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Differences in the prevalence of allergy and asthma among US children and adolescents during and before the COVID-19 pandemic

Yingyu Liang[1†], Qian Li[1†], Man Wang[1,2], Kefan Zhou[1], Xiaofang Yan[1], Jiamin Lu[1], Qishan Li[1], Huijuan Yu[1], Chan Xu[1], Xudong Liu[3*] and Wenhan Yang[1,2*]

Abstract

Background The increasing prevalence of allergies and asthma has led to a growing global socioeconomic burden. Since the outbreak of the COVID-19 pandemic, the health and lifestyles of children and adolescents have changed dramatically. It's unclear how this shift impacted allergy and asthma, with limited studies addressing this question. We aim to explore the difference of the prevalence of allergies and asthma among US children and adolescents during and before the COVID-19 pandemic using a nationally representative sample of US children and adolescents.

Methods This cross-sectional study included 31,503 participants in the National Health Interview Survey (NHIS) between 2018 and 2021. Allergies and asthma were defined on an affirmative response in the questionnaire by a parent or guardian. Chi-square tests were used to compare baseline characteristics with allergies and asthma for categorical variables. Differences in prevalence during and before the COVID-19 pandemic were estimated with weighted logistic regression, adjusting for demographic factors. Interaction analyses explored variations across strata.

Results In US children and adolescents aged 0 to 17, prevalence of any allergy was 26.1% (95% CI, 24.8%- 27.4%) in 2018 and 27.1% (95% CI, 25.9%- 28.2%) in 2021. Thereinto, in 2018, prevalence of respiratory allergies, food allergies and skin allergies were 14.0% (95% CI, 13.1%- 15.0%), 6.5% (95% CI, 5.8%- 7.1%) and 12.6% (95% CI, 11.6%- 13.5%), respectively, and in 2021, 18.8% (95% CI, 17.8%- 19.9%), 5.8% (95% CI, 5.2%- 6.4%) and 10.7% (95% CI, 9.9%- 11.5%), respectively. And prevalence of asthma was 11.1% (95% CI, 10.5%- 11.7%) in 2018–2019 and 9.8% (95% CI, 9.2%- 10.4%) in 2020–2021. Prevalence of respiratory allergies, skin allergies and asthma during and before the COVID-19 pandemic in children and adolescents had statistically significant differences. The differences persisted after adjusting for demographic and socioeconomic variables.

Conclusion Prevalence of respiratory allergies increased and the prevalence of both skin allergies and asthma decreased among US children and adolescents during the COVID-19 pandemic compared with the pre-COVID-19 pandemic. Further research is required to explore the association between allergic diseases and the pandemic, with a particular emphasis on the impact of lifestyle changes resulting from measures to prevent COVID-19 infection.

Keywords Allergy, Asthma, COVID-19, Child, Adolescents

†Yingyu Liang and Qian Li contributed equally as co-first authors to this work.

*Correspondence:
Xudong Liu
xdliu.cn@hotmail.com
Wenhan Yang
wenhan-yang@gdpu.edu.cn
Full list of author information is available at the end of the article

Introduction

Allergy and asthma, as immune system related disorders, are major health concerns. The allergic conditions are prevalent medical issues linked to immunological anomalies, characterized by the immune system's hypersensitive reaction to substances in the environment that are typically viewed as innocuous, encompassing respiratory, skin, and food allergies [1]. As a common lung disease caused by swelling and narrowing of the tubes that carry air in and out of the lungs, asthma stands as a prevalent chronic ailment affecting children globally [2]. The global prevalence of allergic diseases and asthma were steadily increasing, with a notable rise in the complexity and severity, particularly among children and young adults, which have a reduced quality of life [3, 4]. These upward trends in allergic diseases and asthma had also led to a growing socioeconomic burden worldwide.

The relationship between allergic diseases and respiratory tract infections has always been the focus of pathological mechanism research [5, 6]. Respiratory infections, particularly viral infections, may trigger allergic reactions and exacerbate allergic diseases such as asthma and allergic rhinitis [5, 6]. The act of wearing a mask in community settings had been demonstrated effectiveness in potentially reducing the transmission of respiratory diseases [7], and the implementation of social distancing measures has also been found to decrease the spread of seasonal influenza within workplace environments [8]. Of note, a study had found that during early 2020, social distancing and other lockdown strategies were effective in slowing down the transmission of common respiratory viral illnesses and reducing the need for pediatric hospitalizations [9].

It is well known that since the end of 2019, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has caused a global pandemic. The measures implemented to control COVID-19 have greatly changed people's daily habits and routines [10], including online classes or home-based working, keeping social distance, wearing a mask, have slowed the spread of not only just COVID-19, but other infectious diseases. Literature reported a significant decline in hospital admissions in the United States with the onset of the COVID-19 pandemic [11]. Asthma hospital visits and hospitalizations also decreased in many countries during the COVID-19 pandemic [11–15]. The incidence of food allergies and food allergic reaction in children were reported lower than pre-pandemic [16, 17]. The implementation of social isolation measures during the COVID-19 pandemic had a profound impact on the seasonality of childhood respiratory diseases [18]. It is also worth noting that the incidence of both atopic dermatitis and eczema increased among young children during this period [16, 19]. However, few large-scale studies have investigated the prevalence of allergic diseases and asthma among children and adolescents during the COVID-19 pandemic.

Therefore, we conducted this study using the nationally representative National Health Interview Survey (NHIS) data for analysis to compare the difference of the prevalence of allergies and asthma in a nationally representative sample of US children and adolescents during and before COVID-19 pandemic.

Methods

Study populations

Our study utilized 2018–2021 cross-sectional data from NHIS, a household survey conducted continuously throughout the year by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC) [20, 21]. NHIS is a nationally representative survey that covers the U.S. civilian non-institutionalized population and has been the primary source of information on health conditions in the U.S. population since 1957 [22]. NHIS collects data through in-person interviews, typically conducted in respondents' homes, and follow-up interviews may be conducted over the telephone to complete the survey [23]. Information about the health of sample children is obtained through interviews with parents or adults responsible for their healthcare. NHIS has an annual sample size of approximately 30,000 households, which includes around 8,400 sample children. Between 2018 and 2021, the total household response rate for NHIS ranged from 50.7% to 64.2%, and the conditional response rate for the sample child component ranged from 86.9% to 93.5%. NHIS has been approved by the Research Ethics Review Board of the NCHS and the US Office of Management and Budget. All respondents provided oral informed consent prior to participation. Considering that the first COVID-19 case in United States was reported in January, 2020 [24], periods in 2020 and 2021 were defined as the COVID-19 pandemic period.

Ascertainment of variables

Our study included children and adolescents between the ages of 0 and 17 years that participated in the NHIS and had available information on allergies (including respiratory allergies, food allergies and skin allergies) and asthma.

The content and structure of the NHIS was updated in 2019, with content on respiratory, food and skin allergies in the children's sample module rotating every three years starting in 2021. Therefore, there was content on allergies in 2018 and 2021, but not in 2019 and 2020, and the data from the questionnaire on allergies content was slightly different in 2018 and 2021. The three allergic types and asthma were defined based on an affirmative response to the questions showed in Table 1 [1, 4]. Any allergy was defined as having any one or more of the three types of allergies listed above.

During the interview, a standardized questionnaire was used to collect demographic data, such as age, sex, race/ethnicity, highest educational level of family members, family income to poverty ratio and geographic region. Participants self-reported their race and Hispanic ethnicity, which were classified according to the 1997 Office of Management and Budget Standards. Family income to poverty ratio is the total family income divided by the poverty threshold.

Statistical analysis

To ensure that the results are representative of the US population, we applied survey sampling weights, strata, and primary sampling units that were created by the NCHS and provided with the NHIS data, which are available at NHIS online website. These were included in all of our analyses, unless otherwise stated.

Comparisons of baseline characteristics among children and adolescents with allergies and asthma were performed using the chi-square test for all categorical variables. We estimated the differences in the prevalence of allergy and asthma in children and adolescents during and before the COVID-19 pandemic using weighted logistic regression models, adjusting for age, sex, race/ethnicity, education, family income to poverty ratio and geographic region. Moreover, interaction analyses were performed by including multiplicative terms of each strata variable with survey cycle in the aforementioned logistic regression models to examine whether the secular differ across strata.

All statistical analyses were conducted using the survey modules of SAS software, version 9.4 (SAS Institute). A 2-sided $P < 0.05$ was considered statistically significant.

Results

Characteristics of participants and the prevalence of allergic conditions and asthma

The characteristics of participants according to their allergies and asthma status were described in Tables 2, 3 and 4. A total of 31,503 children and adolescents aged 0–17 years were included in our final analytical sample (weighted mean [SD] age, 8.64 [0.04] years; 16,265 boys [51.0%] and girls [49.0%]; 7485 Hispanic [25.7%], 16,723 non-Hispanic (NH) white [51.3%], 3364 NH black [12.7%], and 3931 other races [10.3%]).

In 2018 and 2021, the overall prevalence of any allergy, respiratory allergies, food allergies and skin allergies were 26.6% (95% CI 25.7%- 27.5%), 16.4% (95% CI 15.7%- 17.1%), 6.1% (95% CI 5.7%- 6.6%) and 11.7% (95% CI 11.0%- 12.3%), respectively. The overall prevalence of asthma was 10.4% (95% CI 10.0%- 10.9%) from 2018 to 2021.

Specifically, in 2018, among the 8269 participants, 2321(weighted prevalence, 26.1%) had any allergy, 1296 (weighted prevalence, 14.0%) had respiratory allergies, 560 (weighted prevalence, 6.5%) had food allergies, and 1097 (weighted prevalence, 12.6%) had skin allergies. The weighted prevalence of any allergy, respiratory allergies and skin allergies varied by race/ethnicity and highest educational level of family members. In 2021, among the 8259 participants, 2316 (weighted prevalence, 27.1%) had any allergy, 1599 (weighted prevalence, 18.8%) had respiratory allergies, 506 (weighted prevalence, 5.8%) had food allergies,

Table 1 The questions on respiratory allergies, food allergies, skin allergies and asthma in NHIS 2018-2021[a]

Variables	Survey year	Survey question
Respiratory allergies	2018	During the past 12 months, has your child had (1) hay fever OR (2) any kind of respiratory allergies?
	2021	(1) Does your child get symptoms such as sneezing, runny nose, or itchy or watery eyes due to hay fever, seasonal or year-round allergies? (2) Have you ever been told by a doctor or other health professional that your child had hay fever, seasonal or year-round allergies?
Food allergies	2018	During the past 12 months, has your child had any kind of food or digestive allergy?
	2021	(1) Does your child have an allergy to one or more foods? (2) Have you ever been told by a doctor or other health professional that your child had an allergy to one or more foods?
Skin allergies	2018	During the past 12 months, has your child had eczema or any kind of skin allergies?
	2021	(1) Does your child get an itchy rash due to eczema or atopic dermatitis? (2) Have you ever been told by a doctor or other health professional that your child had eczema or atopic dermatitis?
Asthma	2018–2021	Has a doctor or other health professional ever told you that your child had asthma?

NCHS National Health Interview Survey, 2018–2021

[a] Data source

Table 2 Characteristics of study population and numbers of allergies by characteristics before and during the COVID-19 pandemic from 2018 to 2021[a]

Characteristic	2018								
		Any allergies		Respiratory allergies		Food allergies		Skin allergies	
	Sample size (%[b])	No. (%[c])	*P* value	No. (%[c])	*P* value	No. (%[c])	*P* value	No. (%[c])	*P* value
Overall	8269	2321		1296		560		1097	
Age, year									
0–2	1330 (15.7)	261 (11.4)	< 0.001	68 (4.98)	< 0.001	66 (12.5)	0.03	189 (17.4)	0.19
3–5	1247 (16.4)	333 (15.1)		147 (12.3)		82 (15.9)		197 (17.7)	
6–11	2608 (34.4)	768 (35.3)		465 (38.5)		172 (31.3)		345 (34.4)	
12–17	3084 (33.4)	959 (38.2)		616 (44.2)		240 (40.2)		366 (30.4)	
Sex									
Male	4337 (51.0)	1235 (51.9)	0.42	745 (57.1)	< 0.001	287 (50.5)	0.83	564 (49.6)	0.42
Female	3932 (49.0)	1086 (48.1)		551 (42.9)		273 (49.5)		533 (50.4)	
Race/Ethnicity									
Hispanic	1875 (25.5)	445 (22.0)	0.002	247 (21.8)	0.04	113 (23.4)	0.53	211 (21.5)	< 0.001
NH White	4453 (50.7)	1300 (52.7)		751 (54.5)		300 (51.8)		566 (48.5)	
NH Black	972 (13.2)	306 (15.0)		144 (12.4)		68 (12.3)		182 (18.9)	
Other	969 (10.6)	270 (10.3)		154 (11.3)		79 (12.5)		138 (11.1)	
Highest educational level of family members									
Less than high school	697 (9.8)	143 (6.8)	< 0.001	89 (7.4)	< 0.001	34 (6.8)	0.08	65 (6.3)	< 0.001
High school	1196 (14.5)	281 (11.8)		142 (10.4)		72 (12.5)		140 (12.3)	
College or higher	6364 (75.5)	1894 (81.3)		1063 (82.0)		453 (80.7)		892 (81.5)	
Missing	12 (0.2)	3 (0.1)		2 (0.19)		1 (0.1)		*NA*	
Family income to poverty ratio									
< 1.00	886 (12.9)	235 (12.0)	0.005	125 (11.1)	0.10	54 (10.4)	0.07	129 (14.5)	0.39
1.00–1.99	1354 (18.2)	367 (18.3)		206 (18.3)		93 (21.4)		180 (18.9)	
2.00–3.99	2162 (25.3)	606 (23.2)		341 (23.8)		135 (21.2)		290 (22.7)	
≥ 4.00	2705 (28.7)	820 (32.5)		452 (32.3)		206 (33.1)		360 (29.7)	
Missing	1162 (14.8)	293 (14.0)		172 (14.6)		72 (14.0)		138 (14.3)	
Geographic region									
Northeast	1294 (15.8)	330 (13.9)	0.20	176 (13.6)	0.22	86 (15.4)	0.22	161 (14.1)	0.68
Midwest	1775 (20.4)	505 (20.7)		279 (20.7)		105 (16.9)		246 (21.4)	
South	3102 (38.2)	879 (38.5)		493 (38.3)		210 (38.6)		417 (38.7)	
West	2098 (25.6)	607 (26.8)		348 (27.5)		159 (29.1)		273 (25.8)	

[a] Data source: NCHS, National Health Interview Survey, 2018–2021

[b] Unweighted number of participants

[c] Unweighted number of participants

and 932 (weighted prevalence, 10.7%) had skin allergies. Significant variations in the weighted prevalence of all three allergy types and any allergy were noted across different races/ethnicities.

In 2018–2019, among the 17,458 participants, 1995(weighted prevalence, 11.1%) had asthma, varied by all demographic and socioeconomic groups. In 2020–2021, among the 14,045 participants, 1468(weighted prevalence, 9.8%) had asthma, varied by age, sex and race/ethnicity.

Differences in the prevalence of allergies and asthma in children and adolescents during and before the COVID-19 pandemic

Children and adolescents during the COVID-19 pandemic, compared with those before the COVID-19 pandemic, were more prone to respiratory allergies (weighted prevalence, 18.8% vs 14.0%; $P < 0.001$), but less likely to suffer from skin allergies (weighted prevalence, 10.7% vs weighted prevalence, 12.6%; $P = 0.005$) and asthma (weighted prevalence, 9.8% vs weighted prevalence,

Table 3 Characteristics of study population and numbers of allergies by characteristics before and during the COVID-19 pandemic, 2018 to 2021[a]

Characteristic	2021								
		Any allergies		Respiratory allergies		Food allergies		Skin allergies	
	Sample size (%[b])	No. (%[c])	*P* value	No. (%[c])	*P* value	No. (%[c])	*P* value	No. (%[c])	*P* value
Overall	8259	2316		1599		506		932	
Age, year									
0–2	1330 (15.2)	217 (8.3)	< 0.001	78 (4.5)	< 0.001	52 (9.5)	0.002	144 (13.3)	0.04
3–5	1210 (16.5)	292 (14.4)		174 (12.9)		61 (14.4)		146 (17.3)	
6–11	2513 (33.3)	779 (36.2)		561 (37.5)		159 (33.4)		315 (37.5)	
12–17	3206 (35.0)	1028 (41.2)		786 (45.0)		234 (42.7)		327 (31.9)	
Sex									
Male	4257 (51.0)	1248 (52.7)	0.11	889 (54.1)	0.03	268 (51.5)	0.86	479 (51.0)	0.99
Female	4002 (49.0)	1068 (47.3)		710 (45.9)		238 (48.5)		453 (49.0)	
Race/Ethnicity									
Hispanic	2089 (25.7)	516 (22.2)	0.003	345 (20.9)	< 0.001	118 (21.9)	0.002	201 (22.7)	0.002
NH White	4202 (51.1)	1189 (53.1)		855 (55.1)		222 (46.3)		449 (48.6)	
NH Black	814 (12.3)	271 (13.4)		194 (13.9)		67 (16.0)		127 (16.2)	
Other	1154 (10.9)	340 (11.3)		205 (10.0)		99 (15.8)		155 (12.5)	
Highest educational level of family members									
Less than high school	475 (6.9)	92 (4.9)	< 0.001	65 (4.9)	< 0.001	23 (5.4)	0.06	33 (4.4)	0.02
High school	1269 (16.9)	307 (14.4)		211 (14.1)		56 (12.6)		119 (15.0)	
College or higher	6507 (76.1)	1916 (80.7)		1322 (80.9)		427 (82.0)		779 (80.5)	
Missing	8 (0.1)	1 (0.0)		1 (0.0)		*NA*	*NA*	1 (0.1)	
Family income to poverty ratio									
< 1.00	1034 (16.5)	277 (15.8)	0.16	204 (16.3)	0.93	73 (18.6)	0.04	110 (16.3)	0.44
1.00–1.99	1720 (23.1)	465 (21.6)		332 (22.7)		87 (18.2)		186 (21.7)	
2.00–3.99	2453 (28.8)	685 (29.2)		462 (28.5)		133 (26.7)		271 (27.5)	
≥ 4.00	3052 (31.7)	889 (33.4)		601 (32.5)		213 (36.4)		365 (34.5)	
Missing	NA	NA		NA	NA	NA	NA	NA	NA
Geographic region									
Northeast	1190 (15.6)	343 (15.3)	< 0.001	235 (15.4)	< 0.001	88 (17.1)	0.85	130 (13.7)	0.54
Midwest	1759 (21.0)	488 (21.2)		331 (21.1)		101 (20.7)		203 (22.1)	
South	2995 (39.4)	938 (43.8)		711 (46.9)		180 (39.2)		335 (40.1)	
West	2315 (24.1)	547 (19.6)		322 (16.6)		137 (23.0)		264 (24.1)	

[a] Data source: NCHS, National Health Interview Survey, 2018–2021

[b] Unweighted number of participants

[c] Unweighted number of participants

11.1%; $P=0.001$), and there were no differences in any allergy (weighted prevalence, 26.1% vs 27.1%; $P=0.27$) and food allergies (weighted prevalence, 5.8% vs prevalence, 6.5%; $P=0.12$) (Table 5). After adjusting for age, sex, race/ethnicity, family highest education level, family income level, and geographical region, the above differences remained statistically significant (Table 5).

Logistic regression models and interaction analyses

Stratified analyses showed that there were differences in the prevalence of all three allergic types during and before the Covid-19 pandemic in NH White and those with family income to poverty ratio of 1.00–1.99. Among southern children and adolescents, variations in the prevalence of any allergy or asthma were observed during and before the Covid-19 pandemic. Moreover, there was a significant interaction between age and any allergy or asthma, between highest educational level of family members and food allergies, skin allergies or asthma, between geographic region and any allergy, respiratory allergies or asthma (Tables 6, 7 and 8).

Table 4 Characteristics of study population and numbers of asthma by characteristics before and during the COVID-19 pandemic, 2018 to 2021[a]

Characteristic	2018–2019			2020–2021		
		Asthma			Asthma	
	Sample size (%[b])	No. (%[c])	*P* value	Sample size (%[b])	No. (%[c])	*P* value
Overall	17,458	1995		14,045	1468	
Age, year						
0–2	2835 (15.8)	64 (3.5)	< 0.001	2246 (15.6)	35 (2.5)	< 0.001
3–5	2600 (16.4)	185 (10.7)		2052 (16.3)	115 (10.5)	
6–11	2608 (17.3)	325 (19.1)		4216 (33.1)	471 (34.6)	
12–17	9415 (50.5)	1421 (66.7)		5531 (35.0)	847 (52.4)	
Sex						
Male	9042 (51.0)	1180 (58.7)	< 0.001	7223 (51.0)	867 (58.7)	< 0.001
Female	8416 (49.0)	815 (41.3)		6822 (49.0)	601 (41.3)	
Race/Ethnicity						
Hispanic	4048 (25.6)	492 (25.9)	< 0.001	3437 (25.7)	342 (24.7)	< 0.001
NH White	9371 (51.2)	924 (43.3)		7352 (51.5)	684 (46.5)	
NH Black	1994 (13.0)	357 (20.9)		1370 (12.5)	237 (17.8)	
Other	2045 (10.3)	222 (9.9)		1886 (10.3)	205 (11.0)	
Highest educational level of family members						
Less than high school	1307 (9.2)	184 (10.0)	0.008	798 (7.1)	88 (6.7)	0.38
High school	2646 (15.4)	353 (18.3)		2045 (16.0)	244 (17.7)	
College or higher	13,482 (75.2)	1458 (71.8)		11,191 (76.9)	1134 (75.5)	
Missing	23 (0.2)	NA	NA	11 (0.1)	2 (0.1)	
Family income to poverty ratio						
< 1.00	2135 (15.2)	335 (20.4)	< 0.001	1670 (16.2)	219 (19.2)	0.05
1.00–1.99	3301 (20.7)	419 (22.8)		2852 (23.2)	318 (24.0)	
2.00–3.99	5056 (27.8)	568 (27.5)		4254 (29.5)	435 (27.7)	
≥ 4.00	5804 (28.9)	536 (22.3)		5269 (31.1)	496 (29.1)	
Missing	1162 (7.4)	137 (7.0)		NA	NA	
Geographic region						
Northeast	2768 (15.9)	339 (17.4)	0.02	2174(15.7)	207 (14.1)	0.35
Midwest	3760 (20.8)	405 (20.3)		2976 (21.0)	297 (21.1)	
South	6443 (38.4)	786 (40.7)		5015 (39.1)	563 (41.4)	
West	4487 (24.9)	465 (21.5)		3880 (24.2)	401 (23.3)	

[a] Data source: NCHS, National Health Interview Survey, 2018–2021

[b] Unweighted number of participants

[c] Unweighted number of participants

Discussion

Based on a nationally representative sample from NHIS, we found that the prevalence of respiratory allergies increased and the prevalence of both skin allergies and asthma decreased among US children and adolescents during the COVID-19 pandemic compared with the pre-COVID-19 pandemic. The differences persisted after adjusting for demographic and socioeconomic variables.

The findings of the current study are partially consistent with the results observed in the earlier research segment, although not entirely identical. Similar studies have been conducted in Korea, showing a decline in the prevalence of allergic diseases and asthma among adolescents during the COVID-19 pandemic [25–27]. Our study also observed a decline in the prevalence of skin allergies and asthma during the COVID-19 pandemic. However, there was an increase in the prevalence of respiratory allergies during this period, while the prevalence of any allergy and food allergies remained constant.

It was supposed that the increased prevalence of respiratory allergies among children and adolescents during the COVID-19 pandemic may be attributed to

Table 5 Differences in the prevalence of allergies and asthma in children and adolescents before and during the COVID-19 pandemic, 2018 to 2021

Health conditions	Before[a]		During[b]		*P* value	
	n/Total	Prev[c], %(95%CI)	n/Total	Prev[c], %(95%CI)	Unadjusted[d]	Adjusted[e]
Any Allergies	2321/ 8269	26.1 (24.8–27.4)	2316/ 8259	27.1 (25.9–28.2)	0.27	0.53
Respiratory Allergies	1296 /8269	14.0 (13.1–15.0)	1599/ 8259	18.8 (17.8–19.9)	< 0.001	< 0.001
Food Allergies	560/ 8269	6.5 (5.8–7.1)	506/ 8259	5.8 (5.2–6.4)	0.12	0.09
Skin Allergies	1097/ 8269	12.6 (11.6–13.5)	932/ 8259	10.7 (9.9–11.5)	0.005	0.004
Asthma	1995/ 17,458	11.1 (10.5–11.7)	1468/ 14,045	9.8 (9.2–10.4)	0.002	0.001

[a] Before the COVID-19 pandemic, in the year of 2018 in Allergies and years of 2018–2019 in Asthma

[b] During the COVID-19 pandemic, in the year of 2021 in Allergies and years of 2020–2021 in Asthma

[c] Prev, weighted prevalence

[d] *P* values for unadjusted were calculated using χ^2 tests

[e] *P* values for adjusted were calculated using weighted logistic regression models, which included survey cycle as a continuous variable and adjusted for age, sex, race/ethnicity, education and family income to poverty ratio and geographic region

several potential factors. The changes in lifestyle and behavior during the pandemic including reduced outdoor activities and increased time spent indoors were potentially one of the most important aspects [28, 29]. It may have led to greater exposure to indoor allergens and reduced exposure to beneficial outdoor environments. Qing et al. [30] found the children and youth groups exhibited an increasing positive rate for most common allergens, especially indoor inhalant allergens, during the COVID-19 epidemic than before the pandemic in China. Furthermore, the rapid and potent immune response against SARS-CoV-2 infection is the first line of defense against the invasion of the virus. However, excessive natural immune inflammation and impaired adaptive immune response may cause damage to both local and systemic tissues [31]. The COVID-19 virus may activate and disrupt the regulation of the immune system [32], and may lead to an enhanced response to allergens in the body. This may make children and adolescents more sensitive to respiratory allergens and increase the risk of allergic reactions and symptoms. There are also other reasons that may contribute to the increased prevalence of respiratory allergies among children and adolescents. Scientific research indicated that the COVID-19 pandemic had a negative impact on the mental health of children and adolescents [33]. High levels of stress and anxiety can potentially have adverse effects on the immune system [34], thereby potentially increasing the risk of allergic reactions. Additionally, the implementation of infection prevention measures, such as the utilization of face masks and adherence to social distancing, might have unintentionally affected the normal progression of immune tolerance, potentially resulting in an elevated risk of developing allergic sensitization.

The decreased prevalence of asthma among children and adolescents in the United States during the COVID-19 pandemic was observed in the study. A lot of attention has been paid to the reasons for the decline in the prevalence of asthma. The reduction in exposure to common environmental triggers of asthma among children and adolescents may have contributed to it. It was the result of the implementation of public health measures to control COVID-19 and other infectious diseases [26, 27]. These measures effectively limited the exposure of children and adolescents to outdoor allergens, air pollution and irritants, which may trigger or exacerbate asthma [35–37]. What's more, the reduction in prevalence of asthma attacks may had been strongly influenced by the ongoing decrease in respiratory virus levels during the COVID-19 pandemic [38]. Viral respiratory tract infections are commonly associated with induced asthma exacerbations [39]. And the incidence of respiratory viral diseases and the detection of viruses declined significantly during the pandemic [38, 40]. Therefore, the incidence of asthma may be reduced as a result. In addition, reductions in vigorous physical activity during the COVID-19 pandemic may also have had an effect on the reduced prevalence of asthma [26]. It was reported that vigorous physical activity was positively associated with symptoms of asthma in adolescents [41]. During the epidemic, there was a decrease in physical activity among adolescents [42, 43], leading to a corresponding reduction in vigorous exercise, thus resulting in a decrease in the prevalence of asthma. What's more, with less doctor visits during the COVID-19 pandemic, there were less instances of making a doctor's diagnosis also influencing the results.

The decline in the prevalence of skin allergies among children and adolescents in the United States during the

Table 6 Prevalence of any allergies and respiratory allergies in US children and adolescents by characteristics before and during the COVID-19 pandemic from 2018 to 2021

Characteristic	Any allergies, %[a] (95% CI)		*P* value		Respiratory allergies, %[a](95% CI)		*P* value	
	Before[b]	During[c]	Difference[d]	Interaction[e]	Before[b]	During[c]	Difference[d]	Interaction[e]
N/Total	2321/ 8269	2316/ 8259			1296/ 8269	1599/ 8259		
Overall	26.1 (24.8–27.4)	27.1 (25.9–28.2)	0.27		14.0 (13.1–15.0)	18.8 (17.8–19.9)	< 0.001	
Age, year								
0–2	19.0 (16.2–21.9)	14.7 (12.5–16.9)	0.02	0.02	4.5 (3.1–5.8)	5.6 (4.1–7.0)	0.27	0.90
3–5	23.9 (21.1–26.7)	23.6 (20.9–26.4)	0.88		10.5 (8.6–12.5)	14.8 (12.5–17.0)	0.006	
6–11	26.8 (24.7–29.0)	29.4 (27.2–31.7)	0.11		15.7 (14.1–17.3)	21.2 (19.3–23.2)	< 0.001	
12–17	29.8 (27.8–31.8)	31.8 (29.9–33.7)	0.15		18.6 (16.9–20.2)	24.2 (22.4–26.1)	< 0.001	
Sex								
Male	26.6 (24.9–28.3)	28.0 (26.4–29.6)	0.24	0.64	15.7 (14.1–17.0)	20.0 (18.5–21.4)	< 0.001	0.14
Female	25.7 (23.8–27.4)	26.1 (24.1–27.8)	0.68		12.3 (11.1–13.5)	17.6 (16.2–19.1)	< 0.001	
Race/ethnicity								
Hispanic	22.5 (20.0–25.1)	23.4 (21.3–25.5)	0.62	0.82	12.0 (10.2–13.9)	15.3 (13.5–17.1)	0.01	0.25
NH White	27.2 (25.4–28.9)	28.1 (26.5–29.7)	0.42		15.1 (13.9–16.3)	20.3 (18.9–21.7)	< 0.001	
NH Black	29.8 (26.0–33.6)	29.6 (25.9–33.3)	0.94		13.2 (10.6–15.8)	21.3 (17.5–24.8)	< 0.001	
Other	25.2 (21.9–28.6)	28.2 (24.8–31.5)	0.22		14.9 (12.2–17.5)	17.4 (14.8–20.0)	0.20	
Highest educational level of family members								
Less than high school	18.0 (14.8–21.2)	19.2 (15.1–23.3)	0.66	0.93	10.6 (8.0–13.3)	13.3 (10.5–16.5)	0.21	0.63
High school	21.2 (18.2–24.2)	23.1 (20.5–25.8)	0.36		10.0 (8.0–12.1)	15.8 (13.3–18.2)	< 0.001	
College or higher	28.2 (26.6–29.7)	28.7 (27.4–30.0)	0.58		15.3 (14.2–16.3)	20.0 (18.8–21.2)	< 0.001	
Missing	15.4 (0.0–34.2)	11.8 (0.0–33.7)	0.81		12.2 (0.0–29.4)	11.8 (0.0–33.7)	0.98	
Family income to poverty ratio								
< 1.00	24.2 (21.0–27.5)	25.9 (22.9–28.9)	0.46	0.07	12.1 (9.6–14.5)	18.6 (15.9–21.3)	< 0.001	0.31
1.00–1.99	26.2 (23.1–29.4)	25.4 (23.1–27.7)	0.67		14.1 (11.8–16.3)	18.5 (16.4–20.7)	0.005	
2.00–3.99	23.9 (21.8–26.1)	27.5 (25.6–29.5)	0.01		13.2 (11.7–14.7)	18.7 (16.9–20.5)	< 0.001	
≥ 4.00	29.6 (27.5–31.7)	28.5 (26.7–30.4)	0.43		15.8 (14.2–17.4)	19.3 (17.7–20.9)	0.002	
Missing	24.7 (21.4–28.0)	NA	NA		13.8 (11.2–16.4)	NA	NA	
Geographic region								
Northeast	23.0 (20.3–25.7)	26.7 (23.5–29.9)	0.09	< 0.001	12.0 (10.0–14.1)	18.7 (15.7–21.6)	< 0.001	< 0.001
Midwest	26.6 (23.8–29.4)	27.4 (24.9–29.9)	0.20		14.3 (12.5–16.0)	19.0 (16.4–21.1)	< 0.001	
South	26.4 (24.4–28.3)	30.1 (28.2–32.0)	0.003		14.1 (12.5–15.6)	22.4 (20.6–24.3)	< 0.001	
West	27.4 (24.3–30.5)	22.1 (20.0–24.1)	0.003		15.1 (13.1–17.1)	12.9 (11.3–14.5)	0.08	

[a] Prevalence estimates were weighted

[b] Before the COVID-19 pandemic, in the year of 2018 in Allergies and years of 2018–2019 in Asthma

[c] During the COVID-19 pandemic, in the year of 2021 in Allergies and years of 2020–2021 in Asthma

[d] *P* values for difference were calculated using χ^2 tests

[e] *P* values for interaction were calculated by including multiplicative terms of each stratum variable with survey cycle in the aforementioned logistic regression models and adjusted for age, sex, race/ethnicity, education and family income to poverty ratio and geographic region

COVID-19 pandemic was likely due to decreased exposure to allergens [44]. Measures such as wearing masks, washing hands frequently, enhancing indoor ventilation, and maintaining social distance avoided the exposure of children and adolescents to allergens [44]. Also, the reduction in air pollutants may have contributed to the decline in the prevalence of skin allergies. Exposure to air pollutants can increases the risk of skin allergies [45, 46], but the implementation of lockdown measures resulted in a substantial improvement in air quality, marked by a significant reduction in the levels of air pollutants [47]. Thus it may be one of the reasons for the decline in the prevalence of skin allergies. Additionally, studies have pointed out that overexposure to ultraviolet radiation can

Table 7 Prevalence of food allergies and skin allergies in US children and adolescents by characteristics before and during the COVID-19 pandemic from 2018 to 2021

Characteristic	Food allergies, %[a] (95% CI)		*P* value		Skin allergies, %[a] (95% CI)		*P* value	
	Before[b]	During[c]	Difference[d]	Interaction[e]	Before[b]	During[c]	Difference[d]	Interaction[e]
N/Total	560/ 8269	506/ 8259			1097/ 8269	932/ 8259		
Overall	6.5 (5.8–7.1)	5.8 (5.2–6.4)	0.12		12.6 (11.6–13.5)	10.7 (9.9–11.5)	0.005	
Age, year								
0–2	5.2 (3.6–6.7)	3.6 (2.5–4.8)	0.12	0.57	13.9 (11.6–16.3)	9.4 (7.8–11.0)	0.001	0.08
3–5	6.3 (4.7–7.8)	5.1 (3.6–6.5)	0.27		13.5 (11.3–15.8)	11.3 (9.2–13.4)	0.15	
6–11	5.9 (4.9–6.9)	5.8 (4.7–6.9)	0.94		12.6 (11.0–14.1)	12.1 (10.6–13.6)	0.67	
12–17	7.8 (6.5–9.0)	7.1 (6.0–8.1)	0.39		11.4 (10.1–12.8)	9.8 (8.6–11.0)	0.08	
Sex								
Male	6.4 (5.5–7.3)	5.9 (5.0–6.7)	0.35	0.82	12.2 (10. 9–13.5)	10.7 (9.6–11.9)	0.10	0.53
Female	6.5 (5.5–7.6)	5.8 (5.0–6.5)	0.23		12.9 (11.6–14.3)	10.7 (9.7–11.8)	0.01	
Race/ethnicity								
Hispanic	5.9 (4.5–7.4)	5.0 (3.9–6.0)	0.29	0.12	10.6 (8.8–12.3)	9.5 (8.0–11.0)	0.35	0.86
NH White	6.6 (5.8–7.5)	5.3 (4.4–6.1)	0.02		12.0 (10.8–13.2)	10.2 (9.1–11.3)	0.03	
NH Black	6.0 (4.4–7.6)	7.5 (5.4–9.7)	0.26		18.0 (14.7–21.3)	14.2 (11.4–16.9)	0.07	
Other	7.6 (5.5–9.6)	8.5 (6.5–10.4)	0.54		13.2 (10.6–15.7)	12.3 (10.2–14.5)	0.62	
Highest educational level of family members								
Less than high school	4.5 (2.6–6.3)	4.6 (2.2–6.9)	0.95	< 0.001	8.0 (5.6–10.5)	6.8 (4.1–9.5)	0.52	< 0.001
High school	5.6 (3.7–7.5)	4.3 (2.9–5.7)	0.30		10.6 (8.4–12.8)	9.6 (7.5–11.6)	0.50	
College or higher	6.9 (6.2–7.6)	6.3 (5.6–6.9)	0.17		13.5 (12.4–14.7)	11.4 (10.5–12.2)	0.003	
Missing	3.2 (0.0–9.7)	NA	NA		NA	11.8 (0.0–33.7)	NA	
Family income to poverty ratio								
< 1.00	5.19 (3.6–6.7)	6.56 (4.8–8.3)	0.25	0.07	14.0 (11.2–16.9)	10.6 (8.3–12.9)	0.07	0.51
1.00–1.99	7.57 (5.3–9.8)	4.59 (3.5–5.7)	0.008		13.0 (10.8–15.1)	10.1 (8.5–11.7)	0.04	
2.00–3.99	5.42 (4.3–6.5)	5.38 (4.4–6.4)	0.96		11.2 (9.6–12.8)	10.2 (8.9–11.6)	0.34	
≥ 4.00	7.46 (6.3–8.6)	6.68 (5.7–7.7)	0.32		13.0 (11.5–14.6)	11.7 (10.4–13.0)	0.18	
Missing	6.09 (4.5–7.7)	NA	NA		12.1 (9.5–14.7)	NA	NA	
Geographic region								
Northeast	6.29 (4.8–7.8)	6.38 (5.0–7.8)	0.93	0.33	11.2 (9.1–13.3)	9.5 (7.7–11.2)	0.19	1.00
Midwest	5.36 (4.2–6.6)	5.74 (4.4–7.1)	0.68		13.2 (11.1–15.3)	11.3 (9.5–13.1)	0.18	
South	6.53 (5.3–7.7)	5.78 (4.8–6.8)	0.28		12.7 (11.1–14.2)	10.9 (9.6–12.3)	0.10	
West	7.36 (6.0–8.7)	5.54 (4.4–6.7)	0.03		12.6 (10.4–14.9)	10.7 (9.2–12.3)	0.16	

[a] Prevalence estimates were weighted

[b] Before the COVID-19 pandemic, in the year of 2018 in Allergies and years of 2018–2019 in Asthma

[c] During the COVID-19 pandemic, in the year of 2021 in Allergies and years of 2020–2021 in Asthma

[d] *P* values for difference were calculated using χ^2 tests

[e] *P* values for interaction were calculated by including multiplicative terms of each stratum variable with survey cycle in the aforementioned logistic regression models and adjusted for age, sex, race/ethnicity, education and family income to poverty ratio and geographic region

cause skin irritation [48], and the lockdown policy had led to a reduction in sun exposure, which may have led to a decrease in the prevalence of skin allergies.

Previous studies had shown an increase in the prevalence of food allergies among children [25–27]. In contrast, we found the prevalence of food allergies in current study remained constant during the COVID-19 epidemic. Whether this was because COVID-19 primarily affects the respiratory system remains unknown [49]. During the epidemic, concerns were focused on respiratory symptoms and infection prevention rather than on issues related to food allergies.

This study has several notable strengths. Firstly, the study was a large-scale study to compare the differences in the prevalence of allergic diseases and asthma among US children and adolescents during the COVID-19 pandemic and preceding the pandemic. Moreover, it utilizes extensive nationwide population-based data,

Table 8 Prevalence of asthma in US children and adolescents by characteristics before and during the COVID-19 pandemic, 2018 to 2021

Characteristic	Asthma, %[a] (95% CI)		*P* value	
	Before[b]	During[c]	Difference[d]	Interaction[e]
N/Total	1995/ 17,458	1468/ 14,045		
Overall	11.1 (10.5–11.7)	9.8 (9.2–10.4)	0.002	
Age, year				
0–2	2.5 (1.7–3.2)	1.6 (0.9–2.2)	0.08	0.04
3–5	7.2 (5.9–8.4)	6.3 (4.7–7.9)	0.42	
6–11	12.2 (10.7–13.8)	10.3 (9.2–11.3)	0.03	
12–17	14.6 (13.7–15.5)	14.7 (13.4–15.9)	0.95	
Sex				
Male	12.7 (11.3–13.6)	11.3 (10.4–12.2)	0.02	0.28
Female	9.3 (8.5–10.1)	8.3 (7.5–9.1)	0.07	
Race/ethnicity				
Hispanic	11.2(10.0–12.4)	9.4 (8.2–10.6)	0.03	0.09
NH White	9.4 (8.6–10.1)	8.9 (8.1–9.6)	0.32	
NH Black	17.9 (15.8–20.0)	14.0 (11.9–16.1)	0.008	
Other	10.7 (9.0–12.4)	10.5 (8.8–12.1)	0.87	
Highest educational level of family members				
Less than high school	12.0 (10.0–14.0)	9.3 (6.99–11.54)	0.07	< 0.001
High school	13.1 (11.3–14.9)	10.9 (9.3–12.5)	0.06	
College or higher	10.6 (9.9–11.2)	9.6 (8.9–10.3)	0.04	
Missing	NA	16.2 (0.0–37.8)	NA	
Family income to poverty ratio				
< 1.00	14.9 (13.1–16.7)	11.7 (9.7–13.6)	0.02	0.09
1.00–1.99	12.2 (10.7–13.7)	10.1 (8.8–11.4)	0.04	
2.00–3.99	10.9 (9.9–12.0)	9.2 (8.2–10.2)	0.02	
≥ 4.00	8.6 (7.7–9.4)	9.2 (8.2–10.2)	0.38	
Missing	10.4 (8.2–12.5)	NA	NA	
Geographic region				
Northeast	12.1 (10.5–13.8)	8.8 (7.2–10.5)	0.007	0.04
Midwest	10.8 (9.5–12.2)	9.8 (8.5–11.2)	0.25	
South	11.7 (10.8–12.7)	10.4 (9.4–11.4)	0.05	
West	9.6 (8.4–10.7)	9.4 (8.4–10.4)	0.87	

[a] Prevalence estimates were weighted

[b] Before the COVID-19 pandemic, in the year of 2018 in Allergies and years of 2018–2019 in Asthma

[c] During the COVID-19 pandemic, in the year of 2021 in Allergies and years of 2020–2021 in Asthma

[d] *P* values for difference were calculated using χ^2 tests

[e] *P* values for interaction were calculated by including multiplicative terms of each stratum variable with survey cycle in the aforementioned logistic regression models and adjusted for age, sex, race/ethnicity, education and family income to poverty ratio and geographic region

incorporating a large sample size and encompassing a diverse multiracial/multiethnic population. The adoption of a nationally representative sampling strategy through the NHIS enables the findings to be more broadly applicable to the general population. And the study benefits from a relatively high response rate in the NHIS [22], which helps mitigate concerns related to selection bias.

This study is subject to several limitations. First, the assessment of both allergic disease and asthma relied on self-reported and retrospectively reported information, which introduces the potential for recall bias and misreporting. And the NHIS underwent a planned redesign in 2019 and there was a lack of consistency on how questions on allergies were collected before and during pandemic for allergies. However, it is important to note that the prevalence rates of the allergic disease and asthma observed in this study align with those reported in other nationwide studies conducted during similar time periods. This suggests a degree of consistency and supports the reliability of the findings despite the reliance on self-reported data. Second, because this study was cross-sectional, we were unable to determine the long-term effects due to the COVID-19 pandemic. Therefore, longer-term observations are needed in the future to determine the specific effects of pandemics on allergic diseases and asthma. In addition, some of the results of our observations including the rising prevalence of respiratory allergies and the constant prevalence of any allergy and food allergies were inconsistent with other studies. Therefore, future explorations for specific allergy types are needed.

Conclusion

Based on nationally representative data in large cross-sectional surveys, we found significant differences in the prevalence of respiratory allergies, skin allergies and asthma in children and adolescents during and before the COVID-19 pandemic. More research is necessary to examine the relationship between the prevalence of allergic diseases and the COVID-19 pandemic time period using survey data representing that time period, especially focusing on the impact of lifestyle changes due to infection prevention measures.

Abbreviations

CI	Confidence interval
NCHS	National Center for Health Statistics
NHIS	National Health Interview Survey
Prev	Prevalence
NA	Not applicable
NH	Non-Hispanic

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Authors' contributions

WY conceived the study; XL and WY and supervised the study; YL, QL, MW, KZ, XY, JL, QL, HY and CX collected the data, YL and QL analyzed the data, YL and QL drafted the manuscript, MW, KZ, XY, JL, QL, HY and CX reviewed and edited the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Availability of data and materials

The original contributions presented in the study are publicly available. The datasets analyzed during current study are available at NHIS online website: https://www.cdc.gov/nchs/nhis/index.htm

Declarations

Ethics approval and consent to participate

This research analyzed de-identified information downloaded from the National Health Interview Survey public database. All methods were carried out in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Child and Adolescent Health, School of Public Health, Guangdong Province, Guangdong Pharmaceutical University, Guangzhou 510006, China. [2]Department of Nutrition and Food Health, School of Public Health, Guangdong Province, Guangdong Pharmaceutical University, Guangzhou 510006, China. [3]Department of Epidemiology and Health Statistics, School of Public Health, Guangdong Province, Guangdong Pharmaceutical University, Guangzhou 510006, China.

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