RESEARCH ARTICLE

Body composition, fitness, and eating behaviors deteriorate during the COVID-19 pandemic in at-risk pediatric patients

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Abstract

The COVID-19 pandemic has significantly altered children's daily routines. The health impacts of our obesogenic environment are exacerbated by COVID-19. Many clinicians have concerns that the lack of structured activity, increased stress and altered eating behaviors would lead to increases in adiposity in children. The present study examined changes in body composition as a result of the COVID-19 pandemic in pediatric patients in larger bodies and demonstrates significant increases in total body fat, percent body fat (%fat), and BMI z-score, as well as markers of insulin resistance. In this retrospective, longitudinal study, body composition was measured by dual energy x-ray absorptiometry (DXA) within a multidisciplinary pediatric fitness clinic at an academic medical center. Visit dates were categorized into Pre-COVID-19 (before 4/1/2020) and Peri-COVID-19 (on or after 4/1/2020). Linear mixed effects modeling was conducted to evaluate changes in clinical and laboratory outcomes from Pre- to Peri-COVID-19.

Baseline assessment was obtained from 650 patients with higher BMI scores (52% male) with a mean (SD) age of 12.3 (3.2) years. The adjusted mean BMI z-score (BMIz) was significantly higher in the Peri-COVID-19 sample when compared to the Pre-COVID-19 samples (2.31 vs. 2.25, $P < 0.0001$) which can be attributed to greater total fat mass (TFM) of 93.0 (90.0-96.4) lbs. ($P = 0.007$) and %FAT of 40.2% (39.2-41.2) as compared to the Pre-COVID-19 patients. The COVID-19 pandemic influenced social determinants and lifestyle factors. Most notable changes observed were negative changes in physical activity and screen time. The need for social isolation in a pandemic has resulted in worsening obesity and its comorbidities, and pediatricians need to be aware of this issue. The COVID-19 pandemic exerts disproportionate burden on children and families, magnifying their vulnerability to changes in body composition and chronic disease risk.

Key Words: Body Mass Index Z-score; Dual Energy X-Ray Absorptiometry; Body Composition, COVID-19

1. Introduction

Coronavirus disease 2019 [COVID-19], a contagious viral respiratory disease in humans which resulted in high rates of infection, hospitalization, and death in 2020 and into 2021 in the global community. The World Health Organization declared COVID-19 a pandemic on March 11, 2020.[1] Responses to the COVID-19 pandemic required major lifestyle modifications to mitigate risks of exposure including school closures due to stay-at-home orders and physical distancing requirements; all of which disrupted the routines of children, adolescents, and their caregivers.[2] These changes increased the risk of alterations in children's growth trajectories, especially in children with prior exposure to obesogenic environments.[3] The psycho-social stress upon metabolic health within the pediatric population suggests that physical activity is a moderator of this perceived relationship.[2]

1.1 Quarantine and changes in health-related resources

Many worried about children's health when in-person schools were suspended because children have been shown to gain weight and lose fitness while out of school over the summer months.[4] School closures reduced many students' connection with others perpetuating social isolation, as well as, their food and physical activity safety net due to access to the National School Breakfast and Lunch programming and mandatory physical education. Ecological and biological factors preceding the pandemic, exacerbated the potential consequences. Consequences identified during the COVID-19 pandemic disproportionally impacted the black, indigenous and people of color (BIPOC) communities due to exposure to many of these factors including stress from systemic racism, inter-generational trauma, greater risk of food insecurity and threats to family finances, limited safe spaces for daily physical activity and scarcity of mental healthcare resources.[5-7]

1.2 COVID-19 and psychosocial stress

Children in larger bodies, predisposed to chronic disease states including obesity, insulin resistance, hypertension and dyslipidemia were at greater risk of potential consequences from the pandemic. The relationship between chronic and acute stress, mental health, and childhood obesity is complex.[8] Psychological consequences have been documented as the most prevalent co-morbidity of childhood obesity due to the increased emotional distress related to body acceptance and image and risk of bullying from peers.[9] Periods of stress also test children's coping abilities; some children report eating in response to stress which would increase risk of negative changes in body composition.[10]

1.3 COVID-19 and Social Determinants of Well-being

Socio-economic resources are recognized as a potential area of stress for children, adolescents, and caregivers. COVID-19 dramatically altered family's food security and financial resources due to mandated furloughs, job loss and safer-at-home orders which may have impacted one's ability to access food in their community. Social determinants of well-being, including access to safe, quality foods and safe environments for physical activity, were taxed during the COVID-19 pandemic. Therefore, it can be assumed that these exposures to stressors amidst less access to coping resources may have precipitated negative changes in health-related routines.

1.4 Summary

The impact of COVID-19 on children predisposed to weight-related disease states

remain relatively unknown.[11] However, the enduring evidence on weight-related stigma heightens alarm about the potential long-standing impact of COVID-19 on children with obesity.[12-14] The present study sought to examine changes in body composition, changes in cardiovascular fitness and stress-related eating behaviors as a result of the COVID-19 pandemic in at-risk pediatric patients.

2. Methods

In this retrospective, longitudinal study, all subjects were obese boys and girls (BMI-for-age ≥ 95 percentile) ages 4 to 18 years evaluated as part of their routine clinical care at a multidisciplinary weight management program within an academic medical center. Anthropometric and body composition measurements were collected in accordance with previously published methods.[15-17] Study procedures were approved by the Health Sciences Human Subjects Committee at the University of Wisconsin- Madison.

Demographic characteristics at the initial visit were summarized in terms of frequencies and percentages or means and standard deviations. Visit dates were categorized into Pre-COVID-19 (before 4/1/2020) and Peri-COVID-19 (on or after 4/1/2020). Linear mixed effects modeling with patient specific random effects was conducted to evaluate changes in body composition, fitness, and biochemical indices from Pre- to Peri-COVID-19. Age (at visit date), gender, calendar month and race/ethnicity (non-Hispanic Black/African American, non-Hispanic White, non-Hispanic Other and Hispanic) were included as covariates. An autoregressive correlation structure of order one was used to account for correlations between repeated visits. The results were summarized in terms of adjusted means and the corresponding 95% confidence intervals (CI). Furthermore, two-way interaction effects between time (Pre- vs. Peri-COVID) vs. race/ethnicity and time vs. gender were evaluated. If significant interaction effects were observed, then corresponding subgroup analyses were conducted. Furthermore, subgroup analyses were conducted for patients who established care prior to the COVID-19 pandemic and continued care in the peri-COVID period. Normal probability and residual plots were examined to verify model assumptions. All reported P-values are two-sided and $P < 0.05$ was used to define statistical significance. Statistical analyses were conducted using SAS software (SAS Institute, Cary NC), version.

3. Results

Subjects were 650 boys and girls (52% male) in larger bodies with a mean (SD) age of 12.3 (3.2) years and BMIz of 2.28 (0.48) (**Table 1**). Mean criterion body composition values were assessed between those establishing care for weight-related concerns prior to April 1, 2020 (Pre-COVID) versus those who established care during the COVID-19 pandemic (After April 1, 2020). The adjusted mean BMI z-score (BMIz) was significantly higher during the Peri-COVID-19 sample when compared to Pre-COVID-19 (2.31 vs. 2.25, $P < 0.0001$) which can be attributed to greater total fat mass (TFM) of 92.0lbs (87.6-96.4; $P = 0.008$) and %FAT of 39.5% (38.740.2%; $P = 0.029$) as compared to the pre-COVID patients who had a mean TFM of 88.1 (83.8-92.4) lbs. and 8.8% (38.1-39.5%) (**Table 2**). Patients who have established care prior to the COVID-19 pandemic and continued care in the peri-COVID period also experienced significant increases in fat mass (91.3 vs. 86.9 lbs., $P = 0.017$) and specifically abdominal visceral fat mass (7.9 vs. 7.3 lbs., $P = 0.02$) during this time period (**Table 3**). A significant

interaction effect was observed between time of clinical encounter and race/ethnicity for total fat mass (TFM, $P = 0.02$). There were no observed changes in TFM for black or white subjects, only for Hispanic subjects ($P = 0.007$); therefore, the changes in TFM were driven by Hispanic subjects.

Table 1: Baseline characteristics of the sample at the initial clinic visit in the Pre-COVID (Prior to 4/1/2020) versus Peri-COVID (After 4/1/2020) era (N=650)

	All Subjects N=650		**Pre-COVID N=401**		**Peri-COVID N=249**		***P*-value†**
	N	**%**	**N**	**%**	**N**	**%**	
Sex							
Female	314	48	199	50%	115	46%	0.3934
Male	336	52	202	50%	134	54%	
Race							
Black/African American	97	15%	58	14%	39	16%	10.870
American Indian/Alaska	25	4%	18	4%	7	3%	
Native	23	4%	14	3%	9	4%	
Asian	5	1%	4	1%	1	0%	
Native Hawaiian/Pacific	466	72%	290	72%	176	71%	
Islander	34	5%	17	4%	17	7%	
White							
Unknown							
Ethnicity							
Hispanic/Latino	151	23%	92	23%	59	24%	0.7039
Not Hispanic/Latino	493	76%	307	77%	186	76%	
Unknown	6	1%	2	0%	4	2%	
Spoken Language at home							
English	564	87%	351	87%	213	86%	0.5626
Non-English	86	13%	50	13%	36	14%	
Insurance							
Medicaid	295	45%	172	43%	123	49%	0.1240
Private	355	55%	229	57%	126	51%	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	***P*-value†**
Age (yrs)	12.3	3.2	12.3	3.3	12.3	3.1	0.9702
BMI%	97.8%	4.4%	97.8%	4.5%	97.9%	4.0%	0.7360
BMI z-score	2.28	0.48	2.28	0.49	2.29	0.45	0.9396

†: Comparison between Pre- vs. Peri-COVID

Table 2: Changes from the Pre-COVID to Peri-COVID time period for all subjects (N=650)

	Pre-COVID				Peri-COVID				
	N†	**Adjusted Means±**	**Lower 95% CI**	**Upper 95% CI**	**N†**	**Adjusted Means±**	**Lower 95% CI**	**Upper 95% CI**	***P* -value***
Body Composition Indices									
BMI%	1221	97.4	96.9	97.9	767	97.5	97.0	98.0	0.1360
BMI z-score	1220	2.25	2.20	2.30	766	2.31	2.25	2.36	<0.0001
Pulse	1213	86.2	84.7	87.7	756	91.5	89.9	93.0	<0.0001
Waist circumference (inches)	740	38.5	37.8	39.2	304	38.8	38.0	39.6	0.3544
% Body Fat	388	38.8	38.1	39.5	279	39.5	38.7	40.2	0.0203
Lean mass, lbs.	389	93.7	91.0	96.3	280	94.2	91.4	96.9	0.6043
Fat mass, lbs.	389	88.1	83.8	92.4	280	92.0	87.6	96.4	0.0080
Visceral Fat, lbs.	389	7.5	7.0	7.9	280	7.9	7.4	8.4	0.1122
Fitness Indices									
Syst-BP	1212	108.9	107.6	110.2	765	111.9	110.5	113.3	<0.0001
Dias-BP	1212	66.5	65.6	67.5	765	68.3	67.4	69.3	0.0004
Pred_VO2	224	2484.8	2419.0	2550.6	197	2478.3	2410.1	2546.5	0.8439
VO2_max	224	31.8	31.0	32.7	197	31.1	30.3	32.0	0.0950
Biochemical Indices *(Acceptable Ranges)*									
ALT (< 49 U/L)	319	37.5	28.9	46.1	342	43.0	34.6	51.4	0.0974
AST (< 59 U/L)	296	30.3	24.5	36.1	311	31.8	26.1	37.4	0.6176
Total Chol (< 170 mg/dL)	263	167.7	162.3	173.2	249	169.0	163.6	174.4	0.5664
HgbA1C (4.0-5.6%)	210	6.0	5.7	6.3	280	6.0	5.7	6.2	0.6684
HDL (> 45 mg/dL)	270	42.0	40.6	43.5	254	41.5	40.1	43.0	0.3455
Insulin (< 20 mg/dL)	148	26.7	21.0	32.3	148	34.2	28.6	39.9	0.0138
LDL (< 110mg/dL)	241	102.3	97.6	107.1	225	100.7	96.0	105.4	0.4112
Trig (< 90 mg/dL)	346	119.1	100.1	138.1	393	139.7	121.1	158.3	0.0282

†Number of visits

±Adjusted by sex, age, race/ethnicity and month (to account for seasonal effects)

*Comparison pre vs. post COVID19

Table 3: Changes from the Pre-COVID to Peri-COVID time period for subjects with both pre- and peri-COVID encounters (n=145)

	Pre-COVID				Peri-COVID				
	N†	**Adjusted Means±**	**Lower 95% CI**	**Higher 95% CI**	**N†**	**Adjusted Means±**	**Lower 95% CI**	**Higher 95% CI**	***P* - value**
Body Composition Indices									
BMI%	611	97.9	97.3	98.6	338	98.0	97.4	98.6	0.4691
BMI z-score	610	2.26	2.15	2.37	338	2.31	2.20	2.43	0.0001
Pulse	604	85.6	83.0	88.3	334	91.9	89.0	94.8	<0.0001
Waist circumference	347	38.7	37.2	40.2	114	39.3	37.7	40.8	0.1398
% Body Fat	173	38.8	37.4	40.1	98	39.4	38.0	40.8	0.1162
Lean mass, lbs.	174	93.7	88.2	99.3	99	94.4	88.7	100.1	0.5122
Fat mass, lbs.	174	86.9	80.1	93.8	99	91.3	84.1	98.6	0.0173
Visceral Fat, lbs.	174	7.3	6.5	8.1	99	7.9	7.0	8.8	0.0212
Fitness Indices									
Syst-BP	601	106.6	103.9	109.3	337	109.2	106.3	112.1	0.0116
Dias-BP	601	65.5	63.7	67.4	337	67.1	65.1	69.0	0.0354
Pred_VO2	86	2480.5	2332.9	2628.1	63	2551.5	2393.6	2709.3	0.2062
VO2_max	86	33.6	31.9	35.2	63	33.1	31.4	34.9	0.5038
Biochemical Indices *(Acceptable Ranges)*									
ALT (< 49 U/L)	215	39.8	30.9	48.7	212	44.4	35.9	52.9	0.1487
AST (< 59 U/L)	181	32.1	26.3	37.9	194	31.9	26.4	37.5	0.9537
Total Chol (< 170 mg/dL)	146	170.6	163.0	178.3	131	169.2	161.6	176.8	0.6154
HgbA1C (4.0-5.6%)	124	6.1	5.8	6.4	142	6.0	5.7	6.3	0.6885
HDL (> 45 mg/dL)	153	41.8	39.3	44.3	130	41.2	38.7	43.6	0.3575
Insulin (< 20 mg/dL)	83	31.4	23.0	39.7	79	35.2	26.8	43.7	0.3742
LDL (< 110mg/dL)	137	101.4	94.9	107.9	118	98.2	91.7	104.7	0.1799
Trig (< 90 mg/dL)	170	149.2	111.2	187.3	172	163.7	125.4	201.9	0.3880

†Number of visits

±Adjusted by sex, age, race/ethnicity and month (to account for seasonal effects)

*Comparison pre vs. post COVID19

Changes in systolic and diastolic blood pressure (BP) were also observed; these significant increases in blood pressure (systolic BP: 111.9 vs. 108.9 mm Hg; $P < 0.01$ and diastolic BP: 68.3 vs. 66.5 mm Hg; $P < 0.001$). There were no significant changes observed in cardiovascular fitness (predicted VO2 max treadmill testing) (**Table 2**).

The COVID-19 pandemic also greatly influence social determinants of well-being and thus a baseline assessment of eating behaviors and social factors was also completed for all subjects (N=650) as well as the patients seen prior to COVID-19 (n=401) and during COVID (n=249) (**Table 4**). Most notably were changes in physical activity and screen time. Patients in the Peri-COVID era were more likely to achieve 30 minutes (48% vs. 39%, $P = 0.014$) and/or 60 minutes (42% vs. 34%, $P = 0.033$) of intentional physical activity less frequently than their pre-COVID counterparts. A significant increase in screen time on both school days (mean difference 0.8 hours, $P < 0.001$) and weekends (mean difference 0.2 hours, $P < 0.001$) was also observed.

It is now accepted that individuals, especially children and adolescents, experienced changes in food choices, eating behaviors and physical activity during the COVID-19 pandemic. It can be assumed that these changes impacted the biochemical landscape. We specifically observed increases in fasting insulin concentrations (mean difference 7.5 mg/dL, $P = 0.014$) and fasting triglyceride levels (mean difference 20.6 mg/dL, $P = 0.028$), both indicators of insulin resistance, in patients who established care in the peri-COVID versus pre-COVID time periods (**Table 2**). A significant interaction was also observed between time of the encounter and HDL cholesterol ($P = 0.01$) and time and triglycerides ($P = 0.01$). A significant increase in HDL cholesterol was observed in black subjects ($P = 0.03$) but not for any other subjects examined by race/ethnicity. Additionally, there was a significant increase in triglycerides observed for white subjects exclusively ($P < 0.001$); no changes were observed for black or Hispanic subjects.

Although insignificant, more patients in the peri-COVID time period admitted to hiding and sneaking food constantly, as well as, expressing increased appetite and hunger between meals (**Table 4**). Of note, food insecurity prevalence of 10-12% in all patients and time periods remained stable throughout the pandemic. This prevalence is consistent with regional prevalence.

Table 4: Baseline behaviors and social factors of the sample at the initial clinic visit in the Pre-COVID (Prior to 4/1/2020) versus Peri-COVID (After 4/1/2020) era (N=650)

	All Subjects N=650		Pre-COVID N=401		Peri-COVID N=249		*P* -value†
	N	**%**	**N**	**%**	**N**	**%**	
Currently Hiding Food							
Yes	108	29%	64	28%	44	32%	0.3324
No	260	71%	168	72%	92	68%	
Expresses hunger/appetite between meals	202	55%	125	54%	77	57%	0.5804
Yes	167	45%	108	46%	59	43%	
No							
"Worried whether our food would run out before we got money to buy more."	282	87%	159	86%	123	88%	0.6505
Never	36	11%	23	12%	13	9%	
Sometimes	6	2%	3	2%	3	2%	
Often							
"Worried the food we bought just didn't last and we didn't have money to get more."	289	89%	163	88%	126	91%	0.7593
Never	32	10%	20	11%	12	9%	
Sometimes	3	1%	2	1%	1	1%	
Often							
Gets at least 30 minutes activity	290	45%	194	48%	96	39%	0.0143
Gets at least 60 minutes activity	253	39%	169	42%	84	34%	0.0325
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Screen time school days (hours)	2.6	1.2	2.3	3.1	3.1	3.3	<0.001
Screen time weekends (hours)	3.2	1.0	3.1	1.0	3.3	1.0	<0.001

†: Comparison between Pre- vs. Peri-COVID

4. Discussion

4.1 Changes in body composition and biochemical indices

These data show significant increases in total fat mass, %body fat, and BMIz in children during the COVID-19 pandemic. The changes in body composition (TFM, %Fat), decrease in daily physical activity and increases in screen time observed in this patient population are likely downstream products of the pandemic. Children in larger bodies, predisposed to chronic disease states including obesity, insulin resistance, hypertension and dyslipidemia were at greatest risk during and after the pandemic.[8] Our data show that the increases in TFM included increasing visceral fat mass. Visceral fat in the abdominal region, as well as, total body fat is associated with a clustering of CVD risk factors inclusive of dyslipidemia and glucose intolerance.[18-19] These subsequent changes in fasting insulin and triglycerides were observed in this study. Baseline fasting insulin pre-COVID qualified as insulin resistance (25.2 mg/dL) and this

worsened in the COVID era to 32.6 mg/dL (P = 0.02). Similarly, triglyceride concentrations were already observed to be elevated at baseline prior to the pandemic and baseline means increased to 145.7 mg/dL during the pandemic (P = 0.02). While not significantly different between the COVID time periods, hemoglobin A1c values were observed to be elevated (> 5.6%).

Changes in systolic and diastolic blood pressure (BP) were also observed; these significant increases in blood pressure (systolic BP: 111.9 vs. 108.9 mm Hg; P < 0.01 and diastolic BP: 68.3 vs. 66.5 mm Hg; P < 0.001) may be associated with poorer food choices, loss of fitness in this segment of the patient population and/or psycho-social stressors. When these biochemical abnormalities are compounded with increases in blood pressure and waist circumference- as observed in this study- the criteria align with diagnoses of the metabolic syndrome.[20]

4.2 Quarantine and changes in health-related resources

Responses to the COVID-19 pandemic prompted major modifications in routine to mitigate risks of exposure including school closures and physical distancing requirements in both indoor and outdoor spaces.[2] Prior to the pandemic, school environments provided a viable source for physical activity, in-person instruction decreasing the need for in-school screen use and balanced nutrition. During the pandemic period, families lost access to consistent nutrition and safe physical environments that foster recreational exercise and play. In turn, families were quarantined and if they didn't have safe physical space for activity, exercise routines decreased and were often times replaced with screen time. This transition made marked changes children's growth trajectories, especially in children with prior exposure to obesogenic environments such as the present patient sample.[3] As health care providers, we need to help children find and achieve health-related resources even more since the COVID-19 pandemic began.

4.3 COVID-19 related psychosocial stress and coping

School closures also reduced many students' connection with others perpetuating social isolation. In the absence of healthy coping strategies, children and families may turned to food for comfort.. The prevalence of increased appetite and decreased satisfaction between meals, as well as, tendency to hide and/or sneak foods increased in the pediatric patient sample. Our data assessed food hiding, hunger between meals, and worrying about food security. The pandemic tested coping abilities; some children and adolescents reported eating in response to stress which further predisposes these patients to negative changes in body composition.[10] Digitale (2021) remarks that children and adolescents at both ends of the weight spectrum witnessed increases in eating disorders and disordered eating behaviors.[21] Patients with a history of eating disorder reportedly were at greater risk for recession and relapse during the COVID-19 pandemic.[21] These detrimental and risky eating behaviors compounded with the alterations in physical activity laid the foundation for alterations in the patients' growth trajectory, body composition and biochemical wellbeing. The pandemic has reinforced that increased attention of children's psychological well-being, and mental health assessment are even more important for clinicians taking care of children and adolescents.

The incidence of children with obesity has increased over the past 30 years, but the COVID-19 pandemic has triggered substantial changes in the past year. The pandemic has altered the social determinants

of health of many communities, and these data support that measurements of health risk (TFM, physical fitness, blood pressure, access to healthy food and safe spaces for activity) have significantly worsened during the pandemic. Pediatric healthcare providers need to be more aware of these changes, and how to address them.

5. Conclusion

The present study demonstrates significant increases in TFM, %fat, BMIz, markers of insulin resistance (fasting insulin and triglycerides), as well as stress-related eating behaviors, and less physical activity as a result of the COVID-19 pandemic. Underlying assessment of children's eating and activity behaviors also demonstrated worsening during COVID-19. Our findings highlight how the problem of obesity can be accelerated by societal causes. These data reinforce the importance of addressing these underlying health behaviors, as well as highlighting the importance of clinicians attending to overall well-being and mental health of children due to the pandemic.

6. Acknowledgements

Not Applicable.

7. Ethics approval and consent to participate

The study was approved by the Institutional Review Board of University of Wisconsin at Madison. Need for signed consent and assent was waived because this study presents a minimal risk for the breach of confidentiality to subjects. The waiver did not adversely affect the rights and welfare of subjects. Confidentiality protections are in place. The research could not practicably be carried out without a waiver of informed consent since the large volume of research subjects proposed along with the difficulty that many patients are lost to follow-up and the time to get permission of each patient for the outcomes analysis would not be practical. In addition, clinical care for patients will already be completed when those patients' data will be extracted from the medical records for use in future outcomes analysis done under the IRB protocol. Therefore, it was deemed impractical by the IRB to obtain consent from these subjects.

8. Consent for publication

Not applicable.

9. Availability of data and materials

All data analyzed during this study are included in this published article. The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

10. Competing interests

The authors declare no competing of interest, financial or other.

11. Funding

There is no funding.

12. Authors' contributions

CV, RC, and AC conceptualized the study in accordance with all authors, drafted the initial manuscript and led the process for revising the manuscript for submission. JE was responsible for the statistical methods, analysis, and results section. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work. No funds were received or distributed to anyone to produce this manuscript.

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