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Pediatric Obesity in the Post-pandemic Era: A Narrative Review of Trends, Setbacks, and New Interventions

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Abstract

The COVID-19 pandemic has significantly disrupted global efforts to combat pediatric obesity, exacerbating pre-existing trends and creating new public health challenges. This review overviews current evidence on the pandemic's impact, highlighting the urgent need to understand its lasting consequences on child and adolescent weight status. A critical appraisal of emerging data is essential to inform effective post-pandemic intervention strategies and policies. This review examines the alarming epidemiological trends and post-pandemic setbacks in pediatric obesity rates, including sustained increases in body mass index (BMI) and the rising prevalence of severe obesity. We analyze the key behavioral, environmental, and socioeconomic factors driving these trends, such as increased sedentariness and dietary changes. The overview of recent clinical studies from various countries provides a detailed account of BMI changes and metabolic complications. Furthermore, we evaluate existing public health interventions, from school-based programs to policy initiatives, and assess their effectiveness in the current landscape. The review also explores emerging interventions, including the role of telehealth and integrated care frameworks. Finally, we discuss the critical integration of mental health support within obesity management strategies. Future directions must prioritize the development of equitable, multi-sectoral strategies that address the complex social determinants of health. Research should focus on long-term outcomes of novel interventions, their cost-effectiveness, and scalability across diverse populations. Sustained commitment to adaptive policies and robust monitoring systems will be vital to reversing these trends and safeguarding the health of future generations.

Keywords: Behavioral factors, Body mass index, COVID-19, Pediatric obesity, Post-pandemic, Public health interventions, Socioeconomic disparities, Telehealth

Introduction

COVID-19 pandemic has markedly influenced pediatric obesity, with multiple studies highlighting a concerning rise in obesity rates among children and adolescents during and after the pandemic era [1-8]. The pandemic's impact on pediatric health, particularly in the context of obesity, has multifaceted, involving behavioral, healthcare delivery, and policy-related factors. One of the primary observations across literature is the significant increase in BMI among children during the pandemic period [9-14]. According to a longitudinal study examining trends before and during the pandemic, children aged 2 to 19 who were already overweight or obese experienced a more rapid increase in BMI during the pandemic compared to pre-pandemic times [15]. This suggests that the pandemic exacerbated existing trends of pediatric obesity, possibly due to lifestyle changes such as reduced physical activity and altered dietary habits. Supporting this, a systematic review covering a 6-year period found that post-pandemic data continues to reflect elevated obesity prevalence, indicating that the surge observed during the pandemic has persisted into the post-pandemic era [16].

The persistence of increased obesity rates post-pandemic is further corroborated by regional studies. For instance, in Central Indiana, the spike in childhood obesity observed during the pandemic has not significantly reversed, with trends through 2023 showing sustained high prevalence rates [17]. This persistence underscores the challenge of reversing pandemic-induced health behaviors and highlights the need for targeted intervention strategies. Behavioral factors during the pandemic played a crucial role in influencing pediatric obesity [18-25]. Lockdowns, school closures, and social distancing measures led to decreased physical activity levels among children, coupled with increased sedentary behaviors such as screen time. These behavioral shifts contributed to weight gain and the development of obesity-related complications. The importance of addressing these behavioral factors is emphasized in studies that advocate effective policy interventions to mitigate BMI increases and prevent long-term health consequences [10].

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Healthcare delivery adaptations during the pandemic, notably the increased utilization of telemedicine, have also impacted pediatric obesity management [26-33]. Telehealth emerged as a valuable tool for delivering nutritional counseling and behavioral interventions remotely, ensuring continuity of care despite restrictions on in-person visits [29]. While telehealth has facilitated ongoing management, its effectiveness in reversing obesity trends remains an area for further research, especially considering disparities in access and engagement. The pandemic has also been associated with a rise in severe obesity and metabolic complications among children. An outbreak of severe obesity cases with accompanying metabolic issues has been documented, indicating that the pandemic may have contributed not only to increased prevalence but also to the severity of pediatric obesity [34]. This trend raises concerns about the long-term health implications for affected children, including increased risks for type 2 diabetes, hypertension, and other metabolic disorders.

Public health implications are profound, as the pandemic has highlighted vulnerabilities in pediatric health systems concerning obesity prevention and management [35-42]. The need for effective policy interventions is urgent, especially considering that the increase in BMI and obesity prevalence has shown signs of persistence beyond the pandemic period [10]. Strategies such as promoting physical activity, improving nutritional environments, and leveraging telehealth for behavioral interventions are critical components of a comprehensive approach. In addition to physical health concerns, the pandemic's broader impact on pediatric health services has included challenges in early diagnosis and management of obesity-related conditions. The shift towards telemedicine, while beneficial, also underscores disparities in healthcare access, which may hinder equitable management of pediatric obesity in the post-pandemic era [43].

In summary, the post-pandemic landscape of pediatric obesity is characterized by a sustained increase in prevalence, severity, and associated metabolic complications. The pandemic has underscored the importance of multifaceted intervention strategies, including behavioral, clinical, and policy-level approaches, to address this growing public health concern. Continued research and targeted policies are essential to reverse these trends and promote healthier outcomes for children in the post-pandemic era.

Epidemiological Trends and Post-pandemic Setbacks

Recent systematic reviews and epidemiological studies underscore a troubling rise in pediatric obesity rates during and after the pandemic period [44-50]. According to the systematic review by Koliaki et al. [51], there has been a notable increase in obesity prevalence among children, with data from Ireland indicating a rise in obesity rates post-2012, suggesting that the pandemic may have exacerbated existing trends. Similarly, the review by the Lee [52] study reports that in the United States, the average weight of children increased by more than 5 kg during recent years, with approximately one-third of children now classified as overweight or obese. These findings point to a widening gap in childhood weight issues, which is consistent across different regions. The global perspective provided by the World Health Organization based analysis reveals that changes in body weight and obesity prevalence are not isolated phenomena but part of a broader, persistent pandemic. The narrative review on the 'War on Obesity' emphasizes that despite ongoing efforts, the prevalence of overweight and obesity continues to rise, challenging the effectiveness of current strategies [53]. The post-pandemic period appears to have intensified these trends, with disruptions in routine physical activity, dietary patterns, and healthcare access contributing to the setbacks.

Pandemic-induced trends in pediatric obesity

- Increased obesity rates: During the pandemic, obesity rates among children increased significantly. For instance, a study found that obesity rates rose from 12.8% pre-pandemic to 15.4% during the pandemic, with a slight decrease to 15.0% post-pandemic [10]. Another study reported an 88.5% increase in obesity rates during the pandemic in Austria, reaching a peak of 15.2% during restrictions [54]. In China, the COVID-19 lockdown led to a 1.86% increase in obesity prevalence in 2020, with primary and junior middle school children being most affected [55]. In Germany, severe obesity peaked in 2021, particularly among adolescents, and while younger children returned to pre-pandemic levels by 2023, older children, especially girls, continued to experience elevated weight levels [56].

- BMI increases: The pandemic saw a substantial increase in BMI-standard deviation scores across all age groups and socioeconomic positions, with the most significant increases observed in children who were already overweight or obese [10, 57].

- Behavioral changes: Contributing factors included increased sedentary behavior, decreased physical activity, and changes in dietary habits, such as higher consumption of unhealthy foods [58].

Post-pandemic setbacks

- Sustained high obesity levels: Despite some recovery post-pandemic, obesity levels have not returned to pre-pandemic levels. For example, while some studies noted a return to pre-pandemic obesity levels by December 2022, disparities and high BMI-standard deviation scores persisted in certain groups [54, 59].

- Challenges in weight management: Obese children continued to gain weight post-pandemic, indicating a need for targeted interventions. The lack of normalization in weight among obese children suggests that pandemic-related weight gain has long-term implications [54].

- Psychological impact and sleep dysregulation: The pandemic's psychological impact, including increased stress and anxiety, contributed to sleep dysregulation in children. Poor sleep quality is associated with weight gain and obesity, as it affects metabolism and appetite regulation [58]. The mental health challenges faced by children during the pandemic underscore the importance of addressing psychological well-being as part of obesity prevention efforts [58].

- Long-term consequences and need for intervention: The increase in pediatric obesity rates during the pandemic has long-term health implications, including a higher risk of hypertension, diabetes, and other obesity-related conditions [60, 61]. Effective policy interventions are

crucial to prevent further escalation of pediatric obesity rates. These interventions should focus on promoting physical activity, improving dietary habits, and addressing socioeconomic disparities [10, 62].

In summary, while the pandemic has highlighted and exacerbated the issue of pediatric obesity, it has also underscored the need for effective interventions and policies to address this public health challenge. The persistence of high obesity rates post-pandemic, particularly among vulnerable groups, calls for comprehensive strategies that include education, nutrition, and family support to mitigate the long-term effects of the pandemic on childhood obesity. Additionally, the pandemic has revealed the importance of addressing sociodemographic disparities to ensure equitable health outcomes for all children.

Causes and Contributing Factors

The causes of pediatric obesity are multifaceted, involving behavioral, environmental, and socioeconomic factors (Table 1) [63-68]. The review by Jebeile et al. [37] highlights that the epidemiology of childhood obesity is influenced by a complex interplay of these elements, including decreased physical activity, increased sedentary behaviors, and dietary shifts towards high-calorie, low-nutrient foods. The pandemic further amplified these factors by restricting outdoor activities and increasing screen time, which are associated with weight gain in children. Moreover, the literature indicates that health disparities and inequities have played a significant role in the pandemic's impact on childhood obesity. The systematic review on telemedicine by Haimi [69] discusses how the rapid shift to remote healthcare delivery, while beneficial in maintaining some level of care, may have inadvertently worsened health inequities, especially among vulnerable populations. This suggests that the pandemic not only increased obesity prevalence but also highlighted existing disparities in access to effective prevention and treatment.

- Sedentary lifestyle and physical inactivity: The pandemic restrictions led to a significant reduction in physical activity among children, as schools and sports activities were suspended, and children spent more time indoors [54, 70]. Increased screen time due to online classes and entertainment further contributed to a sedentary lifestyle, which is a known risk factor for obesity [70].

- Dietary changes and eating habits: The pandemic altered family food environments, leading to increased consumption of high-calorie, low-nutrient foods. This change was driven by stress, convenience, and limited access to healthier options [58]. Emotional eating due to stress and anxiety during the pandemic also contributed to weight gain in children [70].

- Socioeconomic and demographic factors: Children from lower socioeconomic backgrounds were disproportionately affected, as they had less access to resources that promote healthy lifestyles, such as safe outdoor spaces and organized sports [10, 54]. Ethnic disparities were noted, with certain groups experiencing higher rates of obesity, highlighting the need for culturally sensitive interventions [71].

- Psychological and emotional impact: The pandemic has had a profound impact on children's mental health, with increased rates of anxiety and depression. These psychological factors can lead to unhealthy eating patterns and reduced motivation for physical activity [58]. Social isolation and the disruption of routines contributed to emotional distress, which is linked to weight gain [70].

- Long-term health implications: Pediatric obesity is associated with a range of health issues, including type 2 diabetes, cardiovascular diseases, and psychological disorders. The pandemic has potentially accelerated the onset of these conditions in children [72]. The persistence of increased BMI levels post-pandemic suggests that the effects of the pandemic on pediatric obesity may have long-lasting consequences [54].

While the pandemic has undoubtedly exacerbated pediatric obesity, it is important to consider that obesity is a multifactorial condition influenced by genetic, environmental, and behavioral factors. The pandemic highlighted existing vulnerabilities and disparities, but these issues were present before COVID-19. Addressing pediatric obesity requires a comprehensive approach that includes policy interventions, community support, and family engagement to promote healthy lifestyles and mitigate the long-term impacts of the pandemic on children's health.

Clinical Studies

The COVID-19 pandemic has had a significant impact on pediatric obesity, with various studies highlighting an increase in obesity rates among children during and after the pandemic. The pandemic-induced lifestyle changes, such as reduced physical activity and increased screen time, have exacerbated the issue, leading to a persistent rise in obesity rates even in the post-pandemic era. This section will explore the findings from several studies on pediatric obesity in the post-pandemic period, focusing on changes in BMI and socioeconomic factors.

A longitudinal study by Shalitin et al. [10], which analyzed electronic medical data from 106,871 children, revealed significant changes in BMI and obesity rates during and after the COVID-19 pandemic. The findings highlight persistent effects on pediatric weight status even in the post-pandemic period. The obesity rate in the pediatric population increased from 12.8% pre-pandemic to 15.4% during the pandemic. Post-pandemic, the obesity rate slightly decreased to 15.0% but remained elevated compared to pre-pandemic levels. BMI-standard deviation scores increased

Table 1: Primary contributing factors to the rise in pediatric obesity during and after the pandemic.

Category	Specific factor	Impact on pediatric obesity
Behavioral	Reduced physical activity	Closure of schools and sports clubs eliminated structured activity, leading to a more sedentary lifestyle
	Increased screen time	Shift to online learning and leisure increased sedentary behavior and exposure to food marketing
	Dietary changes	Increased consumption of ultra-processed, high-calorie foods and sugary drinks; more frequent snacking
Socioeconomic	Low socioeconomic status	Disproportionate impact due to limited access to healthy food, safe outdoor spaces, and digital resources
	Parental education	Lower parental education level was associated with higher child BMI and less protective effect during lockdowns
Psychological	Stress and anxiety	Pandemic-related stress led to emotional eating and disordered eating patterns in children and adolescents
	Sleep dysregulation	Disruption of routines and increased stress worsened sleep quality, negatively affecting metabolism and appetite hormones

significantly during the pandemic across various demographic groups, including both sexes, all age groups, all socioeconomic position clusters, and in children who were underweight or had normal weight pre-pandemic (all $p < 0.001$). While BMI-standard deviation scores decreased post-pandemic, it did not return to pre-pandemic levels. This persistence was particularly noted in younger children (aged 2 to 6 years) and those from low/medium socioeconomic position clusters (all $p < 0.001$). In contrast, BMI-standard deviation scores continued to increase post-pandemic in certain subgroups, specifically children aged 6.1 to 16 years, those of Arab ethnicity, and individuals in the high socioeconomic position cluster. The study concluded that the COVID-19 pandemic was associated with an overall increase in BMI-standard deviation scores. Although there was a subsequent decrease in post-pandemic, the scores generally remained above pre-pandemic levels, underscoring the need for effective policy interventions to prevent pediatric obesity.

A study by Yang et al. [55] analyzed data from 656,396 children aged 3 to 19 across China between January 2017 and April 2021. This included 447,481 hospital-measured cases and 208,915 parent-reported cases. The mean age of the study population was 7.22 ± 3.18 years. Girls generally had a higher BMI z-score than boys (0.20 ± 1.30 vs 0.15 ± 1.33, $p < 0.0001$). However, BMI z-score distribution varied by age group; boys had higher scores in the 3 to 5 age group, while girls had higher scores in the 6 to 8, 9 to 11, and 12 to 14 age groups (Figure 1). No significant difference was observed for adolescents aged 15 to 19. According to Chinese standards, the standardized prevalence of obesity in the study population was 8.05% (95% confidence interval (CI) 7.76% to 8.39%), and obesity/overweight combined was 19.19% (95% CI 18.73% to 19.70%). These figures were comparable to those from China National Nutrition Surveys conducted between 2015 to 2019. Boys showed a higher standardized prevalence of obesity (9.03% (95% CI 8.65% to 9.46%)) compared to girls (6.91% (95% CI 6.46% to 7.47%)). Geographically, Northern China exhibited the highest standardized obesity prevalence (10.85% (95% CI 9.37% to 12.73%)), followed by the Northeast (9.48% (95% CI 8.98% to 10.04%)). The South (6.16% (95% CI 5.75% to 6.61%)) and Southwest (6.68% (95% CI 6.41% to 7.31%)) regions had the lowest prevalence. Obesity prevalence increased

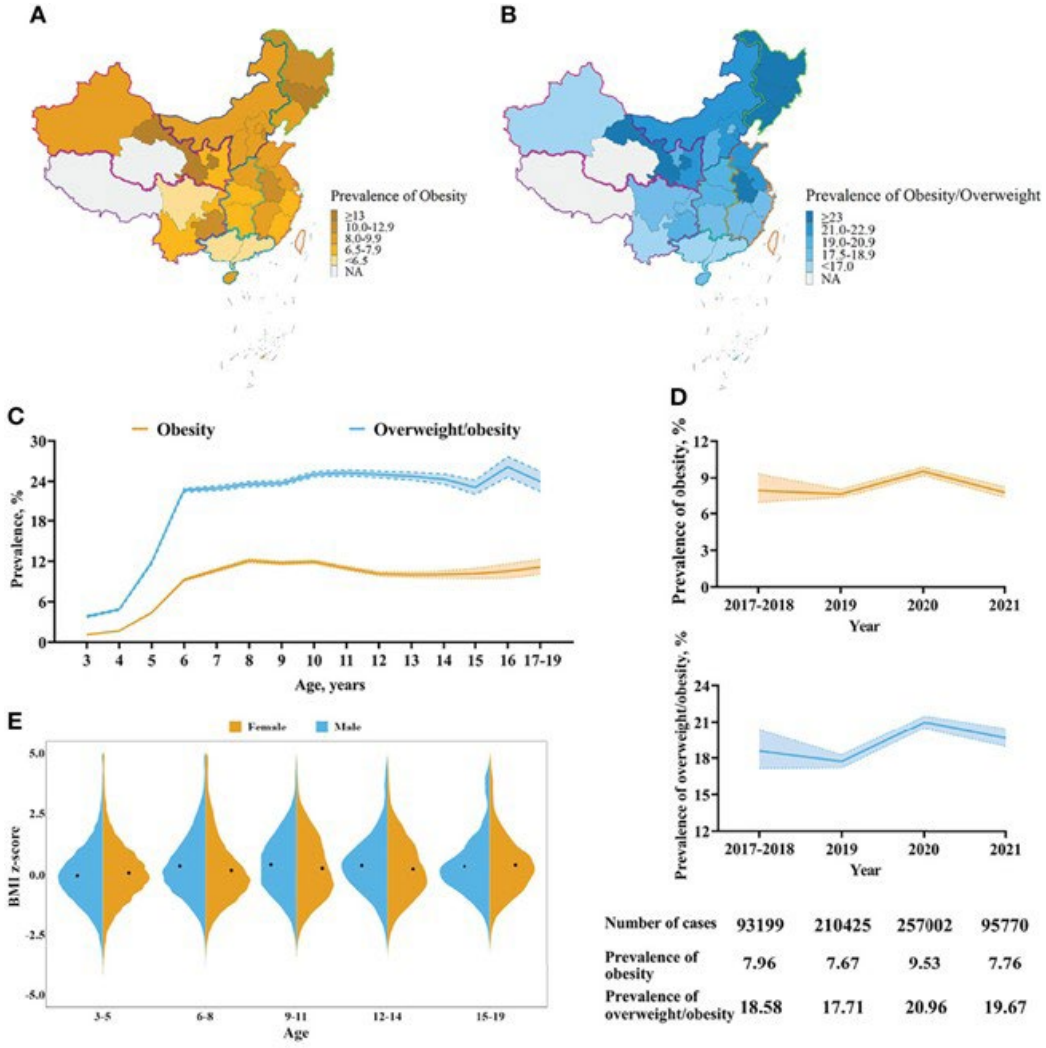

Figure 1: The analysis of standardized obesity and overweight prevalence and BMI z-score. **(A)** Illustrates the provincial distribution of standardized obesity prevalence. **(B)** Expands on this, showing the combined prevalence of both obesity and overweight by province. In both maps, prevalence rates were adjusted for sex and age, and data from Taiwan, Hong Kong, Macao, Tibet, and Qinghai were excluded. **(C)** Depicts the age-specific trajectories for the prevalence of obesity and overweight. **(D)** Displays the overall trends over time for these conditions, standardized for sex and age, with bands representing the 95% confidence interval. Finally, **(E)** presents the BMI z-score across different sexes and ages, where black points indicate the mean values for each group [55].

significantly after age four, peaked at age eight, then gradually declined between ages 9 to 14, and rose again at age 15. Despite a significant increase in 2020 due to COVID-19 lockdown, the prevalence of obesity and obesity/overweight among Chinese children showed a steadily decreasing trend overall. Compared to 2017 to 2018, the prevalence of obesity and obesity/overweight decreased by 0.26% and 0.87% respectively in 2019. Although it increased to 9.53% in 2020 (a 1.86% increase), the prevalence of obesity returned to 7.76% in the first 4 months of 2021, closely aligned with 2019 levels. The mean BMI z-score for children and adolescents increased over the 5 years, from 0.09 ± 1.35 in 2019 to 0.23 ± 1.34 in 2020, and further to 0.27 ± 1.23 in the first 4 months of 2021. COVID-19 lockdown led to significant BMI z-score increases, particularly among children aged 7 to 11 years (0.26 increase in the first half of 2020 compared to 2019) and adolescents aged 12 to 14 years (0.20 increase). Preschool children had a slight increase and then returned to previous levels. Children in the northeast region experienced the most weight gain in the first half of 2020, with central, north, and southwest regions also showing increases over 0.20. The north area showed continuous increases in BMI z-score for both preschool and school-aged children even after 2020. Parent-reported data from mobiles were found to be reliable for monitoring, with 92.3% of duplicate cases reporting the same BMI as hospital data. The differences in BMI for 4096 cases were within 0.20 (95.1%). While parent-reported data showed higher standardized obesity/overweight prevalence compared to hospital data, it could still reflect BMI changes during the pandemic. In summary, the study revealed that while pediatric obesity prevalence in China remained relatively stable with a slight downward trend from 2017 to 2021, the COVID-19 pandemic caused a significant but temporary increase in 2020. Regional and age-specific differences were noted, with northern China and school-aged children experiencing higher obesity rates and greater impact from the lockdown, respectively. Parent-reported mobile data was deemed a feasible and reliable method for monitoring pediatric growth.

A study by Moliterno et al. [73], focusing on 8 to 11-year-old schoolchildren in Vienna, examined trends in childhood obesity from 2017 to 2023, including the initial period of the COVID-19 pandemic. The percentage of obesity among the sampled schoolchildren increased from 23.5% in 2017 to 25.0% in 2023. Over the entire period (2017 to 2023), while overweight/obesity percentages decreased by 25.9%, obesity alone increased by 6.4%. Despite these changes, the observed trend was statistically non-significant ($p \geq 0.38$). During the first period of the COVID-19 pandemic, significant increases were noted. The percentage change in overweight/obesity was 68.4%. The percentage change in obesity alone during this period was 29.2%. The current percentage of obesity in this sample is considered high and peaked in 2020, coinciding with the pandemic. The study analyzed the BMI percentiles of 326 children, with an average age of 9.3 years (ranging from 8.0 to 10.9 years). Trend analysis utilized logistic regression, with overweight and obesity as dependent binary variables, and study year and age as independent continuous variables. These findings highlight a high current percentage of obesity in the sample, with a notable peak during the initial phase of the COVID-19 pandemic. The study emphasizes the need for further investigations to ensure representativeness of the broader school-aged population in Austria to gain a more comprehensive understanding of overweight and obesity trends.

A study by Berisha et al. [56] reported key findings on severe obesity trends in German youth (2002 to 2023). Severe obesity levels remained stable or declined until approximately 2010, with an odds ratio (OR) per 5 years (OR5) ranging from 0.8 to 1 ($p < 0.001$). After 2010, however, there was a significant increase in severe obesity, with OR5 values between 1.1 and 1.2 ($p < 0.001$). Older children and adolescents (12 to 16 years), this age group experienced a continuous increase in severe obesity throughout the pre-pandemic period. The rise was particularly pronounced in boys, with an OR5 of 1.3, compared to girls at an OR5 of 1.1 ($p < 0.001$). Across all age and sex groups, severe obesity peaked in 2021. The OR for severe obesity in 2021 compared to 2019 (OR21 vs 19) ranged from 1.3 to 1.7 ($p < 0.001$). While most prominent in the severe obesity groups, weight gain was also observed in pre-pandemic and pandemic overweight and obesity subgroups. This trend generally decreased towards the end of the pandemic. By 2023, children under 12 years of age had returned to their pre-pandemic severe obesity levels. In contrast, older children, especially girls aged 8 to 16 years, continue to exhibit higher weights compared to pre-pandemic levels. The OR for severe obesity in 2023 compared to 2019 (OR23 vs 19) was between 1.2 and 1.5 ($p < 0.001$ to 0.002) for these groups. In summary, the study revealed a long-term increase in severe obesity among German youth over two decades, with the COVID-19 pandemic significantly accelerating this trend. While younger children showed recovery by 2023, older children, particularly girls, continued to struggle with elevated excess weight.

A study by Emiroğlu et al. [74] included 191 children, with 55.5% being female and 44.5% male to evaluate childhood obesity rates and their underlying causes in İstanbul. A significant portion of families (60.2%) reported their income as less than their expenses, while 39.8% had income in balance with expenses. Health insurance coverage was high, with 95.3% of children covered. Maternal education levels indicated that 68.1% had primary education, 20.4% high school, and 11.5% university or above. Paternal education levels showed 57.1% with primary education, 24.1% high school, and 18.8% university or above. Most mothers (86.9%) were not working, while most fathers (96.3%) were employed. Regarding family size, 46.1% had 2 children, 31.9% had 3, and 14.1% had 4 or more. A small percentage (9.4%) of children had a long-term disease, and only 0.5% had a COVID-19 infection. The average age of mothers was 35.1 ± 5.8 years with an average BMI of 27.55 ± 4.8, while fathers' average age was 38.41 ± 5.7 with an average BMI of 27.26 ± 3.6. No significant relationship was found between parental BMI and children's BMI. Among the children studied, 36.6% (n = 70) were classified as obese or overweight, with an obesity prevalence of 23.3%. Of the obese and overweight children, 60% (n = 42) were female. There were no significant differences in BMI measurements between girls and boys. The mean BMI for children was 15.74 ± 1.81 in 2019, 15.81 ± 2.2 in 2020, and 16.70 ± 3.2 in 2021. The mean BMI in 2021 was significantly higher than in 2019 ($t = 47.24$; $p < 0.001$). The study found a statistically significant increase in overweight/obesity frequency from 2019 to 2021. Low paternal educational level ($p = 0.016$), eating three main meals more often ($p = 0.004$), and regular consumption of packaged food ($p = 0.034$) were significantly associated with being overweight or obese. Specifically, 40.6% of children with fathers who did not have a university degree or higher were in the high BMI group, compared to 19.4% for those with highly educated fathers. 88.6% of children who ate 3 main meals daily were in the high BMI group, versus 11.4% of those who did not. For packaged food consumption, 98.6% of children who regularly consumed packaged food were in the high BMI group, compared to 1.4% of those who did not. 8.9% (n = 17) of the children had chronic diseases such as thalassemia, allergic asthma, and congenital heart disease. 46.3% of children started consuming packaged foods after age 2, and 39.2% started after age 1. On average, children spent 1.83 ± 1.45 h per day watching television and 2.59 ± 2.05 h using tablets. In summary, the study revealed a concerning increase in childhood obesity among six-year-old children in İstanbul during the COVID-19 pandemic, with significant associations found between obesity and paternal education level, meal frequency, and

packaged food consumption. The findings highlight the need for public health interventions to promote physical activity and address behavioral factors influencing childhood obesity.

A study by Lange et al. [15] reported key findings on BMI trends during the COVID-19 pandemic in United States (2018 to 2020). During the COVID-19 pandemic, the monthly rate of increase in BMI nearly doubled compared to the pre-pandemic period. Specifically, the rate of BMI increase went from 0.052 kg/m^2/month pre-pandemic to 0.100 kg/m^2/month during the pandemic, representing a ratio of 1.93. This acceleration in BMI increase was observed in a longitudinal cohort of 432,302 individuals aged 2 to 19 years. The estimated proportion of people aged 2 to 19 years with obesity also increased significantly during the pandemic. For instance, the proportion of individuals with obesity in this cohort rose from 19.3% in August 2019 to 22.4% in August 2020. The rate of change in the proportion of people with obesity during the pandemic was 5.3 times higher than before the pandemic (0.37 percentage points per month versus 0.07). Individuals who were at a healthy weight pre-pandemic experienced a BMI increase rate of 0.03 kg/m^2/month during the pandemic, which was 1.78 times higher than their pre-pandemic rate. Persons who were already overweight or had moderate to severe obesity before the pandemic saw their rates of BMI increase more than double. For those with overweight, the rate ratio was 2.13; for moderate obesity, it was 2.34; and for severe obesity, it was 2.00. These groups also experienced significant increases in weight gain, with those having moderate or severe obesity gaining an average of 1.0 and 1.2 pounds per month, respectively, during March to November 2020. This accelerated weight gain could lead to long-lasting metabolic changes and increased risk for conditions like type 2 diabetes, hypertension, and depression. Children (6 to 11 years), this age group experienced the largest increase in their rate of BMI change, with a pandemic rate 2.50 times higher than their pre-pandemic rate (0.09 kg/m^2/month). Younger children (3 to 5 years), similar to the 6 to 11 age group, children aged 3 to 5 years also showed an increased difference in the rate of BMI change, particularly with increasing initial BMI category. Adolescents (12 to 17 years), this group also saw an increase in BMI change, with a pandemic rate ratio of 1.48. Older adolescents (18 to 20 years): In contrast, this group showed a decrease in the rate of BMI change during the pandemic compared to pre-pandemic, with a ratio of 0.70. The longitudinal cohort comprised 432,302 individuals, with 50.7% male and 65.7% White. Geographically, 45.7% were from the South. Based on initial BMI, 16.1% of the cohorts had obesity, including 4.8% with severe obesity. In summary, the study highlights a significant acceleration in BMI increase and obesity prevalence among children and adolescents during the COVID-19 pandemic, with those already overweight or obese and younger school-aged children experiencing the most substantial changes. These findings underscore the critical need for continued efforts in obesity prevention and management.

A study by Irschik et al. [54] investigated the impact of COVID-19 restrictions on pediatric BMI and weight development in Austria, focusing on changes during and after the pandemic, as well as the influence of socioeconomic factors. The rate of obesity among children increased substantially during the pandemic, rising by 88.5% from 6.4% to 12.1%. This rate peaked at 15.2% during the period of strict restrictions. Overall, age-adapted BMI z-scores showed a significant increase of 0.22 during the restrictions. Even after restrictions were lifted, these BMI z-scores remained elevated by 0.19 compared to pre-pandemic levels. Following the lifting of restrictions, most children in the study population experienced significant weight loss. However, children who were obese prior to or during the pandemic did not show any weight loss; instead, they continued to gain weight without any signs of normalization. Socioeconomic factors, such as participation in organized sports or the availability of outdoor areas, were associated with differences before the pandemic. Despite their prior relevance, these factors offered no protective effect against weight gain during the pandemic. The only socioeconomic factor found to be associated with less weight gain in children during the early phase of the pandemic was a higher level of parental education. In summary, the COVID-19 pandemic and associated restrictions led to a concerning increase in pediatric BMI and obesity rates in Austria. While many children experienced some weight loss after restrictions eased, obese children continued to gain weight, highlighting their particular vulnerability. Socioeconomic factors generally had little protective effect against intra-pandemic weight gain, with parental education being a notable exception.

A study by Rose et al. [75], which longitudinally examined the entire population of Israel, revealed a significant increase in the prevalence of pediatric overweight and obesity during 2020 and 2021. This increase followed a period where the prevalence had been stable or even improved through 2019. Among 7-year-olds, the percentage of children classified as obese rose from 6.8% in 2019 (with a 99% CI of 6.69 to 7.05) to 7.7% in 2021 (with a 99% CI of 7.53 to 7.93). This increase effectively 'erased the improvements of the previous years' for younger children. Significant disparities in overweight and obesity existed based on socioeconomic status. For instance, in 2019, the rate ratio for obesity compared to the poorest 14 to 15 years old with the wealthiest was 1.63 (99% CI 1.55 to 1.72). However, these disparities did not change significantly in 2020 and 2021, indicating that the overall increase in prevalence was not disproportionately distributed across different socioeconomic groups. The study utilized a longitudinal design, analyzing data for the entire Israeli population, which comprises approximately 9 million people. It assessed the proportion of underweight, normal weight, overweight, and obesity at ages 7 and 14 to 15 across the years 2017 to 2021. In summary, the paper concludes that Israel, similar to many other nations, experienced a considerable rise in pediatric overweight and obesity during the COVID-19 period of 2020 - 2021, reversing prior positive trends, although existing socioeconomic disparities in obesity prevalence did not widen during this time.

A study by Choi et al. [76] reported key findings on obesity and metabolic syndrome during COVID-19 in South Korea. Youth aged 2 to 9 years, the mean BMI significantly increased from 16.53 kg/m^2 in 2019 to 17.1 kg/m^2 in 2020 ($p < 0.01$). Youth aged 10 to 18 years: A slight increase in BMI was observed, from 21.25 kg/m^2 in 2019 to 21.41 kg/m^2 in 2020, though this was not statistically significant ($p = 0.64$). Children aged 2 to 9 years, the prevalence of obesity increased in 2020 compared to 2019, with a notable rise among girls ($p < 0.01$) (Figure 2). The prevalence of extreme obesity in this age group also increased significantly in girls ($p < 0.01$). Adolescents aged 10 to 18 years, while there was no overall increase in obesity prevalence, severe obesity increased, particularly among boys ($p = 0.08$). The overall prevalence of metabolic syndrome in adolescents (10 - 18 years) increased significantly from 3.79% to 7.79% during the COVID-19 pandemic ($p = 0.01$). Specific component changes (10 to 18 years): Diastolic blood pressure increased from 66.78 mmHg to 68.56 mmHg ($p = 0.02$), triglycerides increased from 75.52 mg/dL to 83.97 mg/dL ($p < 0.01$), and high-density lipoprotein-cholesterol decreased from 52.62 mg/dL to 51.42 mg/dL ($p = 0.09$). Abdominal obesity: Waist circumference in 6 to 9-year-old children increased from 57.67 cm in 2019 to 59.04 cm in 2020 ($p = 0.05$). The proportion of abdominal obesity (waist circumference > 90th percentile) in this group also rose from 12.08% to 17.23% ($p = 0.09$). Sex-specific metabolic syndrome changes (10 to 18 years), boys, the

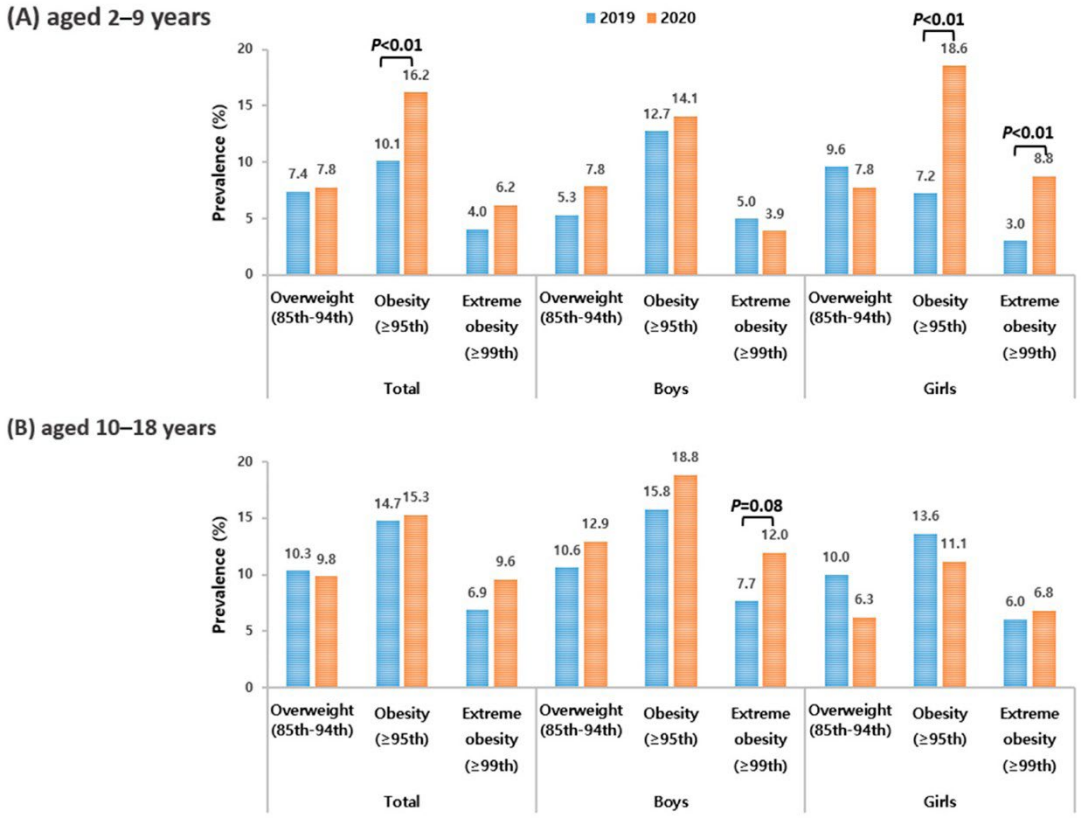

Figure 2: Prevalence of overweight, obesity, and extreme obesity in South Korean children and adolescents aged 2 to 19 years, comparing periods before and after the onset of the COVID-19 pandemic. **(A)** Presents data for children aged 2 to 9 years, and **(B)** for those aged 10 to 18 years. All values are presented as weighted percentages [76].

prevalence of metabolic syndrome increased significantly from 4.58% to 9.47% (p = 0.02). Abdominal obesity also significantly increased from 12.52% to 19.83% (p = 0.02). Girls, diastolic blood pressure significantly increased from 65.91 mmHg to 68.29 mmHg (p = 0.02). Triglyceride values increased from 74.92 mg/dL to 87.9 mg/dL (p < 0.01). Overall energy intake for 10 to 18-year-olds decreased significantly from 2016.15 kcal in 2019 to 1910.08 kcal in 2020. However, other macronutrient intakes showed no significant difference. No significant differences were observed in physical activity, stress, and sleep time before and after the COVID-19 outbreak. In summary, the study revealed a significant increase in obesity and metabolic syndrome prevalence among Korean children and adolescents following the COVID-19 outbreak, particularly affecting younger children's BMI and specific metabolic syndrome components in adolescents, with notable sex-specific differences. These changes are considered a serious public health concern due to their potential long-term health implications.

While the pandemic has undeniably exacerbated pediatric obesity, it is essential to consider the broader context of childhood obesity as a global health issue. The pandemic has highlighted the need for effective interventions and policies to address this growing concern. However, it is also important to recognize that obesity is a complex issue influenced by various factors, including genetics, environment, and individual behaviors. Addressing pediatric obesity requires a multifaceted approach that considers these diverse influences and involves collaboration among healthcare providers, families, and policymakers.

Public Health Interventions and Monitoring

Efforts to combat pediatric obesity have included surveillance, policy initiatives, and clinical interventions. The European review by Chrissini and Panagiotakos [77] notes that surveillance and monitoring of childhood obesity, particularly in children under 5, remain inadequate and discouraging, indicating a need for more robust public health strategies. The importance of early intervention is emphasized, given that childhood obesity often tracks into adulthood, increasing the risk of chronic diseases. In the United States, clinical practice guidelines [78] provide evidence-based recommendations for the evaluation and treatment of pediatric obesity, focusing on both behavioral and medical interventions. These guidelines aim to standardize care and improve outcomes, but their implementation faces challenges, especially in the context of pandemic-related healthcare disruptions.

Intervention strategies

- Integrated frameworks: A comprehensive framework that combines physical therapy, nursing health education, and primary care coordination has been proposed to manage pediatric obesity effectively. This model emphasizes personalized physical therapy, culturally sensitive health education, and coordinated care to address comorbidities and ensure continuity of care [79].

- School-based interventions: Schools are pivotal in implementing obesity interventions. Programs that integrate physical activity with nutritional changes have shown to be more effective than either approach alone. These interventions not only reduce obesity rates but also improve cardiovascular health and self-efficacy among children [80].

- Community and family engagement: Engaging families and communities in obesity prevention efforts is crucial. Interventions that involve family members in promoting healthy eating and physical activity have demonstrated increased effectiveness. Community-based programs can create supportive environments that foster healthy behaviors [72].

- Public policy and environmental changes: Public health policies, such as imposing taxes on sugary drinks and regulating food marketing, can support obesity prevention efforts. These policies, when combined with educational campaigns, can significantly impact dietary behaviors and reduce obesity prevalence [72].

Monitoring and evaluation

- Key indicators: Monitoring childhood obesity interventions requires identifying relevant indicators (Table 2). A Delphi panel study highlighted the importance of indicators related to dietary environments, built environments, and health inequalities. These indicators help in evaluating the effectiveness of interventions and guiding policy decisions [81].

- Longitudinal studies and data collection: Long-term studies are essential for assessing the sustained impact of interventions. Randomized controlled trials and systematic reviews provide valuable data on the effectiveness of dietary and physical activity interventions over different time frames [82].

- Technology-enabled monitoring: The integration of technology into monitoring systems, such as telehealth and wearable devices, can enhance the tracking of physical activity and dietary habits. These tools facilitate real-time data collection and personalized feedback, improving intervention adherence [79].

In summary, while the outlined strategies and monitoring approaches offer promising avenues for addressing pediatric obesity, challenges remain. Socioeconomic and cultural barriers can hinder the implementation and effectiveness of interventions. Additionally, the variability in intervention outcomes across different settings and populations underscores the need for tailored approaches. Addressing these challenges requires sustained commitment from policymakers, healthcare providers, and communities to ensure equitable access to resources and support for all children.

Emerging Interventions and Future Directions

The literature suggests that traditional approaches may be insufficient to reverse the rising trend of pediatric obesity in the post-pandemic era. The narrative review on the 'War on Obesity' advocates for a shift towards more comprehensive, multi-sectoral strategies that address environmental and social determinants of health [53]. This includes promoting healthier food environments, increasing opportunities for physical activity, and integrating community-based programs. Furthermore, the impact of telemedicine and digital health tools has been explored as potential avenues for intervention. However, the review by Haimi [69] cautions that reliance on telehealth may inadvertently exacerbate health inequities if not carefully implemented. Therefore, future interventions should consider equitable access and culturally tailored approaches.

In addition, the broader context of mental health, as discussed in the systematic review by Kim et al. [83], indicates that mental health challenges, including stress and trauma from the pandemic, may influence obesity risk behaviors. Addressing mental health alongside physical health is thus crucial for effective prevention and management.

- Telehealth interventions: Telehealth has emerged as a promising tool for delivering pediatric weight management interventions, addressing barriers such as time, travel, and cost associated with in-person visits. Studies have shown high retention and satisfaction rates, although the reductions in BMI z-scores are often marginal. Future research should focus on improving the reporting of results, employing more rigorous study designs, and incorporating extended follow-up to better assess the clinical impact of telehealth interventions [84].

- Integrated frameworks: A comprehensive framework integrating physical therapy, nursing health education, and primary care has been proposed to manage pediatric obesity more effectively. This model emphasizes personalized physical therapy, culturally sensitive education, and coordinated care to manage comorbidities and ensure continuity. Implementation strategies include interdisciplinary communication, family-centered workshops, and technology-enabled monitoring systems, with future research needed to assess long-term outcomes and cost-effectiveness [79].

Table 2: Key indicators for monitoring and evaluating pediatric obesity interventions.

Indicator category	Specific indicator	Purpose/rationale
Anthropometric	BMI z-score	Tracks weight status relative to age and sex-specific norms; allows for longitudinal comparison
	Waist circumference	Assesses central adiposity, which is a key indicator of metabolic risk
Behavioral	Daily moderate-to-vigorous physical activity	Monitors achievement of recommended activity levels (e.g., ≥ 60 min/day)
	Daily screen time	Tracks sedentary behavior, a major modifiable risk factor
Clinical/metabolic	Blood pressure	Screens for hypertension, a common comorbidity of obesity
	Fasting lipids and glucose	Assesses metabolic health and risk for conditions like type 2 diabetes
Contextual	Family engagement	Measures participation rates in family-based programs, a predictor of success
	Food environment index	Evaluates community-level access to healthy food retailers

- Behavioral and family-based interventions: Family-based behavioral interventions have shown efficacy in reducing adiposity and cardiovascular risk factors in obese youth. These interventions are crucial for sustaining weight loss and improving long-term health outcomes [85]. The integration of motivational interviewing and self-directed goal setting has been explored, with mixed results, suggesting the need for more intensive lifestyle interventions to achieve significant BMI reductions [86].

- Pharmacotherapy: Pharmacologic treatments, such as Orlistat and Sibutramine, are considered for pediatric obesity, particularly in cases with severe comorbidities. However, the lack of insurance coverage and potential adverse effects pose challenges. Future directions include exploring novel pharmacologic agents with improved efficacy and safety profiles, alongside lifestyle interventions [87].

- Seasonal and timing considerations: Recognizing the impact of intervention timing, both in terms of duration and seasonality, can enhance family engagement and intervention effectiveness. Targeting high-risk periods for weight gain may optimize outcomes [88].

- Policy and community engagement: Successful long-term management of pediatric obesity requires a multifaceted approach involving governmental and non-governmental agencies, policy makers, and community groups. Integrated strategies and cohesive health messages are essential for sustainable prevention and intervention programs [89].

While these emerging interventions show promise, challenges remain in ensuring accessibility and effectiveness across diverse populations. The integration of telehealth, interdisciplinary frameworks, and policy engagement represents a significant advancement in pediatric obesity management. However, the complexity of obesity necessitates ongoing research to refine these approaches and address gaps in knowledge. Future efforts should focus on long-term outcome assessments, cost-effectiveness analyses, and the development of scalable models adaptable to various healthcare settings.

Conclusion

In conclusion, the post-pandemic era has seen a concerning escalation in pediatric obesity rates, driven by behavioral, environmental, and systemic factors. Despite ongoing surveillance and clinical guidelines, the effectiveness of current interventions remains limited, necessitating innovative, equitable, and holistic strategies. Emphasizing early intervention, addressing social determinants, leveraging technology judiciously, and integrating mental health support are essential components for tackling pediatric obesity in this new era. Continued research and adaptive public health policies will be vital to reversing these trends and promoting healthier futures for children worldwide.

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Conflict of Interest

None.

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