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# The impact of the COVID-19 pandemic on weight status among children and adolescents with obesity followed at a tertiary care center

Sari Krepel Volsky, MD[1]*, Michal Yackobovitch-Gavan, PhD[1,2], Shlomit Shalitin, MD[1,2]

[1]*The Jesse Z. and Sara Lea Shafer Institute for Endocrinology and Diabetes, National Center for Childhood Diabetes, Schneider Children's Medical Center, Petah-Tikva, 49202-35, Israel.*

[2]*Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, 69978-01, Israel.*

*Corresponding author

*Dr.Sari Krepel Volsky, Institute for Endocrinology and Diabetes, National Center for Childhood Diabetes Schneider Children's Medical Center of Israel, 14 Kaplan Street, Petach Tikva 49202-35, Israel.

*Key Words:

Adolescents, children, COVID -19 pandemic, obesity ,obesity comorbidities

## Abstract

**Objectives** : During the coronavirus disease 2019 (COVID-19) pandemic, changes in lifestyle and daily activities may impact weight management among children with obesity. Our aim was to assess if obesity and related comorbidities were exacerbated during the pandemic among children and adolescents followed at our obesity clinic.

**Methods**: Retrospective study comparing medical and anthropometric data of patients with obesity (BMI> 95th percentile for age and sex) younger than 18 years between the pre-pandemic period (2018/2019) and COVID-19 pandemic period (2020).

**Results**: 113 patients were included (38 males), 30% had severe obesity (BMI≥ 99th percentile for age and sex). BMI-SDS did not change significantly. BMI-SDS declided in patients with severe obesity and was stable in patients with less severe obesity .No significant changes in BMI-SDS were observed across all Tanner stage categories, between participants with or without obesity-related comorbidities, and those with or without reported familial obesity-related comorbidities. All patients reported increased participation rates of diet and physical exercise programs.Rates of cardio metabolic comorbidities were similar before and during the pandemic.

**Conclusions**: BMI-SDS of children and adolescents with obesity followed at our obesity clinic were relatively stable during the COVID-19 pandemic, which may be explained by continuous surveillance by our clinic.

## Introduction

Over the past few decades, childhood obesity rates have increased globally (1). In the pediatric age group, the development of obesity is influenced by genetics, behavioral patterns (2), and socioeconomic status (3). Childhood obesity is associated with various immediate and long-term illnesses such as obstructive sleep apnea (OSA), hypertension, type 2 diabetes (T2D), heart disease, stroke, osteoarthritis, and certain types of cancer (4). children with obesity are also likely to become adults with obesity, associated with increased risk of morbidity and mortality (5). Therefore, controlling the childhood obesity epidemic has become a top public health priority worldwide.

During the coronavirus disease 2019 (COVID-19) pandemic, many governments across the world instituted a number of protective and containment measures including lockdowns, and closure of kindergartens and schools. Previous studies support the hypothesis that youth with obesity will fare worse on weight control lifestyle programs while at home, as compared to when they are engaged in their routine school curriculum (6). Kindergarten/



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school environments seem to provide structure around mealtimes, physical activity, and sleep schedule, which are predominant lifestyle factors implicated in obesity risk. During the unpredictable situation of COVID-19, it was difficult to maintain a clear structure for children. This may result in irregular sleep patterns, and increased sedentary life with prolonged screen times and reduced fitness levels, leading to weight gain (7). It is also reasonable to assume that children were exposed to less favorable diets during lockdown, with greater consumption of processed foods that tend to be high in saturated fat, sugar, and salt (8).

Quarantine and isolation may increase psychosocial distress among children and their families (9), and further promote unhealthy food intake through stress-related eating, thereby leading to obesity and other health problems (10 ).

Changes in lifestyle and daily activities during the COVID-19 pandemic may impact weight management, health behaviors, and psychosocial health among children and adolescents who already have obesity.

The aim of this retrospective study was to assess if obesity was exacerbated among children and adolescents with obesity followed at the obesity clinic during the COVID-19 pandemic.

## Materials and Methods

The study was conducted at the obesity clinic of the Institute of Endocrinology and Diabetes at Schneider Children's Medical Center of Israel, a tertiary, university-affiliated hospital.

Inclusion criteria of the study were: patients aged 2-18 years, body mass index (BMI) > 95th percentile for age and sex, who had at least three follow-up visits between January 2018 and December 2020 (two during 2018/2019, and one in 2020 during the COVID-19 pandemic).

Notably, the year 2020 included three lockdown periods in Israel: March-May, September-October, and December. In addition, during most of this year (2020), kindergarten and schools were closed or functioned only partially, and social distancing was recommended.

However, patients were alowed to arive to the hospitals to have their follow-up visits and to get medical care.

Patients excluded from the study had: genetic syndromes associated with obesity; monogenetic obesity; endocrine disorders associated with obesity (Cushing syndrome, untreated hypothyroidism, craniopharyngioma); and patients who underwent bariatric surgery during the study period or were treated with medications that may impact weight change (steroids, Ritalin and its derivate, anti-psychotic medications).

Data of patients was compared between the pre-pandemic period (2018/2019) and COVID-19 pandemic period (2020).

The following data was collected from medical files of the eligible patients: demographic parameters (gender, ethnicity, age), height, weight, pubertal stage (according to Marshall and Tanner), presence of concomitant illness or use of concomitant medications, presence of obesity-related comorbidities (dyslipidemia, T2D or impaired glucose tolerance, hypertension, OSA, nonalcoholic fatty liver disease (NAFLD), pseudotumor cerebri, orthopedic problems, and in adolescent girls menstrual disorders/ polycystic ovaries), documentation of participation in diet or physical exercise programs as reported by the patients and their parents, and family related data including parental obesity and obesity-related comorbidities.

### Data Collection

Patients at our obesity clinic are usually scheduled for follow-up visits every 4-6 months. They have a thorough physical examination, including measurement of height (using a Harpenden-Holtain stadiometer), weight, and blood pressure, and determination of pubertal stage according to the criteria of Marshall and Tanner.

In accordance with Centers for Disease Control and Prevention (CDC) reference data 2000, height was expressed as standard deviation score (Ht-SDS) for age and gender; BMI calculated as weight (in kilograms) divided by height (in meters) squared; and BMI values converted to age- and sex-specific percentiles (11 ). To compare BMI values across age groups by sex, BMI-standard deviation scores (SDS) was calculated. Obesity was defined as $2.33 >$BMI-SDS $\geq 1.645$ (the 95-99th percentile) and severe obesity as BMI-SDS $\geq 2.33$ (≥ the 99th percentile) (12).

Blood pressure (BP) was measured according to the recommendations of the National High Blood Pressure Education Program (NHBPEP) (13). In childhood, percentiles for systolic BP and diastolic BP were calculated according to height, sex, and age. Normal BP, prehypertension, and hypertension were defined according to the practice guidelines (14).

Laboratory assessment included: measurement of liver enzymes, fasting blood glucose and lipid profile [triglycerides (TGs), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C)]. TC, LDL-C, HDL-C, and TGs were converted to age- and sex-specific percentiles according to the criteria of AAP Lipids in children aged 5–19 years (15-16 ).


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Patients suspected for OSA (snoring, disturbed sleeping with night disordered breathing) were referred to polysomnographic sleep study evaluation, and those suspected to have NAFLD (disturbed liver functions) were referred for liver ultrasound evaluation.

The study was approved by the local institutional review board, which waived the need to obtain informed consent due to the retrospective study design.

**Statistical analysis**

Statistical analyses were performed using SPSS software, version 27 (SPSS Inc., Chicago, Illinois). Data was expressed as mean±standard deviation (SD) for normally distributed variables and as medians (interquartile range) for skewed variables. Comparisons between males and females were conducted using independent samples t-test or Mann-Whitney U-test, for variables with normal or skewed distribution, respectively; or Pearson's chi-square tests for categorial variables. Variables were compared for each person between the years of follow- up (2018/2019 vs. 2020) using paired samples t-test (for variables with normal distribution), Wilcoxon matched-pair signed-rank test (for skewed variables), or Mecnemar's test (for binary variables).

General linear models repeated measures analyses were used to evaluate changes in BMI-SDS before and during Covid-19 pandemic. The models were specified with a within-group factor of time (2018, 2019, 2020), a between-group factor (sex, obesity level, Tanner stage, obesity comorbidities, maternal obesity, paternal obesity, familial obesity related comorbidities), and interaction between time and group.

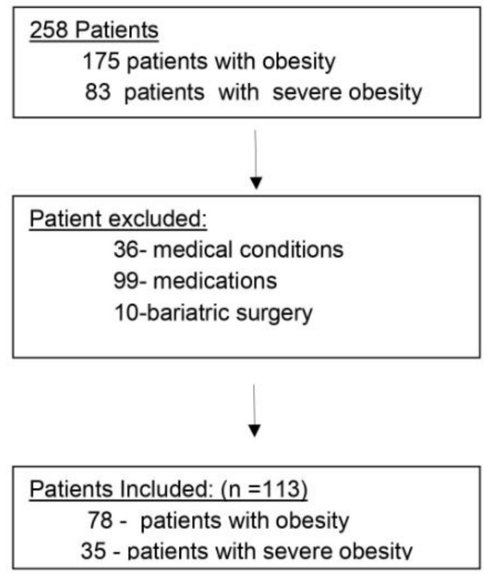
Significance was set at P≤0.05.

## Results

The study population included 113 pediatric patients that met the inclusion criteria. Figure 1 display the flow chart of patient selection.

The characteristics of the 113 included patients (38 males, 75 females) are presented in Table 1. Most (n=94, 83.2%) of the cohort were of Jewish origin and 19 (18.6%) of Arab origin, with no significant differences between males and females. At baseline (pre-pandemic outbreak), the median age was 9.2 (7.1,13.1) years, similar in males and females. Most (55.3%) males were prepubertal (Tanner stage 1), while most (64%) females were already in different stages of puberty (Tanner stage 2-5), P=0.030. More males had concomitant illnesses and were treated with medications as compared to females [(55.3% vs. 39.5%) and (33.3% vs. 18.7%), respectively, P=0.025)]. At last visit during the pandemic, the median age was 11.8 (9.1,15.0) years.

***Figure 1:*** *Flow of chart of patient selection including in the study*




Most (73.9%) patients were in different stages of puberty (Tanner stage 2-5) with no significant differences between males and females (P=0.119).

Maternal obesity was reported in 37.2% of the patients and parental obesity in 28.2% of them. Obesity-related comorbidities (one or more) among first-degree relatives were reported in 61% (54/113) of the study cohort, while the most common comorbidity was type 2 diabetes (39%), with no significant differences between males and females.

Rates of severe obesity, participation in healthy lifestyle behaviors (diet and physical exercise), and obesity-related comorbidities before and during the pandemic were compared (Table 2).

The rate of severe obesity was approximately 30% in our study cohort and was similar between 2018 and 2020. The difference between males and females in the rate of severe obesity was not significant but tended to be higher in females (P=0.175, P=0.054, P=0.079; in 2018, 2019, and 2020; respectively).

Between 2018 and 2020 patients and their parents reported about an increased rate of participation in diet (P=0.018) and physical exercise (P=0.021) programs for all patients, while the increased participation in diet programs was significant only in males (P=0.016) and the increased participation in physical exercise programs was significant only in females (P=0.039). However, the participation rates in diet and physical exercise program were similar in 2019 and 2020.

During the lockdowns, patients reported about participatation in sesssions of physical activities at home, including remoted guided programs of physical trainers.

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***Table 1:*** *Characteristics of the study participants*

| | All | Males | Females | P |
|---|---|---|---|---|
| Number | 113 | 38 (33.6%) | 75 (66.4%) | |
| Age at baseline (2018) years median (IQR) | 9.2 (7.1,13.1) | 10.1 (8.1,13.1) | 9.1 (7.0,14.0) | 0.333 |
| Age during pandemic (2020) years median (IQR) | 11.8 (9.1,15.0) | 12.1 (10.5,15.0) | 11.1 (9.0,15.1) | 0.367 |
| Tanner 2018 n (%) | | | | |
| 1 | 48 (42.5) | 21 (55.3) | 27 (36.0) | 0.03 |
| 2-4 | 41 (36.3) | 14 (36.8) | 27 (36.0) | |
| 5 | 24 (21.2) | 3 (7.9) | 21 (28.0) | |
| Tanner 2019 n (%) | | | | |
| 1 | 43 (38.4) | 20 (52.6) | 23 (31.1) | 0.67 |
| 2-4 | 37 (33.0) | 11 (28.9) | 26 (35.1) | |
| 5 | 32 (28.6) | 7 (21.9) | 25 (33.8) | |
| Tanner 2020 n (%) | | | | |
| 1 | 27 (26.0) | 14 (37.8) | 13 (19.4) | 0.119 |
| 2-4 | 35 )33.7) | 10 (27.0) | 25 (37.3) | |
| 5 | 42 (40.2) | 13 (35.1) | 29 (43.3) | |
| Ethnicity n (%) | | | | |
| Jews | 94 (83.2) | 30 (78.9) | 64 (85.3) | 0.43 |
| Arabs | 19 (16.8) | 8 (21.1) | 114) 1.7) | |
| Concomitant illness n (%) | 46 (40.7) | 21 (55.3) | 25 (33.3) | **0.025** |
| Concomitant medication (%) n | 29 (25.7) | 15 (39.5) | 14 (18.7) | **0.017** |
| Family related data | | | | |
| Maternal obesity n (%) | 42 (37.2) | 13 (34.2) | 29 (38.7) | 0.428 |
| Paternal obesity n (%) | 32 (28.3) | 12 (31.6) | 20 (26.7) | 0.34 |
| Familial obesity-related comorbidities n (%) | | | | |
| Type 2 Diabetes | 45 (39.8) | 13 (34.2) | 32 (42.7) | 0.386 |
| Hyperlipidemia | 21 (18.3) | 5 (13.2) | 16 (21.3) | 0.291 |
| Hypertension | 16 (14.2) | 5 (13.2) | 11 (14.7) | 0.828 |
| Cardiovascular disease | 19 (16.8) | 4 (10.5) | 15 (20) | 0.203 |
| Any comorbidity (one or more) | 61 (54.0) | 17 (44.7) | 44 (58.7) | 0.16 |

*Data is presented as median (interquartile range, IQR) (skewed distribution) or number (percent) (categorial variable). P values represent Mann-Whitney U-test, for variables with skewed distribution or Pearson's chi-square tests for categorial variables.*

The rates of obesity-related comorbidities (OSA, NAFLD, dyslipidemia, and hypertension) were similar before and during the pandemic outbreak in the whole cohort, as well as in males and females. However, there was a significant increase in impaired glucose tolerance or T2D between 2018 -2019, and between 2018-2020, especially in females.

The BMI-SDS did not change significantly between the pre-pandemic and pandemic periods among all participants and in both sexes (Table 3). A significant difference was found in the pattern (slope) of the BMI-SDS change over time between participants with severe obesity and those with obesity (Ptime×group=0.027). While in patients with severe obesity a small but significant decline in BMI-SDS was observed between 2019 and 2020, in patients with obesity BMI-SDS was stable between the pre-pandemic and pandemic periods. No changes in BMI-SDS over the pre-pandemic and pandemic periods were observed across all Tanner stage categories, among participants with one or more obesity-related comorbidities as compared to participants with no comorbidities, and among participants with one or more reported familial obesity-related comorbidities as compared to participants without familial comorbidities.

Participants with maternal or paternal obesity had a higher BMI-SDS as compared to participants with parents without obesity (Pgroup=0.033 and Pgroup=0.037, respectively). However, in both participants with parental obesity and without parental obesity, BMI-SDS was stable between the pre-pandemic and pandemic periods (Table 3).

## Discussion

During the COVID-19 outbreak there have been changes in lifestyle and behavior for children and adolescents. Studies published from different countries, including Israel (17-22), have demonstrated weight gain and changes in body composition during the pandemic. Weight gain was observed in 48.6% of the Italian population (20 ), 30.6% in China (21), and 14%-30% in the USA (22), both in adults and children.

Our hypothesis was that the pandemic and lockdown will result in weight gain that will be more accentuated in children and adolescents with obesity, since they are more prone to be influenced by "forced" obesogenic behavior (lack of activity, altered eating habits, increased screen time and irregular sleep) combined with stress and emotional discomforts. Interestingly, in our cohort children and adolescents with obesity followed at the obesity clinic tended to maintain similar BMI-SDS during the first year of the pandemic as compared to the pre-pandemic years.

This finding is in line with other studies that have shown weight stability in children with overweight and obesity (18



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***Table 2:*** *Rates of morbid obesity, lifestyle behavior and obesity-related comorbidities before and during the Covid-19 pandemic*

| | 2018 | 2019 | 2020 | $P_1$ | $P_2$ | $P_3$ |
|---|---|---|---|---|---|---|
| **Morbid obesity** | | | | | | |
| All (n=113) | 33 (29.2) | 34 (30.1) | 36 (31.9) | 0.999 | 0.549 | 0.791 |
| Males (n=38) | 8 (21.1) | 7 (18.4) | 8 (21.1) | 0.999 | 0.999 | 0.999 |
| Females (n=75) | 25 (33.3) | 27 (36.0) | 28 (37.3) | 0.625 | 0.453 | 0.999 |
| **Lifestyle behavior** | | | | | | |
| Diet | | | | | | |
| All (n=113) | 11 (9.7) | 17 (15.0) | 25 (22.1) | 0.238 | **0.018** | 0.170 |
| Males (n=38) | 1 (2.6) | 6 (15.8) | 8 (21.1) | 0.063 | **0.016** | 0.727 |
| Females (n=75) | 10 (13.3) | 11 (14.7) | 17 (22.7) | 0.999 | 0.210 | 0.238 |
| Exercise | | | | | | |
| All (n=113) | 8 (7.1) | 20 (17.7) | 18 (15.9) | **0.012** | **0.021** | 0.815 |
| Males (n=38) | 2 (5.3) | 7 (18.4) | 4 (10.5) | 0.063 | 0.625 | 0.375 |
| Females (n=75) | 6 (8.0) | 13 (17.3) | 14 (18.7) | 0.118 | **0.039** | 0.999 |
| **Obesity-related Comorbidities** | | | | | | |
| OSA | | | | | | |
| All (n=113) | 5 (4.4) | 3 (2.7) | 6 (5.3) | 0.625 | 0.999 | 0.375 |
| Males (n=38) | 0 | 1 (2.6) | 1 (2.6) | 0.999 | 0.999 | 0.999 |
| Females (n=75) | 5 (6.7) | 2 (2.7) | 5 (6.7) | 0.250 | 0.999 | 0.375 |
| NAFLD | | | | | | |
| All (n=113) | 7 (6.2) | 11 (9.7) | 13 (11.5) | 0.219 | 0.070 | 0.625 |
| Males (n=38) | 0 | 1 (2.6) | 2 (5.3) | 0.099 | 0.500 | 0.999 |
| Females (n=75) | 7 (9.3) | 10 (13.3) | 11 (14.7) | 0.375 | 0.219 | 0.999 |
| Glucose abnormalities | | | | | | |
| All (n=113) | 12 (10.6) | 24 (21.2) | 26 (23.0) | **<0.001** | **<0.001** | 0.727 |
| Males (n=38) | 2 (5.3) | 7 (18.4) | 5 (13.2) | 0.063 | 0.375 | 0.500 |
| Females (n=75) | 10 (13.3) | 17 (22.7) | 21 (28.0) | **0.016** | **<0.001** | 0.219 |
| PCOS | | | | | | |
| Females (n=75) | 2 (2.7) | 4 (5.3) | 5 (6.7) | 0.500 | 0.250 | 0.999 |
| **Blood pressure** | | | | | | |
| All (n=113) | | | | | | |
| Elevated | 23 (20.4) | 14 (12.4) | 25 (22.1) | 0.827 | 0.758 | 0.169 |
| Stage 1 | 19 (16.8) | 19 (16.8) | 29 (25.7) | | | |
| Stage 2 | 0 | 0 | 1 (0.9) | | | |
| Males (n=38) | | | | | | |
| Elevated | 6 (15.8) | 3 (7.9) | 11 (28.9) | 0.564 | 0.366 | 0.166 |
| Stage 1 | 5 (13.2) | 6 (15.8) | 5 (13.2) | | | |
| Stage 2 | 0 | 0 | 0 | | | |
| Females (n=75) | | | | | | |
| Elevated | 17 (22.7) | 11 (14.7) | 14 (18.7) | 0.840 | 0.487 | 0.448 |
| Stage 1 | 14 (18.7) | 13 (17.3) | 24 (32.0) | | | |
| Stage 2 | 0 | 0 | 1 (1.3) | | | |
| **Total cholesterol** | | | | | | |
| All (n=113) | | | | | | |
| Borderline (170-200mg/dl) | 16 (14.2) | 14 (12.4) | 17 (15.0) | 0.999 | 0.637 | 0.527 |
| Elevated (>200 mg/dl) | 5 (4.4) | 5 (4.4) | 7 (6.2) | | | |
| Males (n=38) | | | | | | |
| Borderline (170-200mg/dl) | 5 (13.2) | 4 (10.5) | 5 (13.2) | 0.414 | 0.257 | 0.317 |
| Elevated (>200 mg/dl) | 2 (5.3) | 1 (2.6) | 2 (5.3) | | | |
| Females (n=75) | | | | | | |
| Borderline (170-200mg/dl) | 11 (14.7) | 10 (13.3) | 12 (16.0) | 0.527 | 0.132 | 0.317 |
| Elevated (>200 mg/dl) | 3 (4.0) | 4 (5.3) | 5 (6.7) | | | |
| **LDL cholesterol** | | | | | | |
| All (n=113) | | | | | | |
| Borderline (110-130mg/dl) | 12 (10.6) | 11 (9.7) | 13 (11.5) | 0.527 | 0.963 | 0.248 |
| Elevated (>130 mg/dl) | 5 (4.4) | 4 ( 3.5) | 5 (4.4) | | | |
| Males (n=38) | | | | | | |
| Borderline (110-130mg/dl) | 4 (10.5) | 4 (10.5) | 5 (13.2) | 0.102 | 0.059 | 0.564 |
| Elevated (>130 mg/dl) | 3 (7.9) | 1 (2.6) | 1 (2.6) | | | |
| Females (n=75) | | | | | | |
| Borderline (110-130 mg/dl) | 8 (10.7) | 7 (9.3) | 8 (10.8) | 0.317 | 0.160 | 0.317 |
| Elevated (>130 mg/dl) | 2 (2.7) | 3 (4.0) | 4 (5.3) | | | |
| **Triglyceride *** | | | | | | |
| All (n=113) | | | | | | |
| Borderline | 17 (15.0) | 16 (14.2) | 17 (15.0) | 0.696 | 0.459 | 0.752 |
| Elevated | 25 (22.1) | 29 (25.7) | 27 (23.9) | | | |
| Males (n=38) | | | | | | |
| Borderline | 4 (10.5) | 6 (15.8) | 5 (13.2) | 0.739 | 0.132 | 0.581 |
| Elevated | 7 (18.4) | 7 (18.4) | 11 (28.9) | | | |
| Females (n=75) | | | | | | |
| Borderline | 13 (17.3) | 10 (13.3) | 12 (16.0) | 0.564 | 0.922 | 0.197 |
| Elevated | 18 (24.0) | 22 (29.3) | 16 (21.3) | | | |
| **HDL cholesterol** | | | | | | |
| Males (n=38) | | | | | | |
| Borderline (40-45 mg/dl) | 5 (13.2) | 7 (18.4) | 5 (13.2) | 0.084 | 0.999 | 0.357 |
| Low ( <40 mg/dl) | 7 (18.4) | 6 (15.8) | 8 (21.1) | | | |
| Females (n=75) | | | | | | |
| Borderline (40-45 mg/dl) | 15 (20.0) | 16 (21.3) | 11 (14.7) | **0.025** | 0.123 | 0.158 |
| Low ( <40 mg/dl) | 18 (24.0) | 14 (18.7) | 16 (21.3) | | | |

*Data is presented as number (percent). P values represents between visits comparison using related-samples Mcnemar test for dichotomies variables or related samples Wilcoxon signed Rank test for ordinal variabeled. P1 - 2018 vs. 2019, P2 – 2018 vs. 2020, P3 – 2019 vs. 2020 .*

** Triglyceride - ≤ age 9 years borderline is between 75-99 nmol/l and elevated is over 100 nmol/l, ≥ 10 years borderline is between 90-129 nmol/l elevated is over 130 nmol/l*



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*Table 3: BMI-SDS changes before and during Covid-19 pandemic by sex, obesity level, pubertal stage, obesity-related comorbidities, and parental weight status and obesity-related comorbidities*

| | BMI-SDS 2018 | BMI-SDS 2019 | BMI-SDS 2020 | P time | P group | P time X group |
|---|---|---|---|---|---|---|
| All (n=113) | 2.12±0.42 | 2.12±0.40 | 2.11±0.40 | 0.849 | | |
| **Sex** | | | | | | |
| Males (n=38) | 2.071±0.50 | 2.071±0.40 | 2.113±0.32 | 0.897 | 0.478 | 0.165 |
| Females (n=75) | 2.148±0.40 | 2.154±0.40 | 2.114±0.40 | | | |
| **Obesity level 2018** | | | | | | |
| Obesity (n=80) | 1.909±0.25 | 1.931±0.25 | 1.937±0.32 | 0.213 | <0.001 | 0.027 |
| Morbid obesity (n=33) | 2.640±0.29[a] | 2.600±0.24[a] | 2.541±0.24[b] | | | |
| **Tanner stage category 2018** | | | | | | |
| 1 (n=48) | 2.137±0.50 | 2.130±0.43 | 2.140±0.38 | 0.466 | 0.217 | 0.331 |
| 2-4 (n=41) | 2.036±0.33 | 2.050±0.35 | 2.056±0.37 | | | |
| 5 (n=24) | 2.242±0.38 | 2.245±0.35 | 2.114±0.40 | | | |
| **Obesity related Comorbidities 2018** | | | | | | |
| No comorbidity (n=86) | 2.093±0.42 | 2.095±0.38 | 2.080±0.40 | 0.877 | 0.117 | 0.792 |
| Any comorbidity* (n=27) | 2.218±0.43 | 2.226±0.42 | 2.221±0.39 | | | |
| **Maternal obesity**** | | | | | | |
| No (n=66) | 2.084±0.44 | 2.070±0.39 | 2.049±0.38 | 0.503 | 0.033 | 0.566 |
| Yes (n=42) | 2.220±0.39 | 2.249±0.37 | 2.217±0.44 | | | |
| **Paternal obesity**** | | | | | | |
| No (n=76) | 2.087±0.43 | 2.082±0.39 | 2.072±0.38 | 0.37 | 0.037 | 0.71 |
| Yes (n=32) | 2.253±0.39 | 2.276±0.36 | 2.216±0.45 | | | |
| **Familial obesity related comorbidities** | | | | | | |
| No (n=52) | 2.075±0.38 | 2.089±0.37 | 2.100±0.36 | 0.804 | 0.409 | 0.229 |
| Yes (n=61) | 2.163±0.46 | 2.157±0.41 | 2.114±0.40 | | | |

*Obesity level: obesity defined as 2.33 >BMI-SDS ≥1.645, morbid obesity defined as BMI-SDS ≥2.33.*

*General linear models repeated measures analysis. The models were specified with a within-group factor of time (2018, 2019, 2020), a between-group factor (sex, obesity level, Tanner stage, obesity comorbidities, maternal obesity, paternal obesity, familial obesity related comorbidities), and the interaction between time and goup. Variables with different superscript (a,b,c) significantly differ from each other at p<0.05 at the post hoc least significant difference (LSD) pairwise comparisons.*

** Any comorbidity – one or more comorbidities including: OSA, NAFLD, glucose abnormalities, PCOS, HT, dyslipidemia.*

***for 5 pateints parents obesity status was unknown.*

,23) or even a decrease in BMI-SDS among children and adolescents with overweight and obesity based on a large cohort from the general population in Israel (24). However, it contrasts findings of other publications, especially form Italy (25-26), that found that adolescents with obesity showed a worsening of obesity during the pandemic lockdown, with males mainly affected. We may speculate that our findings can be explained by the observation that participants in our cohort had increased participation in healthy lifestyle behavior that started before the pandemic, maybe with better adherence to diet changes and engagement in physical activity during the pandemic. Thus, behavioral changes were not as dramatic as for children with normal weight. Indeed, a previous study demonstrated that physical activity increased during the pandemic among children with obesity (27). Therefore, our results can be attributed to the increased awareness of healthy habits and the desirability of maintaining them among children and adolescents with existing obesity who had regular follow-up in the obesity clinic.

Even though we did not find a significant change in BDI -SDS during the pandemic, we did find that patients with severe obesity had a small but significant decline in BMI-SDS before the pre-pandemic and pandemic periods, while in children and adolescents with obesity there were no changes in BMI-SDS during the COVID-19 outbreak. The observation is surprising, and perhaps may be explained by


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continuity of surveillance in the obesity clinic, at least in the first year of the pandemic.

The fact that more females were in puberty is not surprising since girls usually begin puberty at an earlier age, and also previous studies have shown that obesity was associated with earlier age at pubertal onset among adolescent girls (28-29 ). However, in our cohort, across all Tanner stage categories, there were no significant changes of BMI-SDS during the pandemic.

Similar to our findings, a large number of studies have reported an association between parental and childhood obesity, especially maternal obesity (30). However, we did not find a correlation between the existences of parental obesity or obesity-related comorbidities in families and changes in BMI-SDS over the pre-pandemic and the pandemic periods.

We also did not find a significant change in the prevalence of most of the obesity-related comorbidities during the pandemic, which may reflect the relatively short period of follow-up, as in other studies. Nevertheless, the change in BMI-SDS over the pre-pandemic and the pandemic period was not significantly different between those with and without obesity-related comorbidities.

Our study has several strengths, first, all patients were already followed at our obesity clinic before the COVID-19 outbreak, therefore the uniformity of anthropometric measurements with use of the same weight and height measurement devices. Second, the longitudinal design of the study with patient's weight and BMI compared to their own weight and BMI allowed maximal accuracy. Third, the cohort was comprised of children and adolescents, of both sexes, over a wide age range, and at various stages of puberty. In addition, due to the urban nature of our hospital location (a big city in the center of Israel and not a rural area) all patients were profoundly affected by the lockdowns.

The main limitation of our study is the relatively small number of participants. Only patients who attended our clinic during the pandemic were included, which constituted a small sample, since many patients avoided visiting hospitals during the first year of pandemic. Therefore, the results may not reflect the BMI-SDS changes of individuals with obesity who were not similarly followed by professional medical care providers. Thus, the generalizability of this study may be limited. Another limitation is the lack of participants' socioeconomic data. Socioeconomic circumstances are recognized as a major determinant of health conditions in children and adolescents that may have impact on changes in lifestyle behavior and weight status, especially during periods of economic insecurity as during the pandemic period. In addition, our study did not include questionnaires of detailed evaluation of nutritional, behavioral, and psychological aspects before and during the COVID-19 pandemic. Finally, we don't have objective information about participation in physical and diet programs of the patients, and data relied only on patients and parents reports.

## Conclusion

In conclusion, the BMI of children and adolescents with obesity attending our obesity clinic was relatively stable during the COVID-19 pandemic. This achievement may be explained by the preservation of continuity surveillance at the obesity clinic and preservation of lifestyle changes with a focus on increasing physical activity, reducing sedentary time, and promoting healthy diets in spite of the pandemic.

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