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Changes in BMI During the COVID-19 Pandemic

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Contributors Statement Page

Drs. Knapp and Chandran conceptualized and designed the study, interpreted the data, drafted the initial manuscript, and reviewed and revised the manuscript. Ms. Dong carried out the data analysis, created tables and figures, and drafted the initial manuscript. Ms. Hodges conducted additional analyses and critically reviewed and revised the manuscript. Drs. Ganiban, Gilbert-Diamond, Chen, Alshawabkeh, Teitelbaum, Hartert, Karagas, Gilliland, O'Connor, and Jacobson provided input on the design and implementation of the analysis, interpreted the data, and critically reviewed and revised the manuscript for important intellectual content. Drs. Dunlop, Aschner, Stanford, Hudak, Carroll, McEvoy, O'Shea, Carnell, Herbstman, Dabalea, Ferrara, Hedderson, Bekelman, Rundle, Fry, Wright, Camargo, Lester, and Hockett critically reviewed and revised the manuscript for important intellectual content.

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Abstract

Background and Objectives.—Experts hypothesized increased weight gain in children associated with the COVID-19 pandemic, potentially due to closures of schools and recreational facilities with consequent reduction of physical activity and dietary changes. Our objective was to evaluate whether the rate of change of child BMI increased during the COVID-19 pandemic compared to pre-pandemic years.

Methods.—The study population of 1996 children ages 2–19 years with at least one BMI measure before and during the COVID-19 pandemic was drawn from 38 pediatric cohorts across the US participating in the ECHO-wide Cohort Study. We modelled change in BMI using linear mixed models adjusting for age, sex, race, ethnicity, maternal education, income, baseline BMI category, and type of BMI measure. Data collection and analysis was approved by the local IRB of each institution or by the central ECHO IRB.

Results.—BMI increased during the COVID-19 pandemic compared to previous years (0.24 higher annual gain in BMI during the pandemic compared to previous years, 95% CI 0.02, 0.45). Children with BMI in the obese range compared to the healthy weight range were at higher risk for excess BMI gain during the pandemic, while children in higher-income households were at decreased risk of BMI gain.

Conclusions.—One effect of the COVID-19 pandemic is an increase in annual BMI gain during the COVID-19 pandemic compared with the three prior years among children in our national cohort. This increased risk among US children may worsen a critical threat to public health and health equity.

Article Summary:

This study evaluates whether the annual rate of change in child BMI was higher during the pandemic than in previous years.

INTRODUCTION

Childhood obesity is a serious problem with long-term health and quality of life concerns; nearly 1 in 5 US children were categorized as obese in 2018[1]. Starting in March 2020, widespread closure of schools, recreation facilities, and recreational or sport activities due to the COVID-19 pandemic may have resulted in decreased physical activity and altered dietary habits in children, placing them at higher risk for excess weight gain[2,3]. Prior to the COVID-19 pandemic, higher rates of weight gain among school-aged children across the US were observed during the summer months, when children are out of school, particularly among children who are overweight or obese and among racial and ethnic groups at higher risk of obesity[4–8]. The Structured Days Hypothesis explains this weight gain as due to changes to or lack of structured opportunities for physical activity through school physical education classes, recess, or recreational sports activities, loss of regulated meal times and limits on amount and types of food, and more obesogenic screen time and sleep routines[9]; changes that were also present as the pandemic disrupted normal school and childcare routines. Such weight gain is problematic because it is maintained at least through the following school year[5], and in general, weight gain in childhood is predictive of later overweight and obesity into adulthood[10,11], with later health consequences. In this context, public health and obesity experts have expressed concern that a byproduct of the COVID-19 pandemic-related shutdowns will be excess weight gain among children[12–15].

Two recently published US studies have suggested that these concerns are well-founded; using medical records data, Woolford *et al.* in Southern California and Lange *et al.* using data from children across the US, showed an accelerated rate of weight gain and increased BMI among children during the pandemic period[16,17]. A study of children who had a height and weight measured at school showed accelerated weight gain during the pandemic-year compared to pre-pandemic years[18]; in particular, accelerated weight gain was demonstrated among children in the healthy BMI category. Similar results have been reported internationally. A retrospective survey of 10,082 adolescents and young adults in China reported increases in BMI during the pandemic[19]. In another survey in Turkey, conducted after the start of the COVID-19 pandemic, 42% of parents reported that their child gained weight, compared to 55% reporting no change in weight, within a 3-week lock-down period[20].

There are some limitations to current knowledge regarding excess weight gain in children during the COVID-19 pandemic. First, the US studies were done using medical records or in a school setting and had limited information available on child/household socioeconomic status (SES). Given the disproportionate impact of both the obesity epidemic as well as COVID-19 pandemic-related hardships on children from lower socioeconomic status levels, it is important to consider SES in examining changes in BMI[21,22]. Second, during the pandemic, many families had limited ability to attend a medical visit. Therefore, studies using solely medical records data may not fully reflect the experiences of the broader US population.

The Environmental Influences on Child Health Outcomes (ECHO) consortium brings together long-standing prospective child cohorts in the United States with the goal of

investigating the effects of environmental exposures on child health outcomes[23]. Leveraging prospectively collected cohort study data, our objective in this analysis was to evaluate changes in children's BMI from the pre-pandemic to the pandemic period. Specifically, we evaluated whether children exhibited accelerated weight gain during the COVID-19 pandemic (from March 2020 through May 2021), when many schools were closed and recreational activities curtailed, compared to the pre-pandemic years (October 2017 – February 2020).

METHODS

Study Population and Outcome

The study population was drawn from the ECHO-wide Cohort Study, a consortium of 69 pediatric cohort studies across the United States[23,24]. A central and cohort-specific institutional review boards monitored human subject activities at each cohort site and the centralized ECHO Data Analysis Center. All participants provided informed consent.

Children's weight and height were obtained by each cohort from measurements taken at the cohort study visit, medical record abstraction, or self- or parent- reported measurements. Height and weight were used to calculate body mass index (BMI; kg/m^2) and percentiles[25,26]. We use BMI as the outcome because it is considered most appropriate for the comparison of BMI changes as across time[27–29]. CDC cutoffs were used to determine implausible measures, which were excluded from analysis[25]. BMI category was defined according to CDC guidelines for defining childhood weight status based on BMI percentiles for age and sex: underweight (<5%); healthy weight (5 – <85%); overweight (85 – <95%); and obese (>=95%)[30].

For this analysis, the COVID-19 "pandemic period" was defined as the 15-month period from March 1st, 2020, to May 31st, 2021 during which the COVID-19 pandemic caused many disruptions of daily routines. The baseline, or "pre-pandemic period" was between October 1st, 2017 to February 29th, 2020. A total of 1996 children from 38 cohorts, representing 53 recruitment sites across the US, who contributed at least one BMI in both the "pre-pandemic" and the "pandemic" study periods, comprised the primary analytic sample (Figure 1).

Sociodemographic and other covariates

Child date of birth was collected at participant registration and age at assessment was recorded continuously in years. Categorical variables included child sex at birth (male, female); highest level of maternal education attained (less than high school; high school or GED equivalent; or at least some college or more), annual household income (less than or equal to $30,000; $30,000 – $49,999; $50,000 – $74,999; $75,000 or greater), and child race and ethnicity (reported by the parent or child as non-Hispanic white; non-Hispanic black; non-Hispanic other race; Hispanic), which we consider a proxy for exposure to structural racism that shapes a range of resources such as housing, education, and employment.[31] All sociodemographic variables were collected via self-report or medical record abstraction. A binary "pandemic period" indicator was introduced to reflect whether a BMI measure was

taken during the pandemic period (March 2020 through May 2021) or the pre-pandemic period (October 2017 through February 2020).

Statistical Analysis

We tabulated participant characteristics in the primary analytic sample for the baseline pre-pandemic period. For continuous variables (child age, BMI, change in BMI), means and standard deviations were calculated. Number of participants and percentages were reported for categorical variables (sex, race and ethnicity, maternal education level, household income level, type of BMI measure and BMI category).

To examine trends in BMI before and during the pandemic, we employed linear mixed effects models to compare the annual change in BMI between the pre-pandemic period and the pandemic period. All models included calendar year, child age, child sex, child race and ethnicity, maternal education, type of measurement (study measure, medical record, or self/parent report), baseline BMI category, household income level, and an indicator for pre-or post pandemic time period, with a random intercept for each child participant and for cohort. Missing data on income, race, and maternal education were imputed using the Multivariate Imputation by Chained Imputation (MICE) package in R, with all other variables from the analytic models included as predictors. Results were pooled after 10 iterations.[32] Our key parameter of interest was an interaction term between the pandemic year indicator and calendar year, which represents the change in slope (rate of BMI change) between the COVID and pre-COVID time periods. To evaluate whether the rate of BMI change during the pandemic differed by key subgroups (race, Hispanic ethnicity, baseline BMI category, and household income), we employed interaction terms between the pandemic year indicator, calendar year, and the subgroup of interest.

All analyses were completed in R version 4.1.0 (2021-05-18). Mixed effects models were fit using the Fitting Linear Mixed-Effects Models (lme4) package.[33]

Sensitivity Analyses—We conducted three additional analyses to evaluate the robustness of our main findings to key assumptions. First, because our study inclusion criteria required completing an in-person or virtual cohort study visit during the pandemic period, we explored whether children who returned for a study visit had different sociodemographic attributes than those who were not seen during the COVID-19 pandemic. Second, we repeated our primary models using two time-periods that were both prior to the COVID-19 pandemic to evaluate whether the BMI changes we observed were due to the COVID-19 pandemic or instead to secular trends in BMI change. Last, we conducted our main analysis among children with study-measured anthropometric measures only, to determine whether changes to BMI ascertainment during the pandemic influenced our results. Additional details and results of these analyses are provided in the Online Supplement.

RESULTS

Of the 1996 children in the primary analytic sample, the mean baseline (pre-pandemic) age was 5.9 years (standard deviation (SD): 3.4 years) (Table 1). Half (N=975) were female, and 53% were non-Hispanic white, 15% non-Hispanic Black, and 16% of Hispanic ethnicity.

The majority (85%) of mothers reported some college or higher level of education, and 49% reported a household income of $75,000 or more. Most children (70%) had a baseline BMI in the healthy weight range (5%−85%).

Mean BMI in the pre-pandemic period was 17.05 (SD 3.3), and an average of 2.6 BMI measures per child were reported across the study period. Pre-pandemic, 80% of BMI measures were ascertained through study measurement compared to 51% of during-pandemic BMI measures. Pre-pandemic, 6.3% of BMI measures were parent or self-reported and 14% were by medical record abstraction, while during-pandemic, 48% were by parent or self-report and 1.3% were by medical record abstraction.

No annual increase in BMI was observed prior to the pandemic, after adjusting for age, sex, race, ethnicity, maternal education, household income, type of BMI measure, and baseline BMI category (−0.04 change in BMI per year, 95% CI: −0.15, 0.07). During the pandemic, the annual change in BMI was 0.24 higher than during the pre-pandemic period (95% CI 0.02, 0.45) (Table 2, Model A). Higher rates of BMI increase during the COVID-19 pandemic period were observed among obese, compared to healthy weight, children. The annual change in BMI during the pandemic, compared to pre-pandemic, among obese children was 1.12 (95% CI 0.47, 1.77) higher than among healthy weight children (Table 2, Model B). There was no observed increase in the rate of change in BMI during the pandemic for Black Children, Hispanic children, or overweight children (Table 2, Models D and B). Children in households with income of $75,000 or greater had decreases in rate of BMI change during the pandemic (−0.83 BMI, 95% CI −1.53, −0.14) (Table 2, Model C).

Sensitivity Analyses

Completing a cohort study visit during the COVID-19 pandemic (whether in-person or by teleconference/telephone) was a burden that we hypothesized would be met by a population that would be sociodemographically different than the overall group of cohort enrollees. To test this hypothesis, we compared our primary analytic sample to the larger group of children enrolled in ECHO who had study visits during our pre-pandemic period but not during the COVID-19 pandemic period (Supplement Table 1). Our primary sample differed from our comparison sample in several important respects. The comparison sample had a higher proportion of Hispanic children (21% compared to 16% in the primary analytic sample) and a lower proportion of non-Hispanic white children (49% compared to 53%). The comparison sample had lower maternal education (81% with some college or more) and lower annual household income (38% with $75,000 or more).

In our second sensitivity analysis to determine if there were temporal trends in BMI change before the COVID-19 pandemic that may explain our main results, we observed no increase in BMI during the first half of the pre-pandemic period, and no statistically significant difference in slope in the final year of the pre-pandemic period (Supplement Table 2). In other words, the COVID-19 pandemic period appears to have a unique effect on trends in BMI among our study sample.

In our third sensitivity analysis, in the subsample of 1052 children who had study measured height and weight before and after the COVID-19 pandemic, similar results are observed

as in our primary analytic sample (Supplement Table 2): there was a statistically significant increase in the change in BMI in the COVID-19 pandemic period as compared to previous years after restricting to children with a study measured height and weight only (Supplement Table 2: 0.42, 95% CI 0.1, 0.74).

DISCUSSION

Our study shows that one important effect of the COVID-19 pandemic is an increase in BMI during the COVID-19 pandemic period compared with the three prior years among children in our national cohort. Using populations combined from multiple prospective cohort studies, our findings underscore what other studies have shown both within[16–18,34,35] and outside of the US[13,36–38]. We find that the COVID-19 pandemic period was associated with an excess increase in BMI of 0.24 kg/m^2 per year more than in the previous pre-pandemic period, even when controlling for socioeconomic status, race and ethnicity, baseline BMI category, and type of BMI ascertainment. Our findings validate the predictions of many scholars that weight would increase among children due to the cumulative effects of anticipated decreases in physical activity and increases in sedentary behavior, screen time, and high-calorie diets among children during the pandemic[12]. Importantly, our study is the first to demonstrate this excess weight gain while controlling for individual SES, an important known predictor of obesity among children.

Alongside the COVID-19 pandemic, our data also highlight known risks of higher BMI among children reporting Black race, Hispanic ethnicity, and lower annual household income. Racial, ethnic, and socioeconomic disparities in obesity prevalence in the US have been well-documented, resulting in a disproportionate burden of physical and mental health consequences of obesity among vulnerable children and adults, reflecting exposure to structural racism and other social and economic determinants of health[39]. The COVID-19 pandemic has also disproportionately affected these same higher-risk groups in terms of both mortality and morbidity from COVID-19 infections in their families and communities[40]. Our study did not find widening disparities in BMI increase during the pandemic among Black or Hispanic children. It is important to note that these groups only comprised 15% and 16% of our sample size, respectively, so we may have been underpowered to detect differences among these subgroups. We encourage ongoing investigation of potential disparities among racial and ethnic minority children due to the pandemic. We observed increasing disparities due to socioeconomic position. Children living in households in the highest income category experienced decreases in BMI during this time, perhaps reflecting greater access to green space, nutritious foods, and other material conditions conducive to healthy growth. It will be important to collect more data on BMI change in children specifically among vulnerable subpopulations as the pandemic continues to alter children's lives and use these data to inform evidenced-based interventions in order to reduce rather than augment health inequities.

The observed excess increase in BMI among children in our study during the COVID-19 pandemic will lead to a greater propensity for children to transition from a healthy BMI to one that is overweight/obese, which will only exacerbate the epidemic of obesity that is already a major public health concern across the US. Children with overweight and

obesity are known to be at increased risk for poor physical and mental health outcomes[41,42]. Once weight is gained it is difficult to lose; thus much effort has been focused on primary prevention methods for avoiding excess weight gain and obesity during childhood[43]. Our study showed a more pronounced BMI increase during the COVID-19 pandemic among children categorized as obese in the baseline pre-pandemic period, putting this subgroup at further increased risk for adverse health outcomes.

We do note that our primary analytic sample is comprised of fewer children from higher-risk subgroups than our larger body of children enrolled in ECHO and therefore likely also when compared to the general US population. This is not surprising because the children in the primary analytic sample are those that were able to fulfill a cohort study visit during a global pandemic. We suspect that if we had BMI data during the COVID-19 year for our broader ECHO community, we would have witnessed an even greater increase in BMI during the widespread closures associated with the COVID-19 pandemic, as was observed in a recent publication of children living in the US[16]. We call for further research to quantify fully the impact of the pandemic on childhood obesity in the US.

Our analysis has several limitations. First, we bring together pediatric cohorts with different visit structures; therefore, the timing of measurements of child height and weight was not uniform. Second, the height and weight measurements were assessed differently through either self-report, medical record extraction, or direct measurement by trained study personnel, with and without repeated measurements per visit and/or adherence to ECHO measurement protocols. The method of ascertainment also differed pre- and during-pandemic. However, a sensitivity analysis of children with only study-measured height and weight mirrored our main findings. Of note, parent or self-reported weight often underestimates true weight[44,45], and therefore findings of weight gain in this study that are partially informed by self-reported weight is likely an underestimation of the true weight gain, since a higher proportion of measures were self-report in the pandemic period.

CONCLUSION

This analysis documents an increase in BMI during the COVID-19 pandemic, in our national cohort of children. We highlight the need for targeted interventions to combat the physical and mental health consequences of the COVID-19 pandemic, particularly among higher-risk communities. Without more vigorous intervention, we can anticipate an exacerbation of the obesity epidemic among US children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

BMI	Body mass index

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What's known on this subject:

The COVID-19 pandemic may have increased the risk of excess weight gain for children, potentially due to closures of schools and recreational facilities with consequent reduction of physical activity and dietary changes.

What this study adds:

This analysis documents an increase in rate of BMI change during the COVID-19 pandemic compared to prior years, particularly among children who were obese at baseline. Higher household income appears to be protective of pandemic-related BMI increases.

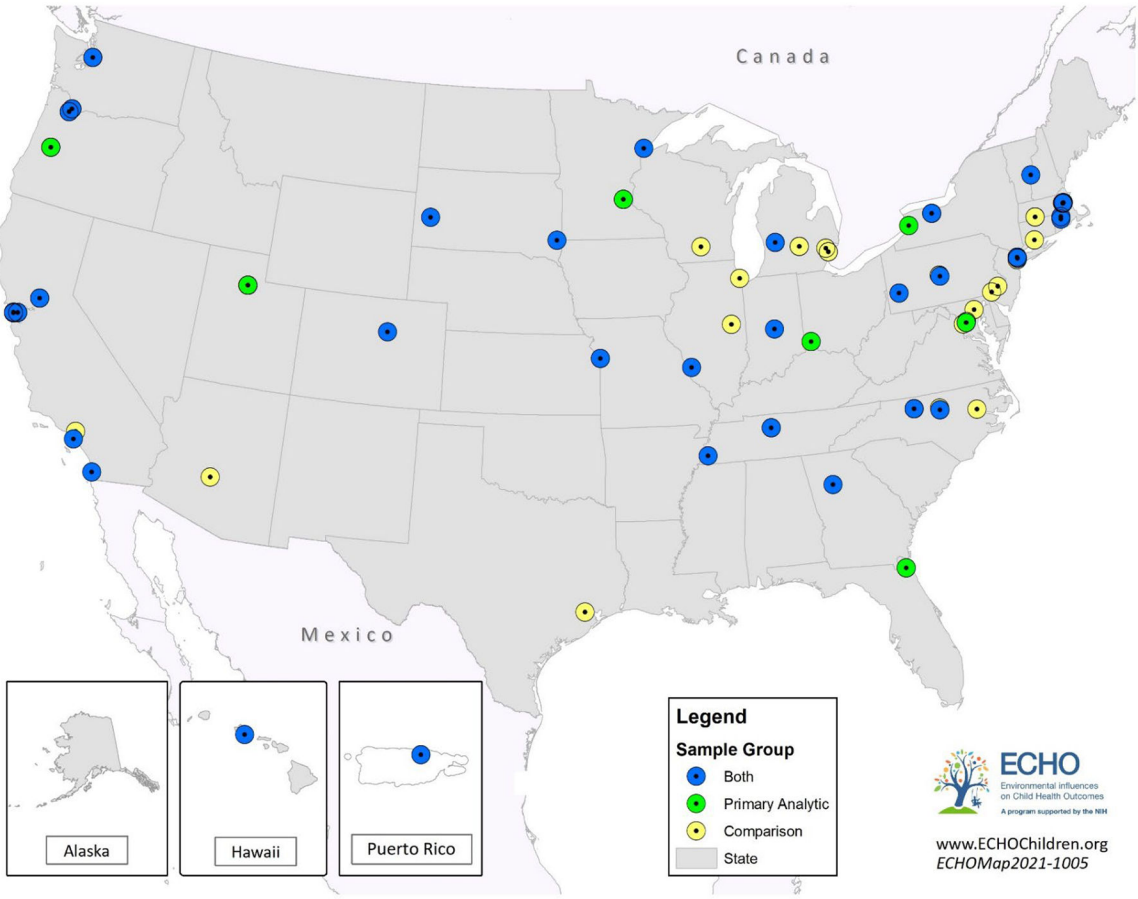

Figure 1. Map of Participating Enrollment Sites

Figure 1 shows the data collection and enrollment sites from which the study population is drawn. Sites that only contributed participants to the primary study sample are in green, sites that only contributed to the comparison sample are shown in yellow, and sites that contributed participants to both samples are shown in blue.

Table 1:

Sociodemographic Characteristics of Analytic Sample[1] in the Pre-COVID-19 Pandemic Time Period

Characteristic	N (%)
Children	**1996**
Child age in 2018, mean ±SD	5.9 ± 3.4
Sex at birth, Female	975 (49%)
Race & Ethnicity	
Missing	8 (0.4%)
Non-Hispanic white	1067 (53%)
Non-Hispanic black	299 (15%)
Non-Hispanic other	294 (15%)
Hispanic, all races	328 (16%)
Maternal Education	
Missing	42 (2.1%)
Less than High School	70 (3.5%)
High school degree, GED or equivalent	178 (8.9%)
Some college and above[2]	1706 (85%)
Income	
Missing	294 (15%)
<= $ 30,000	248 (12%)
$30,000 – $49,999	228 (11%)
$50,000 – $74,999	255 (13%)
$75,000 or more	971 (49%)
BMI Category	
Underweight (<5th percentile)	120 (6%)
Healthy weight (5–85th percentile)	1400 (70%)
Overweight (85–95th percentile)	244 (12%)
Obese(>=95th percentile)	232 (12%)
BMI, mean ±SD, Pre-Pandemic	17.05 ± 3.31
BMI, mean ±SD, During Pandemic	18.30 ± 4.68
Change in BMI, Pre/During Pandemic, mean ±SD	1.14 ± 2.79
BMI Ascertainment Method Pre-Pandemic	
Self-report	80 (2.6%)
Parent-report	113 (3.7%)
Medical record	423 (14%)
Study Measure	2431 (80%)
BMI Ascertainment Method During-Pandemic	
Self-report	591 (28%)
Parent-report	433 (20%)

Characteristic	N (%)
Medical record	27 (1.3%)
Study Measure	1092 (51%)

[1]Children are included in the primary analytic sample if they had at least one BMI in both the pre-pandemic period (October 2017 through February 2020) and the pandemic-period (March 2020 through May 2021).

[2]Includes some college with no degree; Associate degrees (AA, AS); trade school, or higher levels of education.

Table 2:

Longitudinal Associations with Change in BMI from October 2017 – May 2021 (n=1996 children)[1]

	Model A[2]	Model B[2]	Model C[2]	Model D[2]
Change in BMI				
Pre-pandemic change in BMI per year	−0.04 (−0.15, 0.07)	−0.01 (−0.13, 0.12)	−0.1 (−0.42, 0.21)	−0.05 (−0.2, 0.1)
Excess change in BMI during pandemic	0.24 (0.02, 0.45)	0.16 (−0.09, 0.41)	0.83 (0.2, 1.45)	0.26 (−0.04, 0.56)
Excess change in BMI during pandemic among overweight children		−0.39 (−1.05, 0.27)		
Excess change in BMI during pandemic among obese children		1.12 (0.47, 1.77)		
Excess change in BMI during pandemic among children in households with income of $30–50,000			−0.01 (−0.95, 0.93)	
Excess change in BMI during pandemic among children in households with income of $50–75,000			−0.25 (−1.09, 0.58)	
Excess change in BMI during pandemic among children in households with income of $75,000			−0.83 (−1.53, −0.14)	
Excess change in BMI during pandemic among Hispanic children				0.09 (−0.5, 0.69)
Excess change in BMI during pandemic among Black children				0.28 (−0.35, 0.92)
Baseline Characteristics				
Race/Ethnicity (REF: Non-Hispanic White)				
Non-Hispanic Black	0.55 (0.23, 0.88)	0.55 (0.22, 0.87)	0.54 (0.22, 0.87)	0.13 (−0.65, 0.91)
Non-Hispanic other race	0.15 (−0.13, 0.43)	0.15 (−0.13, 0.43)	0.13 (−0.15, 0.41)	−0.03 (−0.79, 0.73)
Hispanic, all races	0.13 (−0.16, 0.41)	0.13 (−0.15, 0.41)	0.12 (−0.17, 0.4)	0.09 (−0.61, 0.78)
Income (REF: Less than $30,000)				
$30–50,000	−0.26 (−0.65, 0.13)	−0.25 (−0.64, 0.13)	−0.39 (−1.42, 0.65)	−0.25 (−0.64, 0.14)
$50–75,000	−0.29 (−0.69, 0.11)	−0.28 (−0.67, 0.11)	−0.28 (−1.32, 0.75)	−0.28 (−0.68, 0.12)
$75,000 or more	−0.68 (−1.04, −0.32)	−0.68 (−1.03, −0.32)	−0.21 (−1.08, 0.66)	−0.68 (−1.04, −0.32)
BMI Category at Baseline (REF: Healthy weight)				
Overweight	2.87 (2.59, 3.16)	2.71 (1.93, 3.49)	2.88 (2.6, 3.16)	2.88 (2.59, 3.16)
Obese	6.93 (6.64, 7.23)	7.19 (6.43, 7.95)	6.94 (6.65, 7.24)	6.93 (6.64, 7.23)
Intercept	14.13 (13.42,14.84)	14.11 (13.39,14.83)	13.96 (12.99,14.93)	14.27 (13.53,15.02)

[1]Children are included in the primary analytic sample if they had at least one BMI in both the pre-pandemic period (October 2017 through February 2020) and the pandemic-period (March 2020 through May 2021).

[2] In addition to the factors shown above, all models adjusted for: age, sex, maternal education (less than high school; high school or GED equivalent; or at least some college or more), type of BMI measure (self-report, parent-report, medical record, or study measure), and an indicator for pre- or during COVID. Models B through D also include group-specific estimates of the pre-pandemic change in BMI.