The Effect of the COVID-19 Pandemic on BMI in Children and Adolescents: A Retrospective Cohort Study

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Abstract

Background:

The COVID-19 pandemic created circumstances with the potential to increase rates of overweight and obesity. We aimed to assess whether there were significant increases in BMI among a sample of children and adolescents during the year 2020 compared to the two years prior to the pandemic.

Methods:

For this retrospective cohort study, data was obtained from the electronic medical records of 8398 children 3-17 years of age who attended 3 consecutive well visits between June 1 and October 31 in 2018, 2019 and 2020 in a single center in the Midwest. Generalized linear mixed models were used to calculate the differences in average BMI and obesity rates over the three years.

Results:

Between 2019 and 2020, the mean BMI for the whole sample increased 3.2 percentile points (from the 70.5th to the 73.7th percentile; $p < 0.001$) compared to an increase of 0.8 percentile point between 2018 and 2019 ($p = 0.008$).

The proportion of children and adolescents with obesity rose from 13% in 2019 to 15.2% in 2020 ($p < 0.001$) compared to no significant increase from 2018 to 2019. Significant disparities in BMI were observed between socioeconomic and ethnic groups.

Conclusions

Significant increases in BMI and obesity rates occurred in 2020 in this sample. We propose that the circumstances surrounding the COVID-19 pandemic contributed significantly to these increases.

Background

The ongoing COVID-19 pandemic is a public health crisis unprecedented in modern times. Measures enacted to contain the spread of infection resulted in widespread disruptions in everyday life. Varying degrees of lockdown, shelter-in-place mandates, and quarantines were implemented, and businesses and schools closed worldwide.

According to a UNICEF report, nearly 1.5 billion learners in 165 countries have been affected by school closures in the past year.¹ School closure was the most consistently applied intervention worldwide to slow community transmission of infection. By the middle of March 2020 most schools in the US were closed for the remainder of the 2019–2020 academic year. The closures affected 55.1 million students at 124,000 public and private schools nationwide.² In the state of Nebraska, schools were ordered to close on March 23rd 2020; a total of 1095 public and many private schools were closed until the end of the

school year.³ Many schools continued the closure and almost all maintained at least partial restrictions on in-person attendance through December of 2020.⁴

Childhood obesity is a major global public health problem⁵ Obesity increases the risk of mental and physical health problems in children.⁶ Children with obesity are also substantially more likely to remain obese as adults.⁷ Obesity is a major risk factor for some of the top causes of morbidity and mortality in the US, including hypertension, type 2 diabetes, and coronary artery disease.⁸ More than 30% of adults and 17% of children in the US are living with obesity, and rates are rising.^{9,10} Significant ethnic disparities exist, with obesity rates in the US being highest among Hispanic children, followed by Black children when compared to their White peers.¹¹ However, the relationship between ethnicity and obesity is complex,¹² and some studies have suggested that economic disadvantage accounts for much of the observed ethnic differences in obesity rates.¹³

Since the beginning of the pandemic, public health and child health experts predicted that school closures would result in increase in childhood obesity.¹⁵ Previous work suggests that school provides a structured environment that protects against obesity through increased opportunities for physical activity, restriction of caloric intake, and reduced screen time.¹⁶ Several studies have noted accelerated weight gain over the summer months compared to during the school year, particularly among minority and already-obese children and adolescents.¹⁷ One longitudinal study of children of various ethnicities found that they gained an average of 5.2 BMI percentile points over the summer months and lost 1.5 points during the school year.¹⁸

In contrast to the structured conditions of school, home environments are associated with more sedentary leisure activities and unsupervised access to foods high in fat and sugar.¹⁹ Screen-based activities have been shown to be associated with increases in acute eating behaviors in children and adolescents.²⁰ Stress associated with quarantine has also been shown to be a risk factor for obesity.²¹

A few studies have specifically explored physical activity and eating behaviors during the COVID-19 pandemic. A survey of 211 parents from 35 US states and the District of Columbia reported that their children experienced decreases in physical activity and an increase in sedentary behaviors during the pandemic.²² A longitudinal study from Italy during lockdown reported changes in activity, sleep, and eating behaviors among children that would be likely to predispose them to further weight gain.²³ 22% of a convenience sample of 1200 adults self-reported that they had gained weight during the pandemic due to quarantine²⁴, and a sample of adult patients with type 2 diabetes showed worsening glucose control in response to an 8-week lockdown, presumably due to reduced activity and increased eating.²⁵ A large study in China that reported data from an Internet-based convenience sample of over 10,000 individuals in their late teen and young adult years noted that self-reported rates of overweight and obesity increased after a 4–5 month period of COVID-19-related lockdown.²⁶ Another study reviewing the electronic medical

records of over 11,000 adults living in the Boston, Massachusetts, area found that after lockdown, obesity rates increased among women, but decreased among men.²⁷

Although the foregoing studies have focused primarily on changes in physical activity and eating behaviors resulting from the pandemic, to our knowledge, no studies have objectively documented weight or BMI changes in children or adolescents during the COVID-19 pandemic. Confirming the presence and scale of weight gain among children during this time period would lend support to these prior observations and improve the ability of policymakers to holistically evaluate the effects of pandemic-related lockdown on children's health when planning for future public health interventions such as school closures.

Methods

Study design:

The aim of this study was to determine if there was a significant increase in BMI and rates of obesity in the months following the COVID 19 pandemic compared to the previous year. We used a retrospective cohort design strategy to obtain BMI data on a cohort of children 3–17 years of age who presented for routine health maintenance visits during a 5-month period (from June 1 to October 31) in each of the years 2018, 2019, and 2020. This time frame was chosen because the ambulatory clinics had been closed to routine visits during the pandemic and were only reopened on June 1st, 2020. Data extraction for the study began in November 2020.

Setting:

Data were collected from the electronic medical record (EMR) (Epic) of a large pediatric health system based in Omaha, Nebraska. The system has around 50% market share of pediatric primary care in Omaha, and its service area includes a contiguous metropolitan area in a neighboring state (Iowa). Eleven ambulatory clinics are located in these urban areas, and three clinics are located in rural areas of Nebraska. The data were extracted from the EMR by a research employee of the organization's research institute. The study protocol was approved by the Joint Pediatric Institutional Review Board of the University of Nebraska Medical Center and Children's Hospital Medical Center.

Data Retrieval

The EMR was queried for health supervision encounters of children aged 3–17 years of age occurring between June 1st and October 31st, 2020. This time frame was chosen to correspond to the opening of outpatient clinics after the pandemic shutdown, and the initiation of the research project in November of 2020. Records of health supervision visits in the same time frame for the same patients were then

retrieved from 2019 and 2018. Standard protocols are followed in all clinics for the measurements of height and weight, which are entered directly into the electronic health record.

The following data from each of the visits were extracted: age, gender, ethnicity, insurance type, height, weight, and BMI. BMI percentile data were not extractable electronically, so they were calculated using a mathematical formula to compute a z-score and converted through the cumulative distribution function of the normal distribution to give the age- and gender- adjusted BMI percentiles. These are the same calculations used to compute the BMI percentiles found on the curves of the CDC growth charts²⁸.

Data analysis:

Two types of generalized linear mixed models (GLMMs) were applied to evaluate actual differences in percentiles and differences in the percent of children with obesity ($\text{BMI} \geq 95\text{th percentile for age}$) versus children in the normal-overweight range ($\text{BMI} < 95\text{th percentile for age}$) across the three years. The models included a random-subject effect to account for the three annual observations collected from each subject. Odds ratios of ethnicity, insurance status, and gender were evaluated, as well as their interaction with year.

These analyses were computed with PROC GLIMMIX from SAS/STAT Software, Version 9.4 (© 2002–2012) of the SAS System for Windows (Cary, NC).

Results

The EMR search identified 8398 unique patients who had records of a health-supervision visit in three consecutive years (2018, 2019, and 2020) in the time frame specified.

The demographic characteristics of the sample are shown in Table 1.

Table 1
Demographic characteristics of
the study sample.

Variable	N	%
Total sample	8,398	100
Race		
Black	500	6.0
Hispanic	615	7.3
White	6489	77.3
Other	794	9.5
Gender		
Female	4087	48.7
Male	4311	51.3
Insurance		
Private	6662	79.3
Public	1713	20.4
Missing	23	0.3
Age	N	%
3	515	6.1
4	338	4.0
5	299	3.6
6	419	5.0
7	631	7.5
8	534	6.4
9	591	7.0
10	616	7.3
11	710	8.5
12	878	10.5
13	897	10.7
14	754	9.0

Variable	N	%
15	581	6.9
16	428	5.1
17	207	2.5
18	0	0.0
19	0	0.0

Six percent of the sample identified as African-American / Black, 7.3 % as Hispanic, and 77.3% as non-Hispanic White. Other ethnic groups, including American Indian, Alaska Natives, Indian, and Middle Eastern, constituted 9.5% of the sample; this group also included individuals identifying as 2 or more races. Females made up 48.7% of the sample, and 20.4% were covered by public insurance. The median age was 11 years. The distribution of age groups is shown in Table 1.

No significant differences in weight percentiles were observed based on the subjects' ages in the 2020 cohort, so the results were averaged across all age groups. The average BMI percentile data for different ethnicity and insurance categories are shown in Table 2. At baseline, the average BMI was highest among Hispanic children and adolescents (75th percentile) followed by Blacks (72nd percentile), then by children from other ethnic groups (67th percentile); average BMI was lowest among Whites (63rd percentile).

Table 2
Average BMI percentiles 2018–2020

	2018	2019	2020	P value: 19 vs 18	P value: 20 vs 19
Total Sample	0.697	0.705	0.737	0.008*	< .001**
Insurance:	0.661	0.666	0.696	0.73	< .001**
Private	0.731	0.734	0.775	0.007 *	< .001**
Public					
Race:	0.727	0.743	0.764	0.15	< .022**
Black	0.751	0.754	0.793	1.00	< .001**
Hispanic	0.673	0.684	0.727	0.41	< .001**
Other	0.630	0.634	0.653		< .001**
White					
Gender:	0.701	0.710	0.740	0.045 *	< .001**
Female	0.693	0.702	0.735	0.042	< .001**
Male					

Between 2019 and 2020, the average BMI percentile for the entire group increased by 3.2 points, from the 70.5th to the 73.7th percentile ($p < .001$). In contrast, the average percentile increased less than one point between 2018 and 2019, although this increase was also statistically significant ($p = 0.008$).

Additionally, as shown in Table 3, the rate of increase in BMI percentiles was also significantly greater for Hispanics, Blacks and other minority groups when compared to Whites.

Table 3
Comparisons of magnitude of increase in BMI percentile between groups (computed on the logit scale)

2018–2019					2019–2020			
Label	Estimate	Adj p	lower	upper	estimate	Adj P	lower	upper
Black vs white	.0321	.76	– .05	0.1190	0.069	0.031	0.0047	.1334
Hispanic vs white	.0018	1.00	– .0799	0.0836	0.1048	< .001	0.0436	.1660
Other vs white	.0227	.79	– .0430	0.0883	0.0769	< .001	0.0269	.1269
Private vs. Public	– .0183	0.65	– .0687	0.0322	-0.059	< .001	-0.0964	-0.0215

Children covered by public insurance demonstrated significantly greater increases in BMI percentiles compared to those covered by private insurance.

The analysis also showed that the proportion of children with obesity, defined as those with a BMI above the 95th percentile for age and gender increased from 13% of the total group in 2019 to 15.2% in 2020. There were no significant differences in rates of obesity between 2018 and 2019. As shown in Table 4, the odds ratio of being obese increased significantly between 2019 and 2020 in the whole sample (OR 1.33 (1.18 – 1.49); $p < .001$). Increases in obesity rates were significant in both genders and all ethnic groups, except for Hispanics, where the increase did not reach statistical significance (OR 1.28 (0.95–1.73); $p = 0.16$).

Table 4
Change in rates obesity from 2018–2020

	2019 vs 2018			2020 vs 2019		
	Odds ratio	(Lower-Upper)	Adj P	Odds Ratio	(Lower-Upper)	Adj P
Total sample	1.15	0.98–1.35	0.088	1.33	1.18–1.49	< .001
Race						
Black	1.06	0.66–1.70	1.00	1.44	1.01–2.03	0.035
Hispanic	1.12	0.74–1.69	0.99	1.28	0.95–1.73	0.16
White	1.17	0.94–1.45	0.30	1.28	1.09–1.49	< .001
Other	1.26	0.82–1.94	0.68	1.32	0.96–1.81	0.11
Insurance status						
Private ins	1.10	0.87–1.40	0.78	1.26	1.06–1.50	0.005
Public ins	1.21	0.95–1.53	0.18	1.40	1.18–1.66	< .001
Gender						
Female	1.17	0.94–1.47	0.27	1.33	1.12–1.57	< .001
Male	1.13	0.92–1.39	0.45	1.33	1.14–1.55	< .001

Discussion

Our study documents a significant pattern of weight gain manifested by an increase of approximately 3.2 percentile points in average BMI and an increase of about 2.2% in the proportion classified as obese in a large population of children and adolescents presenting for health maintenance visits during 2020, when compared to the two years prior. Although the retrospective design can allow conclusions of association

but not causation, the pandemic was associated on a global scale with a cascade of disruptions of normal life and in access to food and physical activity. Since physical activity and eating behaviors are the most important factors in weight status, it would be highly plausible that the observed changes in obesity rate and BMI in our study population were the result of this massive acute event.

Ethnic disparities in rates of obesity have been well established²⁹ and were observed at baseline in our study. Black children did not experience a disproportionate increase in weight in comparison to White children in 2020, although a pattern of disproportionate weight gain was observed among Hispanic and “other” ethnic categories. Another observation was that, as a group, children covered by public insurance experienced significantly higher increases in BMI than those on private insurance. This observation is consistent with previous studies that link low socioeconomic status to childhood obesity.³⁰

This study was based on epidemiologic data from the largest regional children’s ambulatory health system in Nebraska. The increases in weight observed during the time period corresponding to the pandemic are significant and alarming. Given previous observations and predictions, it is likely that this phenomenon is widespread. It is also plausible that children living in regions where stricter and more prolonged limitations of movement were in force may have experienced even greater impacts on body weight.

The study has several limitations. First, the generalizability of these findings may be limited because it was conducted in a small area of the Midwest. Generalizability may be influenced by the anthropometric and demographic composition of the population in different geographic locales. As mentioned above, the retrospective design limits the conclusions to associations, and cannot establish causation, regardless of the plausibility of the cause-effect relationship.

In addition, while circumstances may suggest that extended suspension of in-person school attendance was the primary culprit behind the observed weight gain in this study, efforts to determine the relative contributions of the various pandemic-associated factors would also be helpful in designing targeted interventions to prevent and reverse obesity among children and adolescents. Nonetheless, the strengths of this study include a large sample size, a cohort design with data collection over a three-year time period, and the use of direct measurements of height and weight from EMR data rather than reliance on self-reported measurements. If the observations of our study are extrapolated to the entire population of children and adolescents in the US, it would translate to an additional 1.8 million children becoming obese in a single year. Additionally, the persistence of ethnic and socioeconomic disparities in obesity rates emphasizes the urgency of continued development of targeted interventions to decrease the risk faced by minority and disadvantaged populations. Because of the potential health implications, we believe that these data fill an important gap in existing literature and should prompt the confirmation of our findings in other settings.

Conclusions

Significant increases in the average BMI and in childhood obesity rates were observed in the months following the COVID-19 pandemic in a large sample of children, confirming predications and concerns that the circumstances surrounding the pandemic including quarantine and school closures would do so. Ethnic and socioeconomic disparities in childhood obesity rates were maintained or exacerbated during this period. This has significant implications for policy development and public health interventions to manage the compounding effect of the pandemic on childhood obesity.

Abbreviations

BMI: Body Mass Index

COVID-19: Corona Virus Disease-19

Declarations

Ethics approval:

The study protocol was approved by the University of Nebraska Medical Center and Children's Hospital Medical Center. Informed consent was waived by the IRB.

Availability of data:

The datasets used and or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare no actual or potential financial or personal relationships that constitute conflicts of interest.

Consent for publication:

This study does not include individual data.

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Author contributions:

Dr. Arwa Nasir conceived the idea of the research, contributed significantly to the design of the study and interpretation of the data, and wrote the initial draft and subsequent revisions of the manuscript and approves the manuscript as submitted. She also wrote the author contributions segment.

Mr. Robin High: planned and performed the data analysis, contributed to the drafting of the manuscript, and reviewed and approved the manuscript as submitted. He also reviewed and approved the author contribution section.

Dr. Laeth Nasir: Contributed substantially to the design of the study, the interpretation of the data, and the drafting and revision of the manuscript, and reviewed and approved the manuscript as submitted. He also reviewed and approved the author contribution section.

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Figures

Figure 1

BMI percentile means for the total sample and subgroups in 2018, 2019 and 2020.