describes the key characteristics of the survey population related to ACEs and the prevalence of individual ACEs. For detailed descriptions of the study population, please refer to the original study by McDonalds *et al.*[12]

Results from bivariate polychoric correlation analysis revealed that all eight ACEs were positively correlated, although with different degrees of correlation.[20] For example, a high correlation was observed for physical abuse and verbal insults (0.87), moderate correlations for witnessing violence against mothers and physical abuse (0.69), sexual abuse, and verbal insults (0.52); and negligible correlations for chronic illness/physical disability at home and parental separation/divorce (0.11). Detailed polychoric correlation coefficients including the absolute number of cases per dual exposures for the eight ACE types are presented in Table 2.

Factor analysis based on a bivariate polychoric correlation matrix yielded four ACE latent factors. We retained the four ACE latent factors after interpreting the scree plot criteria (Fig. 1), communalities, and the BIC and AIC values calculated for models that sequentially included the four ACE latent factors. The corresponding BIC/AIC values for the models including one to four latent factors were 924.6/883.8, 334.2/258, 178.3/71.6, and 187.5/55.5, respectively. Thus, BIC favored a three-latent-factor model, whereas AIC favored a four-latent factors model. In the three-latent-factor model, the communality of sexual abuse was 0.32 (very low), whereas the communality in the four-latent-factor model increased to 0.78. The variable-related communality is the variance in the measured variable that is explained by all the factors in the model. Thus, the low communality of sexual abuse in the three-latent-factor solution suggests that this variable is not part of the three domains suggested by the factor model. The inclusion of the four-factor substantially increased the communality for sexual abuse, suggesting that the four-factor-latent model is better compared to the three-latent-factor solution.

As a result of combining all criteria, we retained the four-latent-factor model for further analysis. Table 3 shows the factor loadings, communality, and uniqueness of individual ACEs after rotation of the retained factors. Factor 1 – termed *relational violence* – had the highest positive loadings (i.e., a high correlation between the variable and the latent factor after controlling for other factors in the model) on physical abuse (0.84), verbal insults (0.85), and witnessing violence against mothers (0.52). Factor 2 was closely associated with alcohol/drug use at home (0.71), witnessing violence against mothers (0.67), and parental separation/divorce (0.60) and was termed as *negative home environment* factor. Factor 3 was closely associated with living in a household with someone with depression/mental illness (0.54) and chronic illness/physical disability (0.54) and was termed as *illness-at-home* factor. Factor 4 was mainly associated with sexual abuse (0.79) and was termed *sexual abuse*. Witnessing violence inflicted to the mother was associated with both factors 1 and 2. Chronic illness/physical disability and parental separation/divorce showed communalities below 0.5 (0.30 and 0.43, respectively), indicating that they were not well explained/represented by the latent factors they were related to. Fig. 2 shows a path diagram of the relationship among the eight types of ACE, latent ACE factors, and adult-onset asthma.

Results from the logistic regression analysis showed that three out of the four ACE latent factors were associated with a self-reported diagnosis of asthma in adulthood. Table 4 shows the logistic regression model for the prediction of an asthma diagnosis in adulthood. Adjusted ORs by sex (male/female), area of residence, and country of birth (Canada/elsewhere) indicated that factor 4/sexual abuse (OR: 3.23; 95% CI: 1.89, 5.53), factor 1/relational violence (OR: 1.99; 95% CI: 1.17, 3.38), and factor 2/negative home environment (OR: 1.86; 95% CI: 1.03, 3.35) were significant predictors of a diagnosis of asthma in adulthood, whereas factor 3/illness at home (OR: 1.38; 95% CI: 0.75, 2.56) did not show such association. For comparative purposes, we estimated the OR for the logistic model including the eight ACEs as explanatory variables adjusted by sex and born (yes/no) in Canada, and corresponding variance inflation factors. The results are presented in Supplementary Material (Supplementary Table S1).

Discussion

We conducted a secondary data analysis of the 2013 Alberta ACE survey to evaluate the relationship between latent factors underlying childhood adversities and an increased risk of asthma diagnosis in adulthood. Our study confirms existing evidence that different types of ACEs frequently exist in clusters.[11–13,25] We found that the eight ACEs evaluated in our study had various degrees of

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Table 2. Bivariate polychoric correlation matrix showing correlation coefficients and total number of cases (*n*) for the eight ACEs* ($n = 1207$)

	Verbal insults	Physical abuse	Sexual abuse	Witnessing violence against mothers	Alcohol/drug use at home	Depression/ mental illness in family	Chronic illness/ physical disability at home	Parental separation/ divorce
Verbal insults	1 (205)	0.87 (106)	0.52 (78)	0.67 (90)	0.49 (96)	0.51 (95)	0.24 (63)	0.34 (67)
Physical abuse		1 (133)	0.50 (55)	0.69 (70)	0.46 (65)	0.43 (61)	0.15 (36)	0.37 (49)
Sexual abuse			1 (179)	0.43 (57)	0.33 (69)	0.39 (73)	0.16 (48)	0.33 (59)
Witnessing violence against mothers				1 (160)	0.64 (98)	0.49 (76)	0.14 (42)	0.52 (72)
Alcohol/drug use at home					1 (256)	0.55 (117)	0.25 (76)	0.51 (100)
Depression/mental illness in family						1 (245)	0.35 (85)	0.35 (79)
Chronic illness/physical disability at home							1 (236)	0.11 (52)
Parental separation/ divorce								1 (213)

*This matrix was the input for factor analysis.

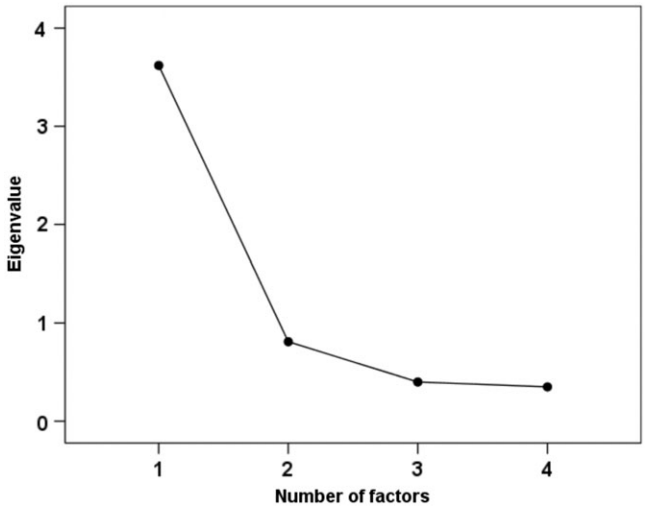

Fig. 1. Scree plot of latent ACE factors extracted from factor analysis.
The scree plot is showing the eigenvalues of the four factors extracted from factor analysis, with eigenvalues on the y-axis and the number of factors on the x-axis. For the first three factors, the curve is reasonably dropping, suggesting that a three-factor model or a four-factor model may be appropriate.

correlation among them. It has been previously reported that exposure to multiple types of ACEs compounds the risk of adverse health outcomes.[9,11–13] ACE management programs need to take into consideration the high likelihood of coexistence of various types of adversities during childhood and design multimodal interventions to prevent the negative impact of ACEs on adult health.

Sexual abuse was identified to be a different exposure compared to the other ACEs. The relationship between childhood sexual abuse and poor health in adult life has been well established[13]; however, most studies have grouped sexual and physical abuse altogether. In our study, experiences of sexual abuse during childhood were identified as a strong predictor of asthma in adulthood. Childhood sexual abuse is an early-life traumatic event with important consequences to the hypothalamic–pituitary–adrenal axis. The trauma generated by these experiences, particularly if they are chronic and pervasive, can trigger specific immunological and neuroendocrine imbalances and lead to different impacts on inflammatory markers associated with asthma.[26]

Results from the exploratory factor analysis suggest that childhood experiences of relational violence – either directly inflicted to the child or indirect experiences of witnessing violence – are highly correlated and together are significant predictors of adult asthma. These findings are consistent with previous studies suggesting that exposure to violent behaviors during childhood (e.g., domestic violence or parental interpartner violence) is linked to increased susceptibility for asthma development in adulthood.[5–8] The biological mechanisms through which childhood experiences of violence continue to impact health later in life are not well understood. It has been hypothesized that ACEs impact respiratory health through stress-induced inflammatory pathways and immune dysregulation[6,12] that trigger a myriad of behavioral and biological responses.[27–29] Studies suggest that exposures to early-life stress can have a deleterious impact on biological stress responses,[29] immune system, and airway development which, in turn, may lead to symptoms of airway hyper-responsiveness in adulthood.[27,28] A recent literature review presented a *biological embedding model* that posits that exposure to stress in childhood creates chronic pro-inflammatory responses and endocrine dysregulations that manifest as risky health behaviors and morbidities in adulthood.[29] The combination of experiencing both first- and second-hand violence in childhood may reflect a milieu of physical and psychological stress that exerts lingering damage and results in poor health outcomes later in life. Future work in this area should further explore biological markers associated with ACE-mediated psychophysiological stress and their role in the ACE-adult asthma causal trajectory.

A negative home environment was also found to be strongly associated with a diagnosis of asthma in adulthood. The fact that diverse ACE types (i.e., witnessing violence against mothers, parental separation/divorce and alcohol/drug use at home) were highly to moderately correlated with each other and that they had a unidimensional effect altogether suggests that the correlation

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Table 3. Matrix of the rotated* factor loadings for the four-latent-factor solution from the eight ACEs

ACE	Factor loadings[a]				Communality[b]	Uniqueness[c]
	Factor 1	Factor 2	Factor 3	Factor 4		
Verbal insults	0.85	0.25	0.28	0.23	0.91	0.09
Physical abuse	0.84	0.30	0.10	0.22	0.86	0.14
Sexual abuse	0.29	0.25	0.22	0.79	0.78	0.22
Witnessing violence against mothers	0.52	0.67	0.10	0.15	0.76	0.24
Alcohol/drug use at home	0.23	0.70	0.33	0.07	0.69	0.31
Depression/mental illness in family	0.25	0.41	0.57	0.19	0.56	0.44
Chronic illness/physical disability at home	0.07	0.06	0.53	0.05	0.30	0.70
Parental separation/divorce	0.15	0.60	0.07	0.18	0.43	0.57

*We used the Kaiser orthogonal varimax method of rotation. After rotation, the proportion of variance was 36.4% for factor 1, 32.2%; for factor 2, 15.9% for factor 3, and 15.5% for factor 4. The overall Kaiser–Meyer–Olkin (KMO) value was 0.835. The minimum KMO value was 0.75 for Chronic illness/physical disability at home (a value of 0.70 or above in considered adequate for factor analysis[20]).
[a]Factor loadings represent the correlation between the variable and the latent factor after controlling for other factors in the model. Values range between −1 and 1 (although in oblique rotations, these coefficients can be greater than 1 or less than −1).
[b]Communality represents the variance in the measured variable that is explained by all the factors in the model.
[c]Uniqueness represents the unexplained variance in each individual item that is not explained by the factors in the model.

Table 4. Logistic regression model for the prediction of adult-onset asthma using ACE latent factors 1, 2, and 3 derived from the exploratory factor analysis

Predictor	Unadjusted odds ratio[a] (95% confidence interval)	Adjusted odds ratio[b] (95% confidence interval)**
Factor 1/relational violence	1.98 (1.17, 3.35)	1.99 (1.17, 3.38)
Factor 2/negative home environment	1.92 (1.07, 3.45)	1.86 (1.03, 3.35)
Factor 3/illness at home	1.51 (0.82, 2.77)	1.38 (0.75, 2.56)
Factor 4/sexual abuse	3.35 (2.01, 5.58)	3.23 (1.89, 5.53)

Variance inflation factors (VIFs): factor 1 = 1.08, factor 2 = 1.07, factor 3 = 1.02, factor 4 = 1.02. These VIFs can be compared with those including the eight ACEs as explanatory variables in Supplementary Table S1. VIF values indicate how much the variance of a coefficient is "inflated" because of linear dependence with other predictors.
Factor scores are estimated from a linear combination of observed variables and factor loadings as a by-product of the factor analysis. Conceptually, factor scores represent the degree to which each individual scores high on the group of items that load high on a factor (See Supplementary Table S2).
The ORs can be interpreted as the odds of asthma increase as the factor loadings increase. An OR above 1 and excluding the 95% CI indicate that the factor loadings were higher in the asthma group compared to the reference group (see Supplementary Table S2).
**Adjusted for sex (male/female) and country of birth (Canada/elsewhere); goodness of fit (Hosmer–Lemeshow test) *P*-value = 0.133.
Reference category: no asthma.
[a]Model statement for unadjusted OR: Outcome: asthma (0 = no/1 = yes): log(odds) = Factor 1 + Factor 2 + Factor 3 + Factor 4. Goodness of fit (Hosmer–Lemeshow test) *P*-value = 0.15
[b]Model for adjusted OR: log(odds) = Factor 1 + Factor 2 + Factor 3 + Factor 4 + sex (0 = female/1 = male) + born in Canada (0 = no/1 = yes). Factors 1 to 4 are continuous variables represented by factor scores; goodness of fit (Hosmer–Lemeshow test) *P*-value = 0.133.

structure underlying several ACEs is complex and that estimation of individual and combined effects of ACEs can be challenging due to collinearity issues. Therefore, classification of ACEs as unique individual exposures or independent groups of experiences may be unrealistic. Our analysis suggests that conceptualization of ACEs based on latent factors provides an alternative and comprehensive approach to understanding the relationships between ACEs and their long-term impact on health outcomes. Future ACE studies can use a similar approach to explore other negative health outcomes commonly associated with ACEs such as heart disease, hypertension, and mental distress.[11,27] Another area that merits further attention is exploring the impact of other related asthma triggers such as maternal smoking, and socioeconomic status[3] on the relationship between a negative home environment and a diagnosis of asthma in adulthood.

Other studies have also used factor analysis and similar techniques to create ACE clusters with similar factorial structure.[30,31] Only a few studies have evaluated the association between ACE clusters and specific long-term outcomes in adulthood (e.g., cancer[32] and mental health disorders[33]). As different factor solutions have been suggested to fit the data in these studies, it is expected that they influence how ACE clusters associate with long-term health outcomes. Our study adds novel information to this area of research as we identified a four-factor solution for ACEs that account for significant associations with asthma in adulthood. This finding highlights the need to identify common risk factors among specific adverse experiences that can convey useful information for targeted prevention and mitigation interventions.

The potential use of latent factors of ACEs as predictors of adult-onset asthma has implications for clinical practice. To date, clinical prediction models for asthma have mainly focused on genetic and environmental risk factors such as family history of asthma, parental atopy, recurrent wheezing, and maternal smoking.[34–36] Researchers developing asthma prediction tools should consider the inclusion of psychosocial stressors such as ACEs as potential asthma predictors for a comprehensive assessment of future asthma risk. It would be interesting to compare the accuracy of traditional asthma prediction models with a clinical tool incorporating evaluation of ACEs and other psychosocial stressors. Comprehensive asthma prediction tools may assist clinicians to devise timely preventive interventions and reduce asthma incidence in adult life.[37]

Our study had several strengths that included the use of population-based survey data that captured ACEs in a sample from the general population in Alberta. Our logistic regression analysis had a statistical power of 80% to detect an OR of at least 2.17. Although some of the effect sizes were smaller than 2.17 (i.e. OR: 1.86 for negative home environment), it is still clinically important

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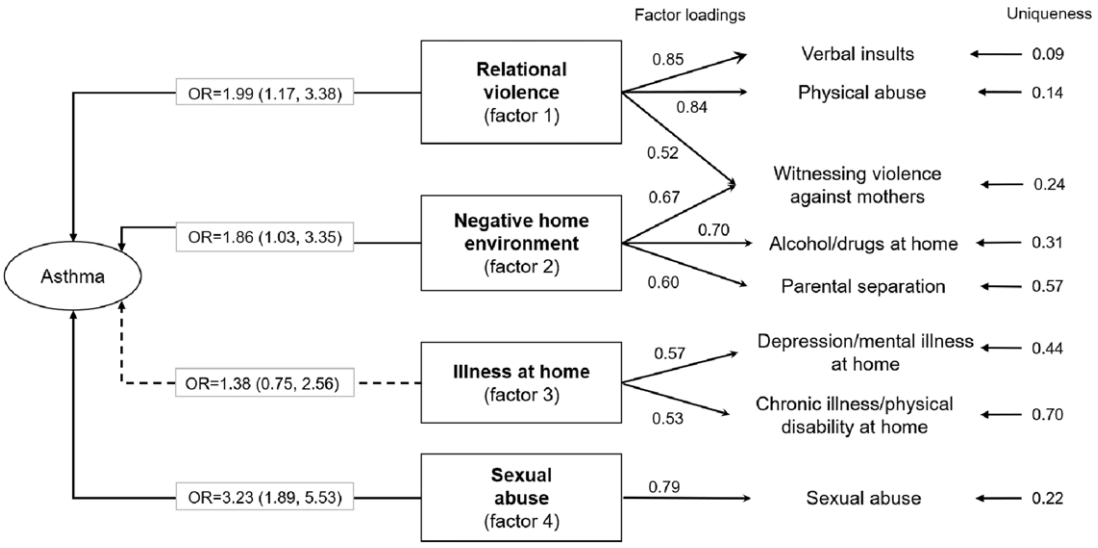

Fig. 2. Path diagram of the relationship among the eight types of ACE, latent ACE factors, and adult-onset asthma.
Outcome: Asthma (0 = no/1 = yes). Reference category: No asthma. Model: log (odds) = Factor 1 + Factor 2 + Factor 3 + Factor 4 + sex (0 = female/1 = male) + born in Canada (0 = no/1 = yes). Dashed lines indicate a 95% CI of OR including the null value of 1 between the latent factor and asthma. Factor loadings represent the correlation between the variable and the latent factor after controlling for other factors in the model. Uniqueness represents the unexplained variance attributed to the factors in the model.

to identify effects smaller than this statistical threshold. Moreover, the large sample size and the correlation structure among ACEs were adequate for investigating latent factors (as indicated by the Kaiser–Meyer–Olkin test). Using factor analysis methods, eight ACE types were reduced to four latent factors which allowed the use of factor scores into a prediction model of adult asthma while avoiding multicollinearity problems and the inclusion of too many parameters related to double and triple interactions.[22]

Our study had some limitations that should be considered when interpreting the results. Due to the cross-sectional nature of the study, caution should be observed while making inferences based on the study results. The use of retrospectively collected survey data has inherent potential for misclassification and recall bias.[12] However, our findings are supported by existing literature[5–10] and have implications for future ACE research, ACE management policies, and clinical practice. The 2013 Alberta ACE survey$_{12}$ had a low response rate that is common among telephone surveys conducted in Alberta.[38] It has been argued that a low participation rate does not necessarily imply a high risk of nonresponse bias,[39] but that the difference between participants and nonparticipants would determine the magnitude of bias. Authors of the 2013 Alberta ACE survey reported that the characteristics of the study sample reflected the sociodemographic profile of the province, strengthening the generalizability of the findings.

The ACE survey did not collect information about the temporality and duration of ACEs, and therefore, we were not able to evaluate whether exposures to ACEs at early ages were more likely among individuals reporting asthma in adulthood.

There is no consensus on the best approach to assess ACEs.[40] The 2013 Alberta ACE survey used self-reported information to assess the prevalence of eight ACE types. Self-reported measures of childhood abuse are likely to be underreported due to hesitance to disclose sensitive information.[40] This characteristic is common in social/psychological research. For example, childhood sexual abuse is likely to be underreported, especially if the child's parents are the main perpetrators.[7] It is possible that underreporting of sexual abuse in our sample accounts for the modest relationship with relational violence (factor 1). Other factors that may influence the accuracy of ACE reporting include time passed since the ACEs occurred, the frequency and intensity of adversity experience, and the type of abuse suffered.[40] It is unknown whether these characteristics may have affected the ACE survey results. The 2013 Alberta ACE study was a telephone survey, administered by trained interviewers, and confidential which is likely to have facilitated the reporting of ACEs.[12] Further studies are needed to find optimal approaches to assess childhood adversities in research and clinical context.

Asthma was defined in the 2013 Alberta ACE survey by self-reported diagnosis as an adult. Defining asthma in epidemiological studies is a well-known challenge as it is prone to misclassification.[41] However, self-reported diagnosis of asthma has been frequently used in population-based studies as a reliable and cost-effective alternative to lung function measurements which may not be readily available in every setting.[9,10,35,41,42] Therefore, the ACE survey definition of asthma was appropriate to explore the relationship between ACEs and adult asthma.

The 2013 Alberta ACE survey did not collect important information about the characteristics of the home environment when the ACEs occurred. Therefore, we were not able to explore the role of important mediators of the relationship between ACE and asthma in adulthood (e.g., socioeconomic status, nutrition, home crowding, parental smoking, or nutrition status in childhood). Data on sociodemographic characteristics (e.g., socioeconomic status, education, and employment) were collected at the time of survey and may not reflect childhood exposures. Hence, we were not able to account for these variables in our analysis.

Using data from the 2013 Alberta ACE survey, the present study evaluated the relationship between latent factors of ACEs and asthma in adulthood. We found that childhood experiences of sexual abuse, relational violence, and a negative home environment are strongly predictive of asthma in adulthood. These findings provide valuable insights into the developmental origins of adult asthma and may help design effective ACE management strategies targeting children at risk of experiencing poor respiratory health in

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adulthood. Conceptualization of ACEs based on latent factors provides a valid alternative approach to understand ACE effects and merits attention in future studies exploring ACEs and their negative effects on long-term health.

Supplementary Material. To view supplementary material for this article, please visit https://doi.org/10.1017/S2040174419000886

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Conflicts of Interest. None.

References

1. Global Initiative for Asthma. Global strategy for asthma management and prevention, 2019 [Internet]. 2019. [cited 25 November 2019]. Available from: www.ginasthma.org.
2. Public Health Agency of Canada. Report from the Canadian Chronic Disease Surveillance System: Asthma and Chronic Obstructive Pulmonary Disease (COPD) in Canada, 2018 [Internet]. 2018. [cited 25 November 2019]. Available from: https://www.canada.ca/content/dam/phac-aspc/documents/services/publications/diseases-conditions/asthma-chronic-obstructive-pulmonary-disease-canada-2018/pub-eng.pdf
3. Subbarao P, Mandhane P, Sears M. Asthma: epidemiology, etiology and risk factors. *CMAJ*. 2009; 181, E181–E190.
4. Bobolea I, Arismendi E, Valero A, Agustí A. Early life origins of asthma: a review of potential effectors. *J Investig Allergol Clin Immunol*. 2019; 29, 168–179.
5. Abajobir AA, Kisely S, Williams G, *et al.* The association between substantiated childhood maltreatment, asthma and lung function: a prospective investigation. *J Psychosom Res*. 2017; 101, 58–65.
6. Exley D, Norman A, Hyland M. Adverse childhood experience and asthma onset: a systematic review. *Eur Respir J*. 2015; 24, 299–305.
7. Cohen RT, Canino GJ, Bird HR, Celedón JC. Violence, abuse, and asthma in Puerto Rican children. *Am J Respir Crit Care Med*. 2008; 178, 453–459.
8. Goodwin RD, Wamboldt MZ, Pine DS. Lung disease and internalizing disorders. *J Psychosom Res*. 2003; 55, 215–219.
9. Remigio-Baker RA, Hayes DK, Reyes-Salvail F. Adverse childhood events are related to the prevalence of asthma and chronic obstructive pulmonary disorder among adult women in Hawaii. *Lung*. 2015; 193, 885–891.
10. Bhan N, Glymour MM, Kawachi I, *et al.* Childhood adversity and asthma prevalence: evidence from 10 US states (2009–2011). *BMJ Open Respir Res*. 2014; 1, e000016.
11. Iniguez KC, Stankowski RV. Adverse childhood experiences and health in adulthood in a rural population-based sample. *J Clin Med Res*. 2016; 14, 126–137.
12. McDonald S, Kingston D, Bayrampour H, Tough S. Adverse childhood experiences in Alberta, Canada: a population based study. *Med Res Arch*. 2015; 3, 1–18.
13. Hughes K, Bellis MA, Hardcastle KA, *et al.* The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. *Lancet Public Health*. 2017; 2, e356–e366.
14. Danese A, McEwen BS. Adverse childhood experiences, allostasis, allostatic load, and age-related disease. *Physiol Behav*. 2012; 106, 29–39.
15. Wing R, Gjelsvik A, Nocera M, McQuaid EL. Association between adverse childhood experiences in the home and pediatric asthma. *Ann Allergy Asthma Immunol*. 2015; 114, 379–384.
16. Moylan CA, Herrenkohl TI, Sousa C, *et al.* The effects of child abuse and exposure to domestic violence on adolescent internalizing and externalizing behavior problems. *J Fam Violence*. 2010; 25, 53–63.
17. Fabrigar LR, Wegener DT. *Exploratory Factor Analysis*, 2012. Oxford University Press, New York.
18. Lew D, Xian H. Identifying distinct latent classes of adverse childhood experiences among US children and their relationship with childhood internalizing disorders. *Child Psychiatry Hum Dev*. 2019; 50, 668–680.
19. The Alberta Adverse Childhood Experiences Survey 2013 [Internet]. 2016 [cited 24 June 2019]. Available from: http://sagemetadata.policywise.com/nada/index.php/catalog/3
20. Hinkle DE, Wiersma W, Jurs SG. *Applied Statistics for the Behavioral Sciences*. 5th ed. 2003. Houghton Mifflin, Boston.
21. Meyers L, Gamst G, Guarino A. *Applied Multivariate Research*. 2nd ed. 2013. SAGE Publications Inc., Thousand Oaks.
22. Preacher KJ, Zhang G, Kim C, Mels G. Choosing the optimal number of factors in exploratory factor analysis: a model selection perspective. *Multivar Behav Res*. 2013; 48, 28–56.
23. Demidenko E. Sample size and optimal design for logistic regression with binary interaction. *Stat Med*. 2008; 27, 36–46.
24. Vandenbroucke JP, von Elm E, Altman DG, *et al.* Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *Epidemiology*. 2007; 18, 805–835.
25. 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, 771–784.
26. Baumeister D, Akhtar R, Ciufolini S, Pariante CM, Mondelli V. Childhood trauma and adulthood inflammation: a meta-analysis of peripheral C-reactive protein, interleukin-6 and tumour necrosis factor-α. *Mol Psychiatry*. 2016; 21, 642–649.
27. Nurius PS, Green S, Logan-Greene P, Borja S. Life course pathways of adverse childhood experiences toward adult psychological well-being: a stress process analysis. *Child Abuse Negl*. 2015; 45, 143–153.
28. Coogan P, Wise L, O'Connor G, *et al.* Abuse during childhood and adolescence and risk of adult-onset asthma in African American women. *J Allergy Clin Immunol*. 2013; 131, 1058–1063.
29. Segerstrom S, Miller G. Psychological stress and the human immune system: a meta-analytic study of 30 years of inquiry. *Psychol Bull*. 2004; 130, 601–630.
30. Ford DC, Merrick MT, Parks SE, *et al.* Examination of the factorial structure of adverse childhood experiences and recommendations for three subscale scores. *Psychol Violence*. 2014; 4, 432–444.
31. Scott BG, Burke NJ, Weems CF, *et al.* The interrelation of adverse childhood experiences within an at-risk pediatric sample. *J Child Adolesc Trauma*. 2013; 6, 217–229.
32. Brown MJ, Thacker LR, Cohen SA. Association between adverse childhood experiences and diagnosis of cancer. *PLoS One*. 2013; 8, e65524.
33. Green JG, McLaughlin KA, Berglund PA, *et al.* Childhood adversities and adult psychiatric disorders in the national comorbidity survey replication I: associations with first onset of DSM-IV disorders. *Arch Gen Psychiatry*. 2010; 67, 113–123.
34. Miller G, Chen E, Parker K. Psychological stress in childhood and susceptibility to the chronic diseases of aging: moving toward a model of behavioral and biological mechanisms. *Psychol Bull*. 2011; 137, 959–997.
35. Luo G, Nkoy F, Stone B, Schmick D, Johnson M. A systematic review of predictive models for asthma development in children. *BMC Med Inform Decis Mak*. 2015; 15, 99.

36. Castro-Rodríguez JA, Holberg CJ, Wright AL, Martinez FD. A clinical index to define risk of asthma in young children with recurrent wheezing. *Am J Respir Crit Care Med*. 2000; 162, 1403–1406.
37. Balemans WA, van der Ent CK, Schilder AG, *et al*. Prediction of asthma in young adults using childhood characteristics: development of a prediction rule. *J Clin Epidemiol*. 2006; 59, 1207–1212.
38. Kingston D, McDonald S, Tough S, *et al*. Public views of acceptability of perinatal mental health screening and treatment preference: a population based survey. *BMC Pregnancy Childbirth*. 2014; 14, 67-2393-14-67. doi: 10.1186/1471-2393-14-67
39. Galea S, Tracy M. Participation rates in epidemiologic studies. *Ann Epidemiol*. 2007; 17, 643–653.
40. McKinney C, Harris T, Caetano R. Reliability of self-reported childhood physical abuse by adults and factors predictive of inconsistent reporting. *Violence Vict*. 2009; 24, 653–668.
41. Pekkanen J, Pearce N. Defining asthma in epidemiological studies. *Eur Respir J*. 1999; 14, 951.
42. Toren K, Palmqvist M, Lowhagen O, *et al*. Self-reported asthma was biased in relation to disease severity while reported year of asthma onset was accurate. *J Clin Epidemiol*. 2006; 59, 90–93.