Original article

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The impacts of COVID-19 on childhood obesity: prevalence, contributing factors, and implications for management

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Purpose: This study aimed to identify changes in the prevalence of obesity and related diseases among children and adolescents during the coronavirus disease 2019 (COVID-19) pandemic.
Methods: This study was conducted using data from the 2016–2021 Korean National Health and Nutrition Examination Survey and included 3,861 children and adolescents aged 10–18 years. The prevalence of obesity and related diseases was adjusted for age, sex, and income. We also analyzed the socioeconomic, nutritional, and physical activity items in the survey.
Results: During the COVID-19 pandemic, there was a significant increase in the prevalence of obesity (P=0.02), central obesity (P=0.001), mean body mass index (BMI, P=0.03), and hemoglobin A1c (P=0.005) among children and adolescents aged 10–18 years. The intake of food and calories was significantly reduced in the normal-weight group (P=0.001 and <0.001) but not in the obese group. Incidences of skipping breakfast increased and eating out decreased, regardless of obesity status. However, the changes in health behaviors were not significant. The prevalence of central obesity and increased BMI showed a significant linear association between children and their parents, especially in the 10–12-year-old age group. A clear increase in the proportion of metabolically unhealthy children and adolescents was observed in the obese group, and the frequency of central obesity in parents also increased.
Conclusion: The number of metabolically unhealthy, obese children and adolescents increased during the COVID-19 pandemic. Age-specific strategies that consider growth, development, and genetic and social factors are required. Health strategies targeting the entire family are required to develop healthier habits.

Keywords: Obesity, Child, Prevalence, Metabolic disease, COVID-19

Highlights

- During the coronavirus disease 2019 (COVID-19) pandemic, obesity and metabolic issues increased in Korean children and adolescents. The characteristic change revealed in this study during COVID-19 highlights the need for age-specific and family-centered health strategies to combat these rising metabolic health issues.

Introduction

Childhood obesity is a major public health problem around the world.[1,2] The prevalence of obesity in children and adolescents continues to increase worldwide, with adolescent obesity recognized as a new epidemic disease.[1,3] Due in part to the occurrence of the new infectious

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disease coronavirus disease 2019 (COVID-19), the number of obese children is steadily increasing.[2]

It is well-known that obesity is closely related to metabolic health status.[3] Obesity causes excessive fat accumulation, leading to dyslipidemia and hypertension. Moreover, obesity increases insulin resistance, resulting in glucose intolerance and metabolic disorders.[2,3] Overweight children show a higher risk of becoming obese adults.[2,4] An increase in the unhealthy population reduces the quality of life of individuals and families and adversely affects the National Health Insurance.[5] Abuse of diet pills and eating disorders are common problems for children and adolescents.[6]

Childhood is an important period of life for health intervention to prevent obesity development. It is common practice to eat less and move more to prevent obesity; however, the factors affecting obesity and metabolic syndromes remain controversial. Various analyses of the factors related to these changes have been attempted, but none have been definitive.

During the COVID-19 pandemic, changes in national policies, such as self-isolation and school/restaurant closures, changed everyday life. Therefore, this is a good opportunity to compare and observe the factors that affected the changes in the prevalence of obesity before and during the COVID-19 pandemic.

We aimed to identify the annual changes in the prevalence of obesity, diabetes, dyslipidemia, and hypertension before and during the COVID-19 pandemic. We also investigated lifestyle-associated factors, such as dietary habits, nutritional differences, and physical activity, which contributed to these changes before and during the COVID-19 pandemic. Through this study, we intend to investigate areas of focus in healthcare for children and adolescents and factors that can improve metabolic health.

Materials and methods

1. Study population and data

This study used data from the Korean National Health and Nutrition Examination Survey (KNHANES). The KNHANES is an ongoing cross-sectional national survey in Korea that has assessed the population's health status, health behavior, nutrition, and prevalence of chronic diseases since 1998. Using Korean population census data as a sampling frame, this survey was conducted on 25 households in the sample survey area, amounting to a total of 4,800 households in 192 survey districts per year, using the 22-stage stratified cluster collection method. Our study used health examinations, nutrition surveys, and health interviews from the 7th (2016–2018) and 8th (2019–2021) KNHANES. Detailed information on KNHANES has been reported by the Center for Korea Disease Control and Prevention Agency and can be downloaded from their website. Of the total of 44,705 participants, 3,861 children and adolescents aged 10–18 years were included. Informed consent was obtained from all individuals who participated in the KNHANES. The study protocol was approved by the Institutional Review Board (IRB) of Pusan National University Yangsan Hospital (IRB No. 05-2023-081). All procedures were performed in accordance with the Declaration of Helsinki.

2. Methods and statistical analysis

The data were divided and compared before and during the COVID-19 pandemic (2016–2019 vs. 2020–2021). Participants were divided into an overweight/obese group with a body mass index (BMI) ≥85th percentile and a normal-weight group (BMI<85th percentile). We analyzed the prevalence of dysglycemia, dyslipidemia, hypertension, and obesity and their trends, which were adjusted for sex, age, and household income. The correlations between obesity of parents and children, nutritional intake, and health behavior were also analyzed to identify the factors affecting obesity and health status. All statistical analyses were performed using for Academics (SAS Institute Inc., Cary, NC, USA) using sampling weights. SURVEYLOGISTIC was used for prevalence analysis, SURVEYFREQ or SURVEYRMENAS were also used for the analysis, depending on the type of variable. SURVEYREG was used for the adjusted linear regression. The results were described as weighted counts (percentages) or weighted means with confidence intervals. Statistical significance was set at $P<0.05$.

3. Definitions of metabolic syndrome variables

Overweight and obesity were defined as a BMI ranging from the 85th to 95th percentile and ≥95th percentile for age and sex, respectively. Dysglycemia was defined as abnormalities in one or more of the following: fasting blood sugar (FBS) ≥126 mg/dL, 126>FBS≥100 mg/dL, hemoglobin A1c (HbA1c) ≥6.5%, or 6.5%>HbA1c≥5.7%. Dyslipidemia was defined as abnormalities in one or more of the following: hypercholesterolemia (total cholesterol ≥200 mg/dL), hypertriglyceridemia (triglycerides [TG] ≥150 mg/dL), hypo-high-density lipoprotein cholesterolemia (high-density lipoprotein cholesterol [HDL-C] <40 mg/dL in males aged 10–18 years and females aged 10–15 years, and <50 mg/dL in females aged 16–18 years), hyper-low-density lipoprotein cholesterolemia (low-density lipoprotein cholesterol ≥130 mg/dL), and hyper-non-high-density lipoprotein cholesterolemia (non-HDL-C ≥145 mg/dL). Hypertension was defined as a systolic blood pressure (BP) ≥130 mmHg or a diastolic BP ≥85 mmHg. Definitions of abnormal levels of TG, HDL-C, and BP were based on the International Diabetes Federation diagnostic criteria.[7] Based on BMI (≥85th percentile or not) and the presence of more than one of the metabolic syndrome-related indicators, subjects were classified into 4 groups: metabolically healthy normal weight (MHNW), metabolically unhealthy normal weight, metabolically healthy obesity (MHO), and metabolically unhealthy obesity (MUHO). The metabolically healthy group was defined as those who met all the normal criteria for BP, HDL-C, TG, FBS, and HbA1c. Central obesity was defined as ≥90th percentile for waist circumference (WC) according to sex and age in children and

adolescents.

Results

1. General characteristics

A total of 3,861 participants (weighted frequency: 4,454,060) aged 10–18 years was included in the survey period, and 53.2% were male (2,053 participants). The number of participants and proportions of genders were similar for each surveyed year, but the proportion of the elementary school aged group was higher in 2020–2021. There was no significant (*P*=0.108) difference in income level in the annual survey; however, starting with the COVID-19 pandemic, the proportion of the population with a high income level decreased (32.38% to 29.76%) and the that with a middle-high income level increased (31.89% to 36.46%) (Supplementary Table 1).

When comparing average values of BMI, BP, HbA1c, FBS, and lipid blood levels, significantly increasing trends of mean BMI (21.0 to 21.4 kg/m^2, *P*=0.03) and mean HbA1c (5.36% to 5.4%, *P*=0.005) were observed after the COVID-19 pandemic (Supplementary Table 2).

2. Prevalence of overweight/obesity and normal weight

Table 1 shows the significant increase in the prevalence of obesity and overweight among children and adolescents aged 10–18 years (from 22.01% to 26.38%, *P*=0.02). The prevalence of obesity was the most prominent, increasing from 12.55% to 17.29% (*P*=0.002), while the prevalence of central obesity significantly increased from 11.67% to 16.39% during the COVID-19 pandemic (*P*=0.016).

Even in the overweight/obese group, a clear increase in the number of metabolically unhealthy children and adolescents was observed. The prevalence of MUHO has not only steadily increased since 2016 (*P* for annual trend <0.001), but it also increased significantly in 2020–2021 (*P* for trend=0.002).

Table 1. Prevalence of obesity and normal weight with or without metabolic unhealthiness in children and adolescents

Variable	2016–2019, weighted (%)	2020–2021, weighted (%)	OR (95% CI)	*P*-value
Obesity and overweight	22.01	26.38	1.28 (1.04–1.57)	0.02
Obesity	12.55	17.29	1.47 (1.15–1.87)	0.002
Overweight	9.46	9.08	0.96 (0.74–1.24)	0.74
Central obesity	11.67	16.39	1.5 (1.17–1.93)	0.001
MUHO	14.91	20.28	1.45 (1.14–1.85)	0.002
MHO	6.67	7.31	1.11 (0.8–1.53)	0.544
MUHNW	31.84	30.40	0.94 (0.78–1.14)	0.521
MHNW	46.55	42.00	0.83 (0.7–0.98)	0.03

OR, odds ratio; CI, confidence interval; MUHO, metabolically unhealthy obesity; MHO, metabolically healthy obesity; MUHNW, metabolically unhealthy normal weight; MHNW, metabolically healthy normal weight.

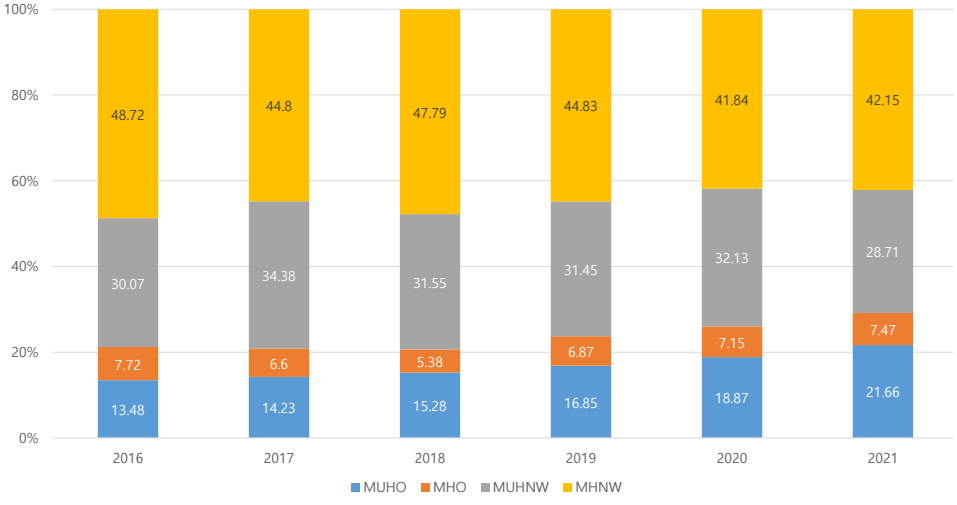

Fig. 1. Trends and proportions of obesity and normal weight with or without metabolic unhealthiness over time. The proportion of MUHO tended to increase, whereas that of MHNW tended to decrease annually between 2016 and 2021. The rate of change was largest in 2020–2021. The odds ratios (confidence interval, *P* for trend) of MUHO, MHO, MUHNW, and MHNW were 1.123 (1.049–1.201, *P*<0.001), 1.006 (0.918–1.101, *P*=0.905), 0.983 (0.936–1.032, *P*=0.480), and 0.951 (0.907-0.997, *P*=0.035), respectively. MUHO, metabolically unhealthy obesity; MHO, metabolically healthy obesity; MUHNW, metabolically unhealthy normal weight; MHNW, metabolically healthy normal weight.

In contrast, MHNW showed a clear declining trend, with the prevalence decreasing not only annually (*P* for annual trend=0.035) but also in 2020–2021 (*P* for trend=0.03) (Fig. 1).

The changes before and after COVID-19 by dividing each metabolic index into overweight/obese and normal weight groups are presented in Table 2. In the overweight/obese group, the proportion of 6.5%>HbA1c≥5.7% increased significantly from 14.53% to 23.16% (*P*=0.038). The prevalence of insulin resistance and dyslipidemia increased in the overweight/obese group; however, the difference was not significant. The increase in dyslipidemia appeared to be due to an increase in TG and a decrease in HDL-C levels. Metabolic indicators in the normal-weight group showed similar prevalence before and after COVID-19.

3. Correlation between parental obesity and child obesity

During the COVID-19 pandemic, there was an increasing trend among parents experiencing central obesity, along with an increase in obesity among children and adolescents. We investigated the frequency of central obesity and obesity among children with obese parents, wherein the 10–12-year-old age group showed the most significant increase (14.2% to 23.3%, *P*=0.033 with mother, and 12.6% to 28.7%, *P*=0.002 with father). The adjusted linear regression analysis showed a significant linear association between the WC and BMI of children and their parents, and this association became stronger during the pandemic. Moreover, the regression coefficient of mothers was greater than that of fathers for both central obesity and obesity. For details and the calculation formula, see Supplementary Tables 3-6.

4. Changes in nutrition, dietary habits, and health behaviors

During the COVID-19 pandemic, a general decline in food intake among children and adolescents aged 10–18 years was observed (Supplementary Table 7). Food and energy intake decreased significantly in the normal-weight group but not in the overweight/obese group. In the normal-weight group, overall nutrient intake, such as calories, protein, saturated fatty acids, sugars, thiamine, and folic acid, as well as carbohydrates, decreased. In the overweight/obese group, only the carbohydrate intake was significantly reduced (from 303.4 g to 276.9 g, *P*=0.014). Throughout the survey period, niacin intake was below the recommended level[8] for middle and high school students. During the COVID-19 pandemic, niacin intake in elementary school students also fell below the recommended level.[8] Similarly, folic acid and vitamin C intake for middle and high school students was below average requirements[8] throughout the survey, while elementary school students had insufficient folic acid intake during the pandemic.

A comparison of dietary habits before and during the COVID-19 pandemic revealed an increase in the proportion of people who skipped breakfast, particularly in the overweight/obese group. The frequency of having lunch with family members increased, while eating out declined across all groups regardless of obesity status (Table 3).

Table 2. Prevalence of dysglycemia, insulin resistance, dyslipidemia, and hypertension in children and adolescents with or without obesity

Variable	Overweight/obesity				Normal weight			
	2016–2019	2020–2021	OR (95% CI)	*P*-value	2016–2019	2020–2021	OR (95% CI)	*P*-value
Dysglycemia								
FBS (mg/dL)								
≥100, <126	15.212	20.705	1.326 (0.878–2.002)	0.179	10.425	9.165	0.873 (0.642–1.186)	0.383
≥126	1.382	0.687	0.836 (0.188–3.717)	0.814	0.153	0.213	1.343 (0.241–7.469)	0.736
HbA1c								
≥5.7%, <6.5%	14.530	23.162	1.542 (1.024–2.321)	0.038	8.591	10.535	1.283 (0.908–1.812)	0.157
≥6.5%	1.167	0.678	1.040 (0.200–5.397)	0.962	0.122	0.208	1.704 (0.261–11.135)	0.577
Insulin resistance								
HOMA-IR >2.0	1.996	1.964	1.172 (0.214–6.416)	0.654	0.238	0.197	0.947 (0.065–10.546)	0.964
TyG index ≥8.45	42.790	48.143	1.231 (0.869–1.745)	0.240	22.033	20.016	0.864 (0.884–1.510)	0.226
Dyslipidemia	51.957	53.472	1.146 (0.807–1.627)	0.445	26.148	24.692	0.918 (0.740–1.139)	0.434
HyperCHOL	18.573	13.045	0.676 (0.424–1.087)	0.106	8.097	7.286	0.877 (0.621–1.239)	0.455
HyperTG	26.742	28.658	1.107 (0.757–1.617)	0.599	10.598	9.772	0.901 (0.659–1.232)	0.514
HypoHDL	26.68	27.55	1.268 (0.850–1.893)	0.243	11.190	10.149	0.924 (0.654–1.306)	0.653
HyperLDL	15.530	11.497	0.779 (0.458–1.325)	0.355	5.516	6.119	1.119 (0.756–1.656)	0.574
HyperNon-HDL	23.558	21.486	0.917 (0.610–1.381)	0.678	7.639	7.033	0.911 (0.641–1.294)	0.601
Hypertension	10.536	9.469	0.888 (0.502–1.568)	0.680	1.995	2.433	1.215 (0.536–2.755)	0.641

Prevalence rates were presented as weighted percentages of categorical variables.
OR, odds ratio; CI, confidence interval; FBS, fasting blood glucose; HbA1c, hemoglobin A1c; HOMA-IR, homeostatic model assessment for insulin resistance; TyG index, triglyceride-glucose index; CHOL, total cholesterol; TG, triglycerides; HDL, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol.

Table 3. Changes in dietary habits among children and adolescents

Dietary habit	Overweight/obesity			Normal weight		
	2016–2019	2020–2021	*P*-value	2016–2019	2020–2021	*P*-value
Skip a meal						
Breakfast	32.2%	41.4%	0.032	31.5%	33.1%	0.569
Lunch	9.7%	9.2%	0.860	7.2%	6.8%	0.731
Supper	6.9%	4.4%	0.187	5.9%	6.5%	0.634
Meals with family within the recent year						
Breakfast	97.1%	98.0%	0.638	98.0%	98.3%	0.749
Lunch	1.9%	19.5%	<0.001	1.0%	2.4%	<0.001
Supper	79.6%	94.9%	<0.001	78.5%	90.7%	<0.001
Eating out (times/wk)			<0.001			<0.001
≥5	94.9%	68.3%		95.2%	67.3%	
3–4	2.2%	19.4%		2.7%	18.6%	
≤2	2.8%	12.3%		2.2%	14.2%	

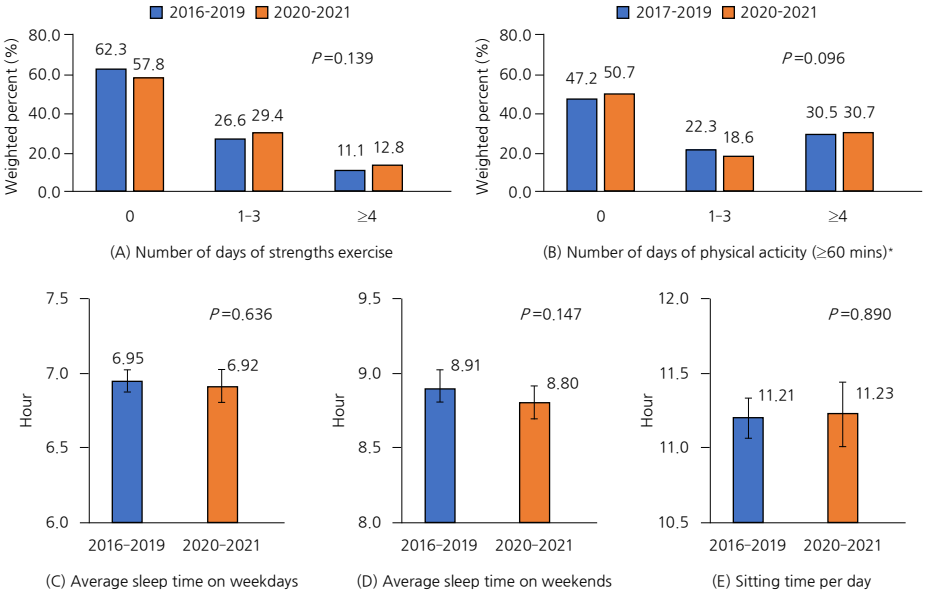

Fig. 2. Comparison of exercise and lifestyle. (A, B) The number of strength training days and days with physical activity ≥60 minutes were compared before and during the COVID-19 pandemic. (C–E) Durations of sleep and inactivity were compared before and during the COVID-19 pandemic. Values are presented as means with confidence intervals. COVID-19, coronavirus disease 2019. *Information on physical activity for more than 60 minutes was not available before 2016.

Physical activity tended to decline in both the number of strength training days per week and the number of days active for at least 60 min/day. The average sleeping time on weekdays and weekends and the duration of inactivity remained unchanged during the COVID-19 pandemic. The results are shown in Fig. 2.

Discussion

The results of this study revealed that the prevalence of childhood obesity and overweight continued to increase before and during the COVID-19 pandemic. The observed increase in the prevalence of overweight/obesity among Korean adolescents from 2018–2021 is consistent with previous epidemiological studies on trends in pediatric obesity[2,9] and reports indicating a surge in obesity among Korean children during the COVID-19 pandemic.[10]

Although obesity is not always metabolically unhealthy, those classified as MHO are at risk of MUHO.[9,11] In 2020–2021, the prevalence of MUHO significantly increased, whereas the prevalence of MHNW decreased. Taken together, these findings indicate that Korean adolescents have become increasingly obese and unhealthy during the COVID-19 pandemic.

The prevalence of diabetes in children and adolescents is gradually increasing.[12] When comparing metabolic factors before and during the COVID-19 pandemic, we found that obesity influenced the increasing trend in prediabetes; however, there were no significant changes in other factors

except 6.5%>HbA1c≥5.7%. Most of the data used in this study was FBS (99.8% of the total). However, since postprandial hyperglycemia serves as an early indicator of insulin resistance and overweight,[13] lack of data on postprandial blood glucose level may affect the results of this study. This may explain why dysglycemia was not high in this study. In addition, considering that the definition of diabetes includes not only FBS ≥126 mg/dL and/or HbA1c ≥6.5% but also random glucose ≥200 mg/dL with symptoms and glucose level ≥200 mg/dL after a two-hour 75 g oral glucose tolerance test, the prevalence of diabetes may be underestimated.

Insulin resistance is a key factor in metabolic syndrome, and blood free fatty acids (FFA) contribute to its early development by stimulating glucose, TG, and very-low-density lipoprotein production in the liver. Our study of obese children and adolescents showed increasing TG and HbA1c levels, along with decreased HDL-C levels, which may lead to other metabolic issues. In addition, as adipose tissue increases, pro-inflammatory cytokines also rise,[14] contributing to insulin resistance. During the COVID-19 pandemic, we observed a trend of increased homeostatic model assessment for insulin resistance level >2.0 in all participants, irrespective of obesity or normal weight groups. Moreover, the prevalence of TG-glucose index ≥8.45[15] also increased, particularly in 2020.

Our study revealed a strong correlation between BMI and central obesity in parents and their children, especially in the elementary school aged group, as children are heavily influenced by their parents. During the COVID-19 pandemic, as the frequency of eating with family members increased, the influence of families on their children strengthened. Previous studies have shown that children with overweight/obese parents exhibited unhealthy dietary and lifestyle habits,[16] wherein the higher was the mother's BMI, the higher was the child's BMI.

Moreover, physical activity decreased, leading to longer periods of sitting.[17] Unhealthy BMI in children has also been associated with increased screen use[5,18] and reduced fruit consumption.[19] These findings support the notion that parental BMI reflects health habits, which affect the child's health habits and weight status.[20] Therefore, family counseling is thought to be more effective to treat obese children, and a family centered healthy life, including diet and physical activity, should be emphasized, especially in younger children. However, this correlation was not significant in the middle school and high school aged groups, possibly because the influence of parents on their children's behavior decreased as the children matured and became more independent[21]. Furthermore, school programs[22] and peer[23] influence can also affect behavior and BMI status in older children. Therefore, adolescents may require a distinct approach that encompasses a wider range of aspects.

It is well-known that reduced fruit and vegetable intake leads to obesity.[2,19] Kim et al.[24] reported a decrease in fruit intake among 12–18-year-olds during the COVID-19 pandemic; however, our study did not identify any significant changes in the intake of fiber or vitamins, which are abundant in these foods. It was confirmed that the intake of niacin, folic acid, and vitamin C was lower than the recommended intake presented in the Dietary Reference Intakes for Koreans in 2020[8] among middle and high school students. Since niacin is known to inhibit TG synthesis and reduce HDL-apoA-I catabolism, reduced niacin intake may play a role in the increasing dyslipidemia in children and adolescents. Folic acid level showed a significant positive correlation with HDL-C and a significant negative correlation with TG.[25] Thiamine is an essential trace element for glucose metabolism, and doubling the daily thiamine intake was significantly associated with a 7% reduction in metabolic syndrome among adults with comorbidities.[26] Folic acid supplementation could protect against obesity and prevent obesity-related complications, such as insulin resistance, and cardiovascular and metabolic disorders.[27] Vitamin C has an antioxidant effect that removes free radicals, which can play a role in improving vascular endothelial dysfunction caused by increased free radicals, owing to paracrine effects in the adipose tissue.[28] Therefore, reduced fruit and vegetable intake may have been responsible for the increased prevalence of obesity during the COVID-19 pandemic due to the reduced intake of vitamins. However, excessive vitamin B intake may contribute to obesity,[29] and high-dose vitamin C does not improve endothelial dysfunction or insulin resistance,[30] and further research is needed into the link between reduced trace element intake and obesity.

According to a previous meta-analysis, skipping breakfast increases the risk of overweight/obesity,[31] and adolescents who regularly eat breakfast have lower body fat.[32] We discovered that the proportion of people who skipped breakfast increased during the COVID-19 pandemic, particularly in the obese group. There are several reasons that skipping breakfast can lead to obesity. Eating breakfast can positively impact obesity by disrupting long-term fasting, regulating glucose homoeostasis and insulin sensitivity[33] and enabling greater physical activity thermogenesis in the morning.[34] While breakfast helps maintain more stable afternoon and evening glycemia than fasting, skipping breakfast leads to increased postprandial hyperglycemia after lunch and dinner,[34] which is associated with insulin resistance, leading to obesity. Postprandial hyperglycemia and insulin resistance can result in increased food intake by increasing insulin and FFA levels and hunger and decreasing satiety.[35] Previous studies have shown conflicting findings on the association between skipping breakfast and overweight,[36] with some suggesting that skipping dinner, not breakfast, may be a predictor of weight gain and overweight/obesity.[37] However, based on our results, it can be inferred that the social influence of COVID-19 affected the frequency of eating breakfast and the occurrence of pediatric obesity. Therefore, additional research is necessary to clearly understand the mechanisms underlying the correlations between eating habits and physiological changes.

Changes in physical activity duration did not decrease significantly in our study, which is presumed to be due to the limited availability of detailed physical activity data for KNHANES. However, in a 2019–2020 comparative study using the Adolescent Health Behavior Survey,[10] sleep time decreased and inactivity increased. Many other studies have also reported a correlation between lifestyle habits such as sedentary behavior

or screen time[5,18] and obesity.

Although this study was conducted using nationwide survey data, it had some limitations. First, the cross-sectional data only allowed evaluation of changes in prevalence and associations among parents; hence, it remains unknown which group was reclassified into MUHO based on annual changes in health status in the same person, and evaluation of long-term child health status was not possible. Second, a fixed cut-off of 130/85 mmHg was applied to the criteria for high BP regardless of age, gender, and height. Third, during the COVID-19 pandemic, social restrictions led to increased food consumption through delivery or take-out. Without consideration of these details, the evaluation of eating habits and food quality before and during the pandemic may not be accurate.

Nevertheless, this study has the strengths of being a multifaceted study of obesity and metabolic syndrome-related indicators in a special COVID-19 environment. Metabolic diseases are not simply caused or controlled by a single factor but are complex phenomena that occur through various mechanisms. This study was meaningful since it investigated factors across age, sex, socioeconomic status, physical activity, lifestyle, parental health status, nutrition, and dietary habits.

In conclusion, obesity in children and adolescents is sensitive to the social environment, and MUHO increased during the COVID-19 pandemic. Attention should be paid during childhood to improve children's health indicators. Age-specific strategies that consider growth, development, and genetic and social factors are required. Furthermore, health strategies targeting the entire family are required to develop healthier habits to ensure that overweight/obesity or unhealthy behaviors are not passed on from parents to offspring. Efforts toward developing healthy habits will ultimately help improve children's health. Further longitudinal studies are needed to explore factors associated with metabolic health and long-term outcomes.

Notes

Supplementary materials: Supplementary Tables 1–7 can be found via https://doi.org/10.6065/apem.2346094.047

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