

Dietary Factors Associated with Asthma Prevalence Among Children in California

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Background: Asthma continues to be the leading chronic disease affecting children in the United States. With mounting evidence of how diet plays a role in both chronic and allergic diseases, it is important to identify types of foods that may potentially promote a pro-inflammatory state. The study aims to examine the association between current asthma prevalence and intake of specific foods among children in California.

Methods: Cross-sectional study conducting secondary analysis of data from the 2001 to 2015 California Health Interview Survey (CHIS) child surveys. A total of 65,565 completed surveys met the eligibility criteria (children ages 2–11) between the years 2001 and 2015. After excluding children with less than 2 years of age (for whom diet questions were not asked), analysis was conducted using 56,312 surveys. Multivariable logistic regression models estimated the adjusted odds ratios (ORs) and 95% CIs for the association of dietary intake with current asthma, controlling for confounding variables: gender, age, race, weight status, parent's education, English language proficiency of parent, household income, and location of residence. Analyses were survey weighted using raking variables to adjust for the oversampling and nonresponse surveys to reflect California Department of Finance Population Estimates for each survey period.

Results: Approximately 13.4% of children in California currently have asthma. Consuming three or more sodas per day (adjusted OR=1.83, 95% CI: 1.22–2.76, $P=0.004$), two or more servings of French fries per day (adjusted odds ratio=1.89, 95% CI: 1.08–3.21, $P=0.026$), and fast food two or more times per week (adjusted odds ratio=1.21, 95% CI: 1.02–1.45, $P=0.031$) were positively associated with the prevalence for asthma.

Conclusion: Analysis showed that children consuming energy dense foods were significantly associated with greater odds for current asthma after controlling for potential confounders.

Keywords: diet, fast food, asthma, children, California Health Interview Survey

Introduction

ASTHMA CONTINUES to be the leading chronic disease affecting children in the United States, ~6.1 million (8.4%).^{1,2}

Asthma is a chronic inflammatory disease where the airways are hyperresponsive to a wide range of stimuli resulting in inflammation and narrowing of the airways.¹ Asthma relates to environmental factors (mites, fungi, pollen, airborne pollutants, and virus infection) and individual genetic factors.³ The connection between external factors and genetic predisposition leads to bronchial hyperactivity with increased IgE production, inflammatory reaction, and bronchial remodeling.

TH2 (Lymphocyte T Helper Type 2) immunity is crucial in asthma pathogenesis. The allergic inflammatory response is initiated by the interaction of environmental allergens with TH2. These, in turn, produce cytokines responsible for initiating and maintaining the inflammatory process—IL-4, IL-5, IL-9, and IL-13. IL-4 plays an essential role in increasing the production of allergen-specific IgE antibodies.³

Oxidative stress may play a pathological role in the production of prooxidants, such as reactive oxidative species, possibly contributing toward asthma.⁴ Ercan et al. found that children with asthma had significantly higher plasma levels of malondialdehyde, an indirect marker for systemic oxidative stress, compared with their healthy counterparts.⁵ In addition

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to elevated markers for oxidative stress, asthma is also highly related to obesity and its comorbidities.⁶

With mounting evidence of how diet plays a role in both chronic and allergic diseases, it is important to identify types of foods that may potentially promote a pro-inflammatory state.⁷ Saturated fats have shown to activate innate immune system and increase the circulation of mediators like IL-6, TNF-alpha, and leptin, all important factors that induce asthma.⁸

Children in the United States are particularly at risk of consuming high energy-dense processed foods, which dominate their palate, as well as potentially decreasing intake of needed vitamins, minerals, and essential fatty acids as evidenced in gut microbiota.⁹ According to Huang et al. (2015), specific microbiota is linked and may modulate the inflammatory process in patients with asthma.¹⁰

In the present study, we want to explore the association of asthma prevalence with types of food consumed by children in California, ages 2–11. We will also explore sociodemographic factors related to asthma prevalence. Ultimately, we want to deliver information to practitioners ensuring a more targeted nutrition intervention for diverse populations.

Methods

Design and participants/settings

This was a cross-sectional study conducting secondary analysis of public use data from the 2001 to 2015 California Health Interview Survey (CHIS) child surveys. CHIS is the nation's largest state survey and examines a variety of health conditions as it relates to diet, environment, and access to health care. CHIS is overseen by the University of California, Los Angeles Center for Health Policy Research (UCLA CHPR) in collaboration with the California Department of Public Health (CDPH) and the California Department of Health Care Services (CDHCS) to gather data on numerous underrepresented racial and ethnic populations, including Latinos, African Americans, American Indian/Alaska Natives, and Asians. Surveys on households using a landline and cell phone random-digit dial method according to geographical strata were designed to provide population estimates for residents in California. The interviews were conducted in various languages, including English, Spanish, Chinese (Mandarin and Cantonese dialects), Vietnamese, and Korean.¹¹ Surveys were weighted by a complex ranking process designed and calculated by UCLA CHPR to account for specific socioeconomic factors, including gender, age, race, household size, education, and residence in one of the 44 geographical strata. Further information about CHIS methodology is described elsewhere.¹²

Between 2001 and 2015, there were a total of 65,565 completed surveys for children (ages 2–11). After excluding those less than 2 years of age (for whom diet questions were not asked), analysis was conducted using 56,312 surveys.

Measures

The primary independent variables of this study are the types of foods consumed by children as reported by their parent or guardian identified as the adult who knew most about the child's general health and daily behavioral pat-

terns. The adult was asked questions related to the child's dietary intake with self-defined portions and/or serving sizes (ie, glasses, boxes, or cans were not defined by the interviewer) in the following manner: (1) Fruit intake: "Yesterday, how many servings of fruit, such as an apple or banana, did (child) eat?"; (2) Vegetable intake: "Yesterday, how many servings of vegetables like green salad, green beans, or potatoes did (he/she) have? Do not include fried potatoes."; (3) Fruit juice consumption: "Yesterday, how many glasses or cans of 100% fruit juice, such as orange or apple juice, did (child) drink, and so on." ¹² (4) Fast Food intake: "In the past 7 days, how many times did {he/she} eat fast food? Include fast food meals eaten at school or at home, or at fast food restaurants, carryout, or drive thru." (Fast Food was defined as "Such as food you get at McDonald's, KFC, Panda Express, or Taco Bell).

In this study, self-reported asthma is the outcome of interest and was identified by answering the following question: "Has a doctor ever told you that you (your child) have asthma?" Socioeconomic factors found most relevant to diet quality and behaviors were included as control measures. Children (female/male) were recoded into 5 age categories: ages 2–4 years, 5–6 years, 7–8 years, 9–10 years, and 11 years. Race and ethnicity were classified as White, Latino, African American, Asian/Pacific Islander, and other. Weight status was divided into two categories: less than 95% percentile or greater than or equal to 95% percentile (indicating obesity for age and gender). Parental self-reported height of children was not considered by CHIS staff to be reliable enough for BMI calculation. Parent's education was recoded and categorized into four levels: Less than 12 years, high school graduate, college graduate, and any graduate school. English language proficiency of parent was defined as very well/well, not well, or not at all. The household income was recoded from 24 federal poverty level (FPL) categories into four levels: 0–99% FPL, 100–199% FPL, 200–299% FPL, and 300% or more FPL. Geographical data were recoded by household zip codes already categorized by CHIS as urban, second city, suburban, or town/rural.

Statistical analysis

Descriptive statistics was analyzed using STATA 14.2 (Stata Corp., College Station, TX). Statistical significance was found using the survey-weighted Pearson chi-square test for categorical variables with Rao-Scott adjustment, using $P < 0.05$. Frequency distribution was analyzed for all independent variables against asthma status. Multivariable logistic regression models were further analyzed to estimate the adjusted odds ratios (ORs) and 95% CIs for the association of dietary intake with current asthma after controlling for confounding variables: gender, age, race, weight status, parent's education, English language proficiency of parent, household income, and location of residence. All analyses were survey weighted using raking variables to adjust for the oversampling and nonresponse surveys to reflect California Department of Finance Population Estimates for each survey period.

Results

The final survey sample of 56,312 of children represented an estimated annual population of 5.2 (5.17) million

children in California of whom an estimated 710,534 (13.7%) had asthma (Table 1). Prevalence of asthma was higher among boys (16.3%) and increased as children progressed in age. Asthma prevalence was highest among African American children (20.6%) and least among Asian/Pacific Islander children (12.8%). There were more children with asthma (17%) whose weight for age was greater than or equal to 95th per-

centile. A majority of the children with asthma came from homes where a parent had at least a college degree with a high proficiency of the English language.

Table 2 shows the univariate analysis and indicates that the prevalence of asthma varied significantly based on consumption frequency of fruits, soda, French fries, and fast food. More specifically, asthma prevalence was 20% among

TABLE 1. SOCIODEMOGRAPHIC DISTRIBUTION

	<i>Total</i> (n = 56,312)	<i>Any asthma</i> (n = 7,687)	<i>No asthma</i> (n = 48,625)	<i>P value</i>
Weighted <i>n</i> (%)	5,178,053 (100%)	710,534 (13.7%)	4,467,519 (86.3%)	
Gender				<0.001
Female	49.0	11.0	89.0	
Male	51.1	16.3	83.7	
Age group				<0.001
2–4 years of age	30.0	9.7	90.3	
5–6 years	19.7	14.6	85.4	
7–8 years	19.6	15.4	84.7	
9–10 years	20.5	15.4	84.6	
11 years	10.3	17.2	82.8	
Race				<0.001
White	41.9	13.3	86.7	
Latino	10.7	13.9	86.1	
African American	6.6	20.6	79.5	
Asian/Pacific Islander	34.6	12.8	87.3	
Other	6.2	14.4	85.6	
Body weight				<0.01
Missing data	6.6	12.0	88.0	
<95th percentile	80.2	13.3	86.7	
≥95th percentile	13.3	17.0	83.0	
Parent's education				<0.001
Less than 12 years	21.5	11.7	88.3	
High School graduate	22.2	14.4	85.6	
College graduate	22.3	17.2	82.9	
Any graduate school	34.1	12.3	87.7	
English language proficiency of parent				<0.001
Very well/well	78.4	14.7	85.3	
Not well	14.4	10.5	89.5	
Not at all	7.2	9.6	90.4	
Household income				0.779
0–99% FPL	23.8	14.2	85.8	
100–199% FPL	22.4	13.9	86.1	
200–299% FPL	13.9	13.9	86.1	
300%+ FPL	39.9	13.3	86.7	
Geography				0.186
Urban	46.3	13.5	86.5	
Second City	24.4	14.6	85.4	
Suburban	19.0	14.0	86.0	
Town and Rural	10.3	12.1	87.9	
Survey year				0.377
2001–2002	11.3	13.2	86.8	
2003–2004	11.2	14.3	85.7	
2005–2006	11.3	14.4	85.6	
2007–2008	11.5	14.1	86.0	
2009–2010	11.4	12.0	88.0	
2011–2012	11.0	15.0	85.0	
2013	10.7	14.8	85.2	
2014	10.7	13.2	86.8	
2015	10.9	12.5	86.5	

(%) of children ages 2–11 according to asthma status (CHIS 2001–2015).

Weighted column percentages are displayed in the “Total” column, while weighted row percentages are displayed in the other columns. FPL, federal poverty level.

TABLE 2. COMPARISON (%) OF DIETARY INTAKE BY ASTHMA STATUS OF CHILDREN AGES 2–11 (CHIS 2001–2015)

Food/Food item	Asthma (%) [*]	No asthma (%) [*]	P value
Fruit, svg/d			0.036
0	16.6	83.4	
1	14.1	85.9	
2	13.4	86.6	
3	12.2	87.8	
4 or more	13.9	86.1	
Vegetables, svg/d			0.251
0	14.9	85.1	
1	12.7	87.3	
2	13.9	86.1	
3	13.7	86.3	
4 or more	15.7	84.4	
Fruit juice, svg/d			0.194
0	14.3	85.7	
1	12.8	87.2	
2	14.7	85.4	
3	12.6	87.4	
4 or more	13.3	86.7	
Milk, svg/d			0.290
0	15.3	84.8	
1	14.4	85.6	
2	13.4	86.6	
3	13.8	86.2	
4 or more	14.0	86.0	
High sugary foods, svg/d			0.227
0	13.9	86.2	
1	13.1	86.9	
2	14.4	85.6	
3 or more	15.0	85.0	
Sodas, svg/d			<0.001
0	13.3	86.7	
1	14.2	85.8	
2	15.0	85.0	
3 or more	20.0	80.0	
French fries, svg/d			<0.001
0	13.6	86.4	
1	15.3	84.7	
2 or more	21.9	78.1	
Fast food, svg/w			<0.001
0	11.7	88.3	
1	12.7	87.3	
2 or more	16.0	84.0	

^{*}Percentage of children ages 2–11 according to asthma status. svg/d, servings per day; svg/w, servings per week.

children who reported soda consumption of three or more servings per day compared to 13.3% among those who did not drink soda every day. Asthma prevalence was at 15% among children who consumed at least one serving of French fries per day and 16% among children who consumed two or more servings of fast food per week. Consumption of at least one serving or more of fruits per day presented with lower prevalence of asthma, with 16.6% among those that consume zero fruits and 13.9% among those who consumed 4 or more servings.

Table 3 shows the association between dietary practices and asthma status of children after controlling for gender, age, race, weight status, parents' education, and English

TABLE 3. ADJUSTED ODDS RATIOS FOR ANY ASTHMA, CHILDREN AGES 2–11 (N=21,608)

	Odds ratio	95% CI	P value
Soda, servings per day			
0	1.0 Ref		
1	0.79	(0.66–0.94)	0.009
2	0.82	(0.60–1.13)	0.222
3+	1.83	(1.22–2.76)	0.004
French fries, servings per day			
0	1.0 Ref		
1	1.13	(0.90–1.42)	0.306
2+	1.89	(1.08–3.21)	0.026
Fast food, servings per week			
0	1.0 Ref		
1	1.08	(0.91–1.28)	0.366
2+	1.21	(1.02–1.45)	0.031
Sociodemographics			
Gender			
Female	1.0 Ref		
Male	1.84	(1.60–2.11)	<0.001
Age group			
2–4 years of age	1.0 Ref		
5–6 years	1.50	(1.20–1.88)	<0.001
7–8 years	1.61	(1.29–2.00)	<0.001
9–10 years	1.57	(1.29–1.92)	<0.001
11 years	2.01	(1.57–2.57)	<0.001
Race			
White	1.0 Ref		
Latino	1.10	(0.88–1.30)	0.545
Black	1.11	(1.06–1.55)	0.491
Asian/Pacific Islander	0.71	(0.73–0.94)	0.001
Other	0.76	(0.75–1.17)	0.094
Body weight			
Less than 95th percentile	1.0 Ref		
Greater than or equal to 95th percentile	1.09	(0.87–1.36)	0.455
Parent's education			
Less than 12 years	1.0 Ref		
High School graduate	1.04	(0.79–1.35)	0.795
College graduate	1.48	(1.16–1.90)	0.002
Any graduate school	1.06	(0.79–1.42)	0.696
English language proficiency of parent			
Very well/well	1.0 Ref		
Not well	0.61	(0.45–0.81)	0.001
Not at all	0.66	(0.46–0.94)	0.021
Household income			
0–99% FPL	1.0 Ref		
100–199% FPL	0.87	(0.68–1.12)	0.279
200–299% FPL	0.77	(0.57–1.04)	0.085
300%+ FPL	0.74	(0.57–0.96)	0.023
Geography			
Urban	1.0 Ref		
Second City	1.19	(0.98–1.44)	0.078
Suburban	1.16	(0.96–1.41)	0.119
Town and Rural	0.95	(0.75–1.21)	0.691

(continued)

TABLE 3. CONTINUED

	<i>Odds ratio</i>	<i>95% CI</i>	<i>P value</i>
Survey year			
2007–2008	1.0 Ref		
2009–2010	0.83	(0.71–0.97)	0.016
2011–2012	1.03	(0.88–1.21)	0.717
2013	0.79	(0.51–1.22)	0.290

Survey-adjusted Hosmer–Lemeshow goodness-of-fit $F(9,311) = 1.11$, $P = 0.3538$.

CI, confidence interval.

proficiency. The odds of having asthma were significantly higher among children who consumed three or more servings of soda per day (adjusted OR = 1.83), two or more servings of French fries per day (adjusted OR = 1.89), and two or more servings of fast food per week (adjusted OR = 1.21).

Discussion

Children with high consumption of soda, French fries, and fast foods presented with higher prevalence of asthma, compared to those with low or no consumption of these foods. Most fast foods are high in sodium, saturated fat, and sugars while displacing more nutritious foods and meals. In addition, these types of meals are usually devoid of fruits and vegetables while constituting highly refined, non-vegetable carbohydrates.^{13,14} Patients with asthma, compared to healthy individuals, showed low concentration of minerals like zinc and selenium, lower antioxidant enzymes, increased concentration of high-sensitive C-reactive protein, oxidative stress markers (TBARS—thiobarbituric acid reactive substances), and CD4/CD8 lymphocyte ratios, aggravating oxidative damage.¹⁵

The high intake of foods with saturated fats stimulates a mechanism that induces an inflammatory response. The pathway is through activation of recognition receptors, endoplasmic reticulum stress, and fatty acid-binding protein activity. A diet with low intake of fiber—present in grains, fruits, and vegetables—decreases anti-inflammatory mechanisms like free fatty acid receptor activation and histone deacetylase inhibition. On top of that, a diet that lacks antioxidants such as vitamin C, E, and carotenoids promotes a pro-inflammatory environment. These mechanisms contribute to airway inflammation, worsen lung function, and loss of asthma control, evidenced by human and experimental models of asthma.¹⁶

According to Gandhi et al. (2018), chronic inflammation of the airways, modulated by dietary intake, is the main component of asthma. Therefore, a diet with reduced saturated fat and with fruits and vegetables, rich in flavonoids, significantly reduced airway inflammation in patients with asthma. These plant components have properties that prevent immune-mediated disorders by managing TH1/TH2 cytokine balance.¹⁷ Lymphocytes contribute to asthma through TH2 cells, which secretes cytokine IL-4, IL-5, and IL-13, stimulating type 2 immunity—IgE elaboration, maintenance, and activation—marked by high antibody titers and eosinophilia.¹⁸

DeChristopher et al., using NHANES data, observed that children aged 2–9, consuming beverages with excess free fructose (eg, apple juice and soda) greater than or equal to 5 times per week were associated with asthma (OR = 2.43; 95% CI).¹⁹ In the current study, the prevalence of asthma was higher among children who had high regular intake of soda (three or more servings) compared to those that did not consume or consumed up to 2 times of soda per week. High fructose diet—in the form of high fructose corn syrup—may possibly increase the formation of glycation end products in the intestines that when absorbed play a role in receptor for advanced glycation end products (RAGE)-mediated asthma.²⁰

Obesity is considered a risk for chronic diseases, including asthma. In our study, Model 1 and 2, which include fruits and soda consumption, respectively, children that were above the 95 percentile BMI presented with higher odds of asthma compared to those below the 95 percentile. Children that are obese are due to a combination of factors such as poor diet, lack of physical activity, or genetic factors. The mechanism that links obesity to asthma includes airway dysfunction due to a thoracic restriction, obesity-related inflammation, and comorbidities that mediate asthma development.²¹ Obesity is also independently associated with airway dysanapsis in children, a condition where a physiological incongruence between growth of lung parenchyma and caliber of airway occurs. Overweight or obesity in children with and without asthma presented with airway dysanapsis.^{22,23} The most consistent mechanism that explains the impact of obesity on asthma comes from studies on adipokines—cytokines produced by adipose tissue—that showed to be associated with pro-inflammatory status and asthma.²⁴ Moreover, a shift in the gut microbiota in patients that are obese is linked to inflammatory environment.²⁵

Consistent with the present research, evidence from the International Study of Asthma and Allergies in Children (ISAAC) Phase III indicated that children from 11 Latin American countries, aged 13–14 years old, showed a positive association with current wheeze, rhinoconjunctivitis, and eczema, with intake of fast food (overall OR 1.33; 95% CI) compared to younger children.²⁶ Our analysis indicates that older children have higher odds of asthma than children 2–4 years old, and there seems to be a dose–response relationship. The CDC National Current Asthma data also presented a higher prevalence of asthma among children 5–11 compared to children 0–4.² Children that are younger than 5 years old may be underdiagnosed, since asthma at this age group is easily mistaken for a transient wheeze due to viral infections. Besides, children these young are at higher risk of recurrent wheezing since they are more sensitive to lower and upper respiratory tract infections, passive smoking, and day care center attendance.²⁶

Male gender was found with higher odds of asthma prevalence in our study. A gender disparity exists in asthma prevalence, with males being more likely to present asthma at a younger age, and women show an increase in asthma symptoms during puberty. Animal studies showed that estrogen increases the TH2-mediated airway inflammation, while testosterone decreases.²⁷ Sex hormones are important in regulating asthma pathogenesis. However, additional studies need to be conducted to further elucidate how sex hormones are initiating and driving the inflammatory response(s) in asthma.²⁸

Children with parents with college degrees presented with higher prevalence of asthma in this present investigation, which was also observed by Zhang (2017). Children with asthma had higher risk of visits to the emergency room when their parents had a college degree.²⁹ This may not represent a higher prevalence of asthma, but education level may alter the behavior of health care utilization, promoting early diagnosis and more visits to the emergency room.

Strengths and weaknesses

This study contains many strengths, including the large number of participants and relatively high percentage of participants with asthma. The population was diverse in terms of sex, race, age, geographic location, parents' educational level, and family income, enhancing the relevance of its findings to the California state.

Potential weaknesses to this study include that we are unable to draw any causal or temporal inferences due to its observational nature. In addition, we were not able to include and control for BMI, smoking, and physical activity due to inconsistent data. There could also be recall bias and discrepancies in how the participants are classifying serving's sizes (in other words, is a kid's meal the same as a supersized hamburger meal?). Moreover, there could have been a lack of knowledge of how the participant actually defines fruits and vegetables (in other words, is a serving of canned corn of similar nutritional value as a serving of kale or a salad?). We could not rely on the self-reported heights and had to use only weight as a marker for obesity, which is not an accurate estimate. Finally, we relied on self-report questionnaires, which are also prone to bias.

Conclusion

This study finds that dietary factors, specifically common in the Western diet, may play a significant role in the prevalence of asthma among children in California. After controlling for covariate factors, consumption of soda thrice or more per day, fast food at least twice or more per week, and French fries at least twice or more per day significantly increases the odds for current asthma. Results of this study encourage intervention and asthma treatment programs that include physical activity, a nutrient level balance, weight loss, and monitoring of children that are obese on their asthma control.

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