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Regional Implications of the COVID-19 Pandemic on Childhood Obesity Prevalence, Denver, Colorado, 2019–2022

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Abstract

Background: During the early COVID-19 pandemic, many US youths experience rapid excess weight gain and increase in BMI and obesity prevalence. We leveraged longitudinal electronic health records from three health care organizations in metropolitan Denver, Colorado, to assess COVID-19 pandemic effects on BMI and obesity prevalence.

Methods: Using a retrospective cohort of 55,429 children aged 2–19 years, each with ≥3 BMI measurements during 2019–2022, we used mixed-effects regression models to estimate rates of change in BMI and obesity prevalence during prepandemic, early pandemic (March–December 2020), and two later pandemic periods (2021, 2022).

Results: The average rate of BMI gain was nearly 70% higher during early pandemic compared to prepandemic [rate ratio (RR): 1.68 (95% confidence interval {CI}: 1.60–1.76)] but attenuated substantially as the pandemic continued [RR: 0.37 (95% CI: 0.34–0.40) for 2021 vs. early pandemic]. This coincided with changes in estimated obesity prevalence from 16% to 17% prepandemic to 21% by December 2020% to 20% by December 2022. School-aged children 6–13 years, those with prepandemic healthy weight, and Hispanic and non-Hispanic Black children had the most pronounced BMI increases in early pandemic.

Conclusions: Although rates of BMI gain leveled out from early pandemic increases, obesity prevalence in health care-seeking youths in metropolitan Denver remained substantially higher in 2022 than prepandemic, particularly in certain subgroups. Opportunities exist to strengthen institutions and programs that support healthy eating, physical activity, and maintenance of a healthy weight. This work underscores the value of regional surveillance systems to monitor disease trends and inform local efforts to support children's health.

Keywords: BMI trends; childhood obesity; COVID-19 pandemic; EHR data; metropolitan Denver

Introduction

Childhood obesity is a serious public health concern in the United States. National data from 2021 to 2023 indicate that nearly 15 million US children (21.1%) had obesity,[1] increasing the risk for type 2 diabetes, abnormal lipid profiles, and poor metabolic health.[2] Childhood obesity also increases risk for severe outcomes from COVID-19 and influenza,[3,4] and adult obesity, which is associated with other chronic diseases.[5]

The COVID-19 pandemic placed unprecedented stress on children and families, particularly early pandemic when schools closed, everyday activities halted, and access to nutrition programs was limited.[6–8] Consequently, many US children experienced rapid weight gain. One study found that among 430,000 children aged 2–19 years, rates of BMI gain doubled during early pandemic.[9] Rates of BMI gain were particularly accelerated among children with preexisting overweight or obesity, those aged 6–11 years, and Black and Hispanic children.[9–11] Another study of subsequent pandemic

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periods found that accelerated rates of BMI increase leveled out in 2021.[12] Still, obesity prevalence remained higher than prepandemic levels (23% vs. 20%).[12]

Several gaps remain in understanding the effects of different pandemic periods on childhood weight, including whether regional and national trends varied and which populations were differentially affected. Understanding these trends can inform tailored interventions and facilitate engagement of regional institutions. We leveraged electronic health record (EHR) data from a distributed data network (DDN) of three large health care organizations in metropolitan Denver, Colorado.[13] DDNs of EHRs are increasingly used for public health surveillance,[14,15] particularly during the pandemic when many surveillance systems were disrupted.[16,17] We conducted a retrospective longitudinal cohort analysis to examine rates of change in BMI and obesity prevalence among children aged 2–19 years in metropolitan Denver before the COVID-19 pandemic (2019–February 2020), during the early pandemic (March–December 2020), and during two later pandemic periods (2021 and 2022), and how trends differed by patient characteristics.

Methods

Data Source

We used data from the Colorado Health Observation Regional Data Service (CHORDS), a regional DDN leveraging EHR data for research and public health. CHORDS contains data for approximately half of the residents in the 7-county Denver metropolitan area, consisting of 14 health care partners that share a common data model in federated virtual data warehouses (VDWs).[13,18] In 2018, the CDC launched the Clinical and Community Data initiative (CODI). CODI built on CHORDS infrastructure by including community data partners and implementing privacy-preserving record linkage (PPRL) to deduplicate patients seen at multiple organizations.[19–23]

This analysis used data from three large health systems that participate in CHORDS and have implemented PPRL. Denver Health and Hospital Authority (Denver Health) is a safety-net hospital system with an emergency department, acute-care hospital, and family, school, and urgent care health centers. Kaiser Permanente Colorado (Kaiser Permanente) is an integrated health care delivery organization, serving over half a million Coloradans across 33 medical offices and partner hospitals. Children's Hospital Colorado (Children's) has a main hospital, 2 satellite hospitals, and 13 outpatient clinics across Colorado.

Datasets were created using an iterative federated process. Each health system ran structured query language queries to generate a potential cohort of children from their VDWs. Results were sent to a data coordinating center at the University of Colorado Anschutz to deduplicate patients using PPRL. Deduplicated lists were sent back to the health systems, which then extracted anthropometric, demographic, and other relevant patient data to create final datasets.

Data Cleaning

We extracted EHR data for 506,772 unique children aged 2–19 years who received outpatient care at any of the three health systems between 2017 and 2022. We excluded 1713 patients (0.3%) who had two different sexes, missing sex, duplicate records, or multiple birth dates more than 3 months apart across health systems. If a patient had multiple birth dates <3 months apart, we used the mode birth date.

We cleaned height and weight measurements for 505,059 children from 2017 to 2022 using growthcleanr, an algorithm for detecting errors in longitudinal growth data.[24] We excluded extreme values of BMI and BMI z-score based on CDC's cut points.[25] Anthropometric data cleaning resulted in the exclusion of 11,446 children (2.3%). We categorized BMIs based on sex-and age-specific percentiles: underweight (<5th percentile), healthy weight (≥5th to <85th percentile), overweight (≥85th to <95th percentile), moderate obesity (≥95th to <120% of the 95th percentile), and severe obesity (≥120% of the 95th percentile or BMI ≥35 kg/m^2).[26] We restricted the dataset to 2019–2022, resulting in 323,236 children with 1.2 million BMI measurements.

Patient age at the start of the pandemic was calculated as March 1, 2020, minus birth date; age was categorized as 2–5, 6–9, 10–13, 14–16, and 17–19 years. Race and ethnicity categories were defined as non-Hispanic (NH) White, NH Black, NH Asian, Hispanic, and NH other/multiple race/ethnicity. NH other/multiple included American Indian or Alaska Native, Native Hawaiian or other Pacific Islander, multiple races, and other. Patients were considered multisite if they had BMI measurements from >1 health system.[1]

Study Population

Inclusion in the longitudinal cohort required ≥1 BMI measurement in each time period: the 14-month period preceding the COVID-19 pandemic (January 1, 2019–February 29, 2020); the early pandemic (June 1, 2020–December 31, 2020); and the later pandemic (January 1, 2021–December 31, 2022) (Fig. 1). Of 323,236 children who had ≥1 BMI in 2019–2022, 260,224 (80.5%) were excluded due to insufficient BMI data in the periods defined above. Notably, the median number of BMIs was 3; thus, ≥50% of patients would have been excluded regardless of how we constructed the periods for BMIs. Demographic comparisons between those with and without sufficient BMIs are in Supplementary Table S1.

[1]The CHORDS data sharing agreement does not allow for presentation of site-specific data from any of the contributing health systems. We conducted site-specific analyses as robustness checks and discuss any data related to specific sites as aggregated findings.

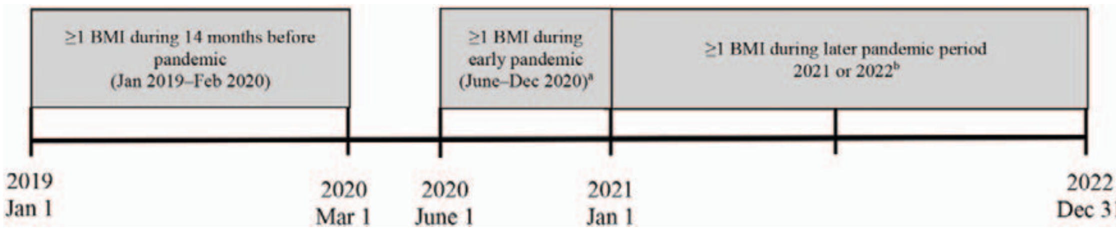

Figure 1. BMI inclusion criteria for longitudinal cohort, metropolitan Denver, Colorado, 2019–2022. [a]BMIs taken during March–May 2020 were included in models in the "early pandemic" period, but were not used to define cohort selection criteria. Thurs, each child was required to have a BMI in June–December 2020 to be included. [b]We allowed the rates of change to vary between 2021 and 2022. However, for the purpose of cohort selection, we only required a child to have 1 BMI in 2021 or 2022.

We required patients to have an address in the 7-county Denver metropolitan area (Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, or Jefferson County) during the study period; this excluded 7573 (12%) of the 63,012 patients with sufficient BMI data. Last, we excluded 1325 children with unknown race/ethnicity (2.4%). Our final longitudinal cohort comprised 54,104 patients aged 2–19 years who lived in metropolitan Denver, had known race/ethnicity, and had ≥1 valid BMI in each of the three periods.

Statistical Analysis

We used linear mixed-effects regression models to examine differences in average rates of BMI change (kg/m^2/month) across time periods. Covariates included time (months from March 1, 2020); an indicator variable for BMI period (prepandemic, early pandemic, 2021, 2022); the interaction of time and period; sex; age on March 1, 2020; race/ethnicity; site; and BMI category (based on last prepandemic BMI). To obtain rates by patient characteristics, we ran models with three-way interactions between time, period, and each characteristic, including lower-order interactions, main effects, and other covariates. To examine race-specific BMI trends by age, we ran age-stratified models with a three-way interaction term for race/ethnicity, including lower-order terms, main effects, and other covariates. We calculated rate ratios (RRs), rate differences, and corresponding 95% confidence intervals (CIs) to compare rates of BMI change in early pandemic to prepandemic, 2021 to early pandemic, and 2022 to 2021 by patient characteristics. Statistical significance was based on nonoverlapping 95% CIs to help focus the results discussed.

We used linear mixed-effects models to generate average rates of change in obesity prevalence (BMI ≥95th percentile) across periods. Despite limitations of linear probability models in estimating binary outcomes, linear mixed-effects models were used for this outcome due to nonconvergence of mixed logit and mixed generalized linear models. These models included covariates listed above, except for the last prepandemic BMI category. Finally, we conducted supplemental analysis with extended BMI z-score[27] as the outcome. Extended BMIz is inherently age-and sex-specific, which allowed us to explore potential differences from BMI. Of note, extended BMIz overcomes the technical limitations of CDC's original BMIz for children with high BMIs.[28]

Models included all BMI measurements from 2019 to 2022 (491,664 BMIs for 54,104 patients). Models accounted for the correlation between repeated measurements within patients by nesting measurements within patient identifiers, as well as variation and unequal spacing in the number of BMI measurements. We performed anthropometric cleaning in R, data management in SAS version 9.4 (SAS Institute Inc.), and modeling in Stata version 15.1 (StataCorp LLC). This project was reviewed by the Colorado Multiple Institutional Review Board on behalf of all participating institutions and by the CDC's Office of Readiness and Response. Both institutional reviews determined that it was research not involving human subjects.

Results

Among 54,104 children aged 2–19 years in the longitudinal cohort, 51% were female (Table 1). Mean age at the start of the pandemic was 10.3 years (standard deviation = 4.4). Approximately 42% were Hispanic, 39% NH White, 11% NH Black, 4% NH Asian, and 4% NH other/multiple. Most children (82%) had ambulatory care visits at a single health care system. There was substantial variation in racial and age composition by health system (data not shown). Based on each child's last prepandemic BMI, 16% had obesity, including 5% with severe obesity. Obesity prevalence was higher in males, older children, and Hispanic or NH Black children (Table 1).

The average monthly rate of change in BMI was 0.061 kg/m^2/month before the pandemic (2019–February 2020), 0.102 kg/m^2/month during the early pandemic (March–December 2020), 0.038 kg/m^2 during 2021, and 0.044 kg/m^2 during 2022 (Fig. 2A, Table 2). The rate of BMI gain greatly accelerated during the early pandemic (RR of early pandemic vs. prepandemic: 1.68) but attenuated substantially as the pandemic continued (RR: 0.37 for 2021 vs. early pandemic).

From prepandemic through 2020, rates of BMI gain were similar between males and females; however, in 2021 and 2022, rates of BMI gain were slightly higher in females than in males (Table 2). Among demographic

Table 1. Characteristics of 54,104 Children Aged 2–19 Years with ≥3 BMI Measurements[a], Metropolitan Denver, Colorado, 2019–2022

	Overall		BMI category[b]				
	N	%	Underweight ($n = 2843$)	Healthy weight ($n = 35,237$)	Overweight ($n = 7619$)	Moderate obesity ($n = 5708$)	Severe obesity ($n = 2697$)
Overall	54,104	100.0	5.3	65.1	14.1	10.6	5.0
Sex							
Male	26,755	49.5	5.7	63.9	13.5	11.2	5.7
Female	27,349	50.5	4.8	66.4	14.6	10.0	4.3
Age category *(at start of pandemic)*							
2–5 years	11,775	21.8	6.9	73.7	10.9	7.2	1.2
6–9 years	12,996	24.0	5.4	67.0	12.7	10.4	4.5
10–13 years	15,661	28.9	5.1	60.8	15.4	12.6	6.1
14–16 years	10,525	19.5	3.5	61.5	16.4	11.3	7.3
17–19 years	3147	5.8	5.0	59.0	17.6	10.6	7.8
Race[c]							
Non-Hispanic White	21,112	39.0	6.3	73.8	11.3	6.3	2.3
Non-Hispanic Black	5663	10.5	5.3	64.0	14.7	10.7	5.2
Non-Hispanic Asian	2190	4.0	9.2	70.3	11.5	6.7	2.4
Hispanic	22,883	42.3	3.9	57.1	16.6	14.8	7.7
Non-Hispanic other/multiple	2256	4.2	5.2	63.7	15.9	10.4	4.8

[a]≥1 BMI measurement in the year directly preceding the COVID-19 pandemic (January 2019–February 2020), ≥1 BMI measurement in the early pandemic period after the initial 3 months (June–December 2020), and ≥1 BMI measurement in the later pandemic period (January 2021–December 2022).

[b]Based on the last prepandemic BMI taken between January 2019 and February 2020. BMI categories were defined as underweight (<5th percentile), healthy weight (≥5th to <85th percentile), overweight (≥85th to <95th percentile), moderate obesity (≥95th percentile to <120% of the 95th percentile), and severe obesity (≥120% of the 95th percentile. or ≥35 kg/m^2). Moderate obesity and severe obesity were mutually exclusive.

[c]Excluded 1325 patients with unknown race and ethnicity.

subgroups, school-aged children 6–9 and 10–13 years experienced the largest absolute increases in rates of BMI gain (rate difference: 0.07 for each group) and large relative increases from prepandemic to early pandemic [RR: 2.26 (95% CI: 2.06–2.46) for 6–9 years, 1.86 (95% CI: 1.74–1.98) for 10–13 years] (Table 3). Rates of BMI gain were similar across racial/ethnic groups prepandemic; however, NH Black, Hispanic, and NH other/multiple race/ethnicity children experienced more rapid BMI gain during the early pandemic than NH White children (Tables 2 and 3, Fig. 2B). For example, NH White children's rate of BMI change was 40% higher during the early pandemic compared to prepandemic [RR: 1.40 (95% CI: 1.26–1.53)], whereas early pandemic rates of BMI change in Hispanic and NH other/multiple children were 80% and 115% higher than prepandemic rates [RR: 1.80 (95% CI: 1.69–1.91) and 2.15 (95% CI: 1.64–2.66), respectively] (Table 3). These disparities were particularly evident in children aged 6–9 years.

Compared to healthy weight, children with overweight, moderate obesity, or severe obesity had much higher absolute rates of BMI gain prepandemic and early pandemic. For example, before the pandemic, average monthly rates of BMI gain were 0.034 kg/m^2 for those with a healthy weight, 0.083 kg/m^2 in those with overweight, 0.121 kg/m^2 in those with moderate obesity, and 0.169 kg/m^2 in those with severe obesity (Table 2). However, compared to their rates before the pandemic, children with healthy weight experienced the greatest relative increase in BMI during the early pandemic [RRs: 2.51 (95% CI: 2.29–2.73, healthy weight), 1.33 (95% CI: 1.22–1.44, moderate obesity), and 0.89 (95% CI: 0.80–0.99, severe obesity)] (Table 3).

Figure 2C and D shows trends in predicted obesity prevalence. The rate of change in obesity prevalence was

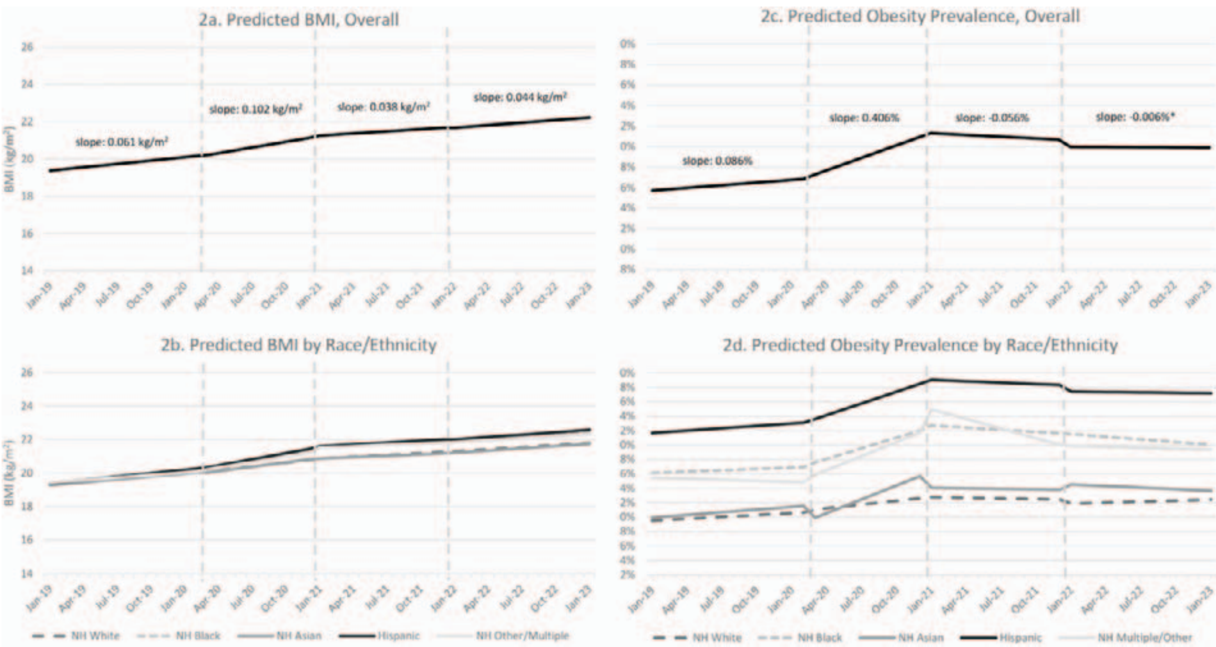

Figure 2. Predicted BMI and obesity prevalence overall and by racial and ethnic groups, metropolitan Denver, Colorado, 2019–2022. Vertical lines delineate the time periods used in the analysis. *Negative slope not significantly different from zero. NH, non-Hispanic.

nearly five times higher during the early pandemic compared to prepandemic (monthly slope estimates: 0.406% vs. 0.086%). This resulted in an increase in predicted obesity prevalence from 16.8% in January 2020 to 20.9% by December 2020. In 2021, the rate of change in obesity prevalence declined (–0.056%), and in 2022, rates stabilized but were not significantly different from zero (–0.006%), resulting in an estimated prevalence of 19.9% in December 2022 (Fig. 2C). Predicted obesity prevalence was consistently highest in Hispanic children and higher in NH Black and Hispanic children than in NH White and NH Asian children. NH White children had the smallest absolute and relative increases in obesity prevalence during the early pandemic period. Children with NH other/multiple races had large increases in predicted obesity prevalence during the early pandemic period, but rates declined substantially in 2021 and stabilized in 2022 (Fig. 2D). Supplemental analyses revealed a similar pattern for BMI and extended BMI z-score (Supplementary Fig. S1).

Discussion

Our study found substantial increases in children's rates of gain in BMI, extended BMIz, and obesity prevalence in the Denver metropolitan area during the early pandemic compared to prepandemic. Although rates steadily increased before the pandemic (2019–February 2020), the pandemic coincided with drastic accelerations in rates of increase. This resulted in an estimated regional obesity prevalence of approximately 21% by December 2020, compared to 16%–17% prepandemic. This increase may have been driven partly by children with healthy weight or overweight prepandemic moving into higher BMI categories, due to higher rates of BMI gain observed in these groups.

Like ours, previous studies showed that early-pandemic accelerations in pediatric weight gain leveled off in 2021.[9,12] Our study uniquely showed a continued leveling in rates of change in obesity prevalence in 2022 in metropolitan Denver. To our knowledge, this was the first study to explore rates in the later pandemic recovery period through 2022. This leveling suggests the potential positive role of social institutions, such as school-based nutrition programs, sports teams, and physical activity norms, that were greatly disrupted during the early pandemic. When children had to stop many activities during the early pandemic, the average rates of BMI change, extended BMIz, and obesity prevalence increased, particularly for school-aged children and children who were NH Black, Hispanic, or NH other/multiple race. When these norms and institutions were reestablished during the later pandemic, patterns of BMI gain attenuated to resemble prepandemic trajectories or even lower. COVID-19 provided an opportunity to observe ways in which disrupting an array of activities affected childhood weight gain, suggesting that preventive activities may be more effective than treatment interventions. Large changes in children's BMI throughout the pandemic also highlight both continued public health concern for high childhood obesity prevalence and potential opportunities to strengthen institutions and norms that help children and adolescents eat nutritious foods, stay active, and maintain healthy weights and overall wellness.

Table 2. Average Monthly Rate of Change in Children's BMI Before the COVID-19 Pandemic and During 3 COVID-19 Periods—Overall and by Sex, Age Group, and BMI Category—Among 54,104 Children Aged 2–19 Years in Metropolitan Denver, Colorado, 2019–2022

	Prepandemic		Early pandemic		Later pandemic			
	January 2019–February 2020		March–December 2020		2021		2022	
	Slope	95% CI	Slope	95% CI	Slope	95% CI	Slope	95% CI
Overall	0.061	(0.059, 0.062)	0.102	(0.098, 0.106)	0.038	(0.035, 0.041)	0.044	(0.041, 0.047)
Sex								
Male	0.063	(0.060, 0.065)	0.107	(0.101, 0.113)	0.032	(0.027, 0.036)	0.036	(0.032, 0.040)
Female	0.059	(0.056, 0.061)	0.098	(0.092, 0.103)	0.043	(0.039, 0.047)	0.052	(0.048, 0.056)
Age group[a]								
2–5 years	0.010	(0.005, 0.014)	0.042	(0.032, 0.051)	0.003	(–0.005, 0.010)	0.032	(0.026, 0.039)
6–9 years	0.057	(0.053, 0.060)	0.128	(0.120, 0.136)	0.056	(0.050, 0.062)	0.068	(0.063, 0.074)
10–13 years	0.080	(0.077, 0.083)	0.149	(0.141, 0.156)	0.049	(0.044, 0.055)	0.038	(0.033, 0.043)
14–16 years	0.066	(0.062, 0.069)	0.086	(0.078, 0.094)	0.033	(0.027, 0.039)	0.039	(0.033, 0.045)
17–19 years	0.046	(0.040, 0.051)	0.047	(0.034, 0.060)	0.017	(0.007, 0.028)	–0.030	(–0.050, –0.010)
BMI category[b]								
Underweight	–0.002	(–0.010, 0.005)	0.049	(0.033, 0.065)	0.025	(0.013, 0.037)	0.028	(0.016, 0.041)
Healthy weight	0.034	(0.032, 0.036)	0.085	(0.080, 0.090)	0.034	(0.031, 0.038)	0.043	(0.039, 0.047)
Overweight	0.083	(0.079, 0.088)	0.124	(0.114, 0.135)	0.040	(0.033, 0.048)	0.050	(0.042, 0.058)
Moderate obesity	0.121	(0.116, 0.126)	0.161	(0.150, 0.172)	0.039	(0.031, 0.048)	0.050	(0.042, 0.059)
Severe obesity	0.169	(0.162, 0.175)	0.151	(0.136, 0.165)	0.081	(0.070, 0.092)	0.054	(0.043, 0.066)
Race/ethnicity[c]								
Non-Hispanic White	0.054	(0.051, 0.057)	0.075	(0.069, 0.082)	0.036	(0.031, 0.040)	0.042	(0.037, 0.047)
Non-Hispanic Black	0.064	(0.058, 0.069)	0.113	(0.101, 0.126)	0.032	(0.023, 0.041)	0.032	(0.023, 0.042)
Non-Hispanic Asian	0.058	(0.049, 0.068)	0.087	(0.066, 0.108)	0.028	(0.013, 0.044)	0.045	(0.029, 0.060)
Hispanic	0.068	(0.066, 0.071)	0.123	(0.117, 0.129)	0.038	(0.034, 0.043)	0.048	(0.044, 0.053)
Non-Hispanic other	0.050	(0.042, 0.058)	0.108	(0.089, 0.127)	0.027	(0.013, 0.041)	0.039	(0.024, 0.054)

[a]Based on age at the start of the pandemic (March 1, 2020), ranging from 2.00 to 19.03 years. Age at first BMI ranged from 2.01 to 19.12 years; age at last BMI ranged from 2.98 to 19.99 years. This longitudinal cohort does not include children who "aged out" of the cohort (*i.e.*, turned 20 years during the study period). A three-way interaction term between age category, time (in decimal months from March 1, 2020), and a variable indicating in which period the BMI was taken was used to generate slope estimates by age category. Model controlled for sex, race/ethnicity, last prepandemic BMI category, and site.

[b]Based on last prepandemic BMI, which had to occur during January 1, 2019, and February 29, 2020. BMI categories were defined as underweight (<5th percentile), healthy weight (≥5th to <85th percentile), overweight (≥85th to <95th percentile), moderate obesity (≥95th percentile to <120% of the 95th percentile), and severe obesity (≥120% of the 95th percentile or ≥35 kg/m^2). A three-way interaction term between BMI category, time (in decimal months from March 1, 2020), and a variable indicating in which period the BMI was taken was used to generate slope estimates by BMI category. Model controlled for age at the start of the pandemic, sex, race/ethnicity, and site.

[c]A three-way interaction term between race/ethnicity, time (in decimal months from March 1, 2020), and a variable indicating in which period the BMI was taken was used to generate slope estimates by BMI category. Model controlled for age at the start of the pandemic, sex, last prepandemic BMI category, and site. Non-Hispanic other race includes multiple race. $N = 1325$ patients with unknown race/ethnicity were excluded from the models.

CI, confidence interval.

Table 3. Rate Ratios and Rate Differences for Average Rates of Change in Children's BMI (in Table 2), $N = 54,104$ Children 2–19 Years in Metropolitan Denver, Colorado, 2019–2022

	Early pandemic vs. prepandemic				2021 vs. early pandemic				2022 vs. 2021			
	Rate ratio	95% CI	Rate difference	95% CI	Rate ratio	95% CI	Rate difference	95% CI	Rate ratio	95% CI	Rate difference	95% CI
Overall	1.68	(1.60, 1.76)	0.04	(0.04, 0.05)	0.37	(0.34, 0.40)	−0.06	(−0.07, −0.06)	1.17	(1.05, 1.29)	0.006	(0.002, 0.011)
Sex												
Male	1.71	(1.59, 1.82)	0.04	(0.04, 0.05)	0.30	(0.25, 0.34)	−0.08	(−0.08, −0.07)	1.14	(0.93, 1.34)	0.004	(−0.002, 0.010)
Female	1.66	(1.55, 1.78)	0.04	(0.03, 0.04)	0.44	(0.40, 0.49)	−0.05	(−0.06, −0.05)	1.21	(1.06, 1.35)	0.009	(0.003, 0.015)
Age group[a]												
2–5 years	4.28	(2.15, 6.41)	0.03	(0.02, 0.04)	0.07	(−0.11, 0.24)	−0.04	(−0.05, −0.03)	11.81	(−19.80, 43.42)	0.029	(0.020, 0.039)
6–9 years	2.26	(2.06, 2.46)	0.07	(0.06, 0.08)	0.44	(0.38, 0.49)	−0.07	(−0.08, −0.06)	1.22	(1.05, 1.38)	0.012	(0.004, 0.020)
10–13 years	1.86	(1.74, 1.98)	0.07	(0.06, 0.08)	0.33	(0.29, 0.37)	−0.10	(−0.11, −0.09)	0.77	(0.63, 0.91)	−0.011	(−0.019, −0.004)
14–16 years	1.31	(1.17, 1.45)	0.02	(0.01, 0.03)	0.38	(0.31, 0.46)	−0.05	(−0.06, −0.04)	1.19	(0.90, 1.47)	0.006	(−0.002, 0.015)
17–19 years	1.03	(0.72, 1.33)	0.00	(−0.01, 0.02)	0.37	(0.12, 0.61)	−0.03	(−0.05, −0.01)	−1.75[b]	(−3.32, −0.18)	−0.047	(−0.070, −0.025)
BMI category[c]												
Underweight	—[d]	—[d]	0.05	(0.03, 0.07)	0.51	(0.21, 0.81)	−0.02	(−0.04, 0.00)	1.14	(0.39, 1.90)	0.004	(−0.014, 0.211)
Healthy weight	2.51	(2.29, 2.73)	0.05	(0.05, 0.06)	0.40	(0.35, 0.45)	−0.05	(−0.06, −0.04)	1.25	(1.08, 1.42)	0.009	(0.003, 0.139)
Overweight	1.50	(1.35, 1.64)	0.04	(0.03, 0.05)	0.32	(0.26, 0.39)	−0.08	(−0.10, −0.07)	1.24	(0.94, 1.54)	0.010	(−0.001, 0.020)
Moderate obesity	1.33	(1.22, 1.44)	0.04	(0.03, 0.05)	0.24	(0.19, 0.30)	−0.12	(−0.14, −0.11)	1.28	(0.93, 1.64)	0.011	(−0.001, 0.023)
Severe obesity	0.89	(0.80, 0.99)	−0.02	(−0.03, 0.00)	0.54	(0.45, 0.63)	−0.07	(−0.09, −0.05)	0.67	(0.50, 0.84)	−0.027	(−0.043, −0.011)
Race/ethnicity[e]												
Non-Hispanic White	1.40	(1.26, 1.53)	0.02	(0.01, 0.03)	0.47	(0.40, 0.55)	−0.04	(−0.05, −0.03)	1.18	(0.97, 1.39)	0.006	(−0.0004, 0.013)
Non-Hispanic Black	1.78	(1.53, 2.03)	0.05	(0.04, 0.06)	0.28	(0.20, 0.37)	−0.08	(−0.10, −0.07)	1.02	(0.61, 1.42)	0.001	(−0.012, 0.013)
Non-Hispanic Asian	1.50	(1.06, 1.93)	0.03	(0.01, 0.05)	0.33	(0.13, 0.52)	−0.06	(−0.08, −0.03)	1.58	(0.56, 2.61)	0.017	(−0.005, 0.038)
Hispanic	1.80	(1.69, 1.91)	0.05	(0.05, 0.06)	0.31	(0.27, 0.35)	−0.08	(−0.09, −0.08)	1.26	(1.07, 1.45)	0.010	(0.004, 0.016)
Non-Hispanic other	2.15	(1.64, 2.66)	0.06	(0.04, 0.08)	0.25	(0.11, 0.39)	−0.08	(−0.10, −0.06)	1.44	(0.51, 2.37)	0.012	(−0.009, 0.032)

Statistical significance of results discussed in the article is based on nonoverlapping 95% CIs.

Rate differences comparing 2022 to 2021 (right-most columns) are shown out to the thousandths decimal place, instead of hundredths, due to very small differences in BMI rates of change between the 2 years.

[a]Based on age at the start of the pandemic (March 1, 2020), ranged from 2.00 to 19.03 years.

[b]Rate ratio of 2022 vs. 2021 for 17- to 19-year-olds is negative, indicating a rate of BMI decline in 2022 that was faster than the rate of BMI increase in 2021.

[c]Based on last prepandemic BMI, which had to occur during January 1, 2019, and February 29, 2020.

[d]Rate ratio of early pandemic vs. prepandemic for those with underweight not calculated because of a prepandemic slope that was very small and negative.

[e]Non-Hispanic other race includes multiple races. $N = 1325$ patients with unknown race/ethnicity were excluded from the entire analysis.

CI, confidence interval.

Differences in BMI gain by race/ethnicity in this study contribute to a broader understanding of how the early pandemic period was particularly disruptive to NH Black, Hispanic, or NH other/multiple race children living in Denver. For example, a survey of food insecurity among Coloradans in December 2020 found that 52% of non-White and Latino residents experienced food insecurity (vs. 30% of NH White residents).[29] Although our study could not directly evaluate associations between children's economic circumstances and changes in BMI, substantial evidence demonstrates that disparities driven by societal factors before the pandemic could have exacerbated the pandemic's negative social and environmental effects on minoritized communities.[30] As institutions continue to recover and strengthen from the pandemic, it is particularly important to support children who face greater barriers to accessing social supports and lifestyle interventions, including family healthy weight programs.[31]

This study has several limitations. First, EHR data from CHORDS are limited to three health systems in the Denver metropolitan area used for the analysis. Despite CHORDS' extensive coverage in the area, results may not be generalizable to Denver entirely or to other regions. Second, many children with health care visits were not included in our final analytic cohort because they did not have sufficient BMI measurements in the specified time periods to meet the inclusion criteria. This resulted in a cohort that was younger, potentially due to routine medical visits at younger ages, and had a higher proportion of NH Black and Hispanic children, potentially due to a need for more frequent health care to manage obesity or conditions associated with obesity (*e.g.*, diabetes), resulting in potential overestimation of obesity prevalence (Supplementary Table S1). Third, estimates were calculated using BMI measurements in different months among different people (vs. having BMI each month for each person), which created discontinuities in estimated BMI and obesity prevalence trends at cutpoints between periods (Fig. 2B, D). This is likely explained not by actual discontinuity in BMI or obesity, but by the nature of the data, in which different children were measured at different calendar periods. Still, caution should be exercised when interpreting estimates at these transition points, particularly for obesity prevalence, as results were based on linear models due to convergence issues. Fourth, EHR data are subject to data quality issues that have been detailed in previous studies.[18] These include inconsistencies in data collection across health systems and time, data entry errors, and errors in data extraction, transformation, and loading from EHRs to structured data tables. To address this, we performed robustness checks by comparing patient characteristics at each site and having representatives from each health system participate in the analysis to understand nuances that could affect the interpretation of results.

The inclusion of robust PPRL processes reduced the risk of duplicating patients across systems and allowed for missing data in one system to be filled in from the same patient's data in another system. However, running PPRL and generating distributed queries using a federated data model are time-consuming and require extensive technical expertise. Regional surveillance systems using EHRs may continue to explore new technologies in cloud-based design to facilitate surveillance efforts. Future work could examine how other regions compare to national trends in childhood weight gain and obesity prevalence. Findings may reveal patterns in regional trends, such as effects of urbanity or similar COVID-19 policies and practices that may have affected children in common ways. These regional analyses, though difficult to conduct, offer utility over national data for targeted interventions and localized efforts.

Conclusions

By the end of 2022, obesity prevalence in a large cohort of health care-seeking children in metropolitan Denver remained substantially higher than prepandemic, highlighting the concerning fact that obesity affects many youths, particularly racially minoritized groups and school-aged children. This work underscores the potential for regional surveillance systems to monitor disease trends, despite differences in care access and patient mix across health care organizations. CODI has partnered with community groups providing weight management interventions to children in Denver. Future work will consist of providing local data to these community organizations, evaluating the impacts of weight management interventions, and using data systems with health system and community data. Lessons learned from this initiative can be used by others using regional surveillance systems to monitor important public health issues.

Impact Statement

EHRs from 54,104 youths in Denver, Colorado, showed a nearly 70% higher early pandemic rate of BMI gain (vs. prepandemic), particularly in certain subgroups, with substantial attenuation later pandemic, resulting in obesity prevalence changes from 16%–17% in 2019% to 21% by December 2020% to 20% by December 2022.

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Authors' Contributions

E.B.: Conceptualization, data curation, project administration, and writing—original draft. S.L.P.: Conceptualization, formal analysis, and writing—original draft. K.A.S.: Conceptualization, data curation, and writing—review and editing. L.K.: Formal analysis and writing—review and editing. S.W.: Formal analysis and software. M.H.: Writing—review and editing. M.F.D.: Data curation, supervision, and writing—review and editing.

Disclaimer

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Author Disclosure Statement

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Supplementary Material

Supplementary Data

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