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2734 17 Avenue SW, Calgary,
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+15878858911
editorial-office@sciformat.ca

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PERSISTENCE AND RECOVERY OF CHANGES IN WEIGHT STATUS ASSOCIATED WITH THE COVID-19 PANDEMIC AMONG CHILDREN AND ADOLESCENTS: A SYSTEMATICALLY INFORMED NARRATIVE REVIEW

Joanna Jarzębska (Corresponding Author, Email: joanna.jarzebska@hotmail.com)
Military Institute of Medicine - National Research Institute, Warsaw, Poland
ORCID ID: 0009-0008-7085-0066

Jakub Marek Baran
Bielanski Hospital, Warsaw, Poland
ORCID ID: 0009-0003-1682-5867

Maja Śmigielska
Bielanski Hospital, Warsaw, Poland
ORCID ID: 0009-0005-4771-8508

Damian Grusiecki
Miedzylesie Specialist Hospital, Warsaw, Poland
ORCID ID: 0009-0001-4882-4733

Zuzanna Waszak
Praski Hospital, Warsaw, Poland
ORCID ID: 0009-0003-3745-6933

ABSTRACT

Introduction: The COVID-19 pandemic disrupted schooling, physical activity, diet, and daily routines, contributing to excess weight gain among children and adolescents. Whether these changes persisted after restrictions eased remains uncertain.

Objectives: To evaluate the persistence of pandemic-associated changes in weight status among children and adolescents after major restrictions were eased.

Methods: PubMed, Scopus, and the Cochrane Library were searched through December 2025 for observational studies of general pediatric populations (<18 years) reporting weight-related outcomes before the pandemic, during lockdown, school closure, or other major restrictions, and at least six months after school reopening or restriction easing. Owing to methodological heterogeneity, findings were synthesized narratively without meta-analysis.

Results: Ten studies from nine countries were included. Most reported increases in BMI-related measures or the prevalence of overweight or obesity during the pandemic or restriction period. After restrictions eased, adverse trends generally attenuated, but complete normalization was inconsistent. Recovery was more frequently observed among younger children, whereas residual or renewed elevations occurred in some older children and adolescents and in selected groups with obesity or severe obesity. Findings by sex and baseline weight status were inconsistent, while socioeconomic and geographic disparities persisted in several settings.

Conclusions: Pandemic-associated changes in pediatric weight status partially or completely resolved in some populations but persisted in others. Continued growth monitoring and longer-term, population-representative studies using standardized outcome definitions are needed to identify children with persistent adverse trajectories.

KEYWORDS

Children, Adolescents, Overweight, Obesity, COVID-19, Persistence

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1. Introduction

Overweight and obesity among children and adolescents constitute a major and growing global public health concern (Zhang et al., 2024). According to the Child Nutrition Report 2025, one in twenty children under the age of five worldwide (5%) and one in five children and adolescents aged 5–19 years (20%) are affected by overweight. This corresponds to approximately 35 million children under five years of age and 391 million children and adolescents aged 5–19 years, amounting to a total of 427 million young individuals with excess body weight globally (United Nations Children's Fund, 2025).

Children and adolescents with overweight and obesity are at increased risk of numerous adverse health outcomes resulting from excess body weight. This population more frequently experiences mental health problems, including depression, low self-esteem, and emotional disorders, which, when combined with weight-related stigma and peer rejection, lead to a substantial reduction in overall quality of life (Rankin et al., 2016). Moreover, excess body weight in childhood is strongly associated with an elevated risk of cardiovascular diseases (Friedemann et al., 2012), including type 2 diabetes mellitus (Pulgaron & Delamater, 2014) and hypertension (Brady, 2017). Other commonly reported comorbidities include asthma (Lang et al., 2018), liver disease (Uppal et al., 2016), and musculoskeletal disorders (Smith et al., 2014). Over the life course, individuals affected by childhood overweight and obesity are more likely to develop disability and face an increased risk of premature mortality in adulthood (Park et al., 2012).

The COVID-19 pandemic and the public health restrictions implemented during this period created conditions that were particularly conducive to weight gain in children and adolescents. One of the key contributing factors was the sudden disruption of daily routines previously structured by school attendance. Educational institutions supported healthy weight maintenance by providing regular meals and opportunities for daily physical activity. School closures resulted in the loss of this structure, promoting irregular eating patterns, increased snacking, and disturbances in sleep schedules.

A critical role was also played by the transition to remote learning, which substantially reduced levels of physical activity. Prolonged screen time confined children to sedentary behaviors, leading to a marked decline in spontaneous physical activity such as walking to school, moving between classrooms, and engaging in outdoor play. At the same time, digital devices became the primary means for education, social interaction, and entertainment, further reinforcing a sedentary lifestyle.

These reductions in physical activity were accompanied by unfavorable dietary changes. Continuous access to food in the home environment, combined with heightened psychological stress related to social isolation and fear of illness, contributed to more frequent consumption of snacks and highly processed foods. Consequently, the imbalance between increased caloric intake and reduced energy expenditure resulted in significant weight gain among many children.

Most existing studies have focused on the short-term impact of COVID-19 lockdowns on child health, consistently demonstrating a clear increase in body weight during periods of isolation. However, a significant research gap remains regarding the persistence of these changes after the lifting of pandemic-related restrictions. The literature lacks clear evidence as to whether children returned to normative growth trajectories following the resumption of in-person schooling and regular physical activity, or whether pandemic-related weight gain has become a lasting precursor to chronic obesity.

Understanding the long-term persistence of pandemic-associated weight gain is essential for predicting future burdens on healthcare systems related to metabolic diseases. Pediatric research has long described the concept of metabolic programming, whereby disturbances in energy balance during critical developmental periods may induce lasting alterations in an individual's metabolic profile (Vickers, 2014). If excess weight gained during lockdown was not reduced shortly after the return to regular routines, there is a substantial risk that these children will remain on a trajectory toward obesity in adulthood. Identifying the extent of this phenomenon is crucial for the development of targeted preventive and interventional strategies aimed at mitigating the long-term health consequences of the COVID-19 pandemic.

The primary objective of this review was to assess whether pandemic-associated changes in weight status among children and adolescents persisted after major COVID-19 restrictions were eased or lifted.

2. Materials and Methods

2.1. Protocol and registration

This article was prepared as a systematically informed narrative review, not as a full systematic review, and was therefore not registered in PROSPERO. Prior to conducting the literature search, screening and data extraction, an internal review protocol was prepared to define the scope, search strategy, eligibility criteria and planned approach to evidence synthesis. The search and selection process were structured and informed, where applicable, by the PRISMA 2020 recommendations (Page et al., 2021). A PRISMA-style flow diagram is included to transparently document the identification, screening and selection of records.

2.2. Eligibility criteria

Eligibility criteria were defined according to the PICO (Population, Exposure, Comparison, Outcome) framework. Eligible studies included children and adolescents under 18 years of age drawn from the general pediatric population, reporting BMI, BMI z-score, BMI percentile, weight percentile, overweight or obesity prevalence, or another clearly defined measure of weight status at three or more time points:

1. before the pandemic or major restrictions
2. during the lockdown or school closure period (full or partial) or other major restriction period
3. at least six months after full school reopening or the easing or lifting of major restrictions.

The UNESCO school closure map was used to establish the timing of full school reopening where relevant (UNESCO Institute for Statistics, 2021).

Studies in adults aged 18 years or older, mixed adult-pediatric studies without separately extractable pediatric data, studies lacking weight-related outcome data for any required time point, and studies focused exclusively on selected pediatric populations, including but not limited to children with monogenic or syndromic obesity, chronic diseases affecting growth or body weight, or use of medications known to influence weight gain, were excluded.

The exposure of interest was the COVID-19 pandemic period and associated public health restrictions affecting children's daily routines, including lockdowns, school closures, remote learning, reduced access to organized physical activity, and other major restrictions implemented between 2020 and 2021, defined according to study-specific pandemic periods, national or regional lockdown dates, school closure periods, or other clearly described restriction periods.

The primary comparison was children's weight-related outcomes before the pandemic or major restrictions against outcomes during the restriction period and after full school reopening, assessed within the same children over time, between repeated population samples, or against expected pre-pandemic trends or historical cohorts where applicable.

The outcome of interest was the persistence, decline, or progression of pandemic-associated changes in weight status, assessed using BMI, BMI z-score, BMI percentile, weight percentile, overweight, obesity, or severe obesity prevalence, or other clearly defined anthropometric measures.

Observational studies reporting pediatric weight-related outcomes across the three required time points, including prospective and retrospective cohort studies, longitudinal surveillance studies, and repeated cross-sectional studies with identifiable follow-up, were eligible.

Narrative reviews, systematic reviews, meta-analyses, editorials, commentaries, letters to the editor, protocols, case reports, book chapters, and guidelines were excluded. Interventional studies focused on weight management, obesity treatment, diet, physical activity, or medication were excluded unless anthropometric data from a non-intervention or usual-care comparison group were reported separately and met the required time-point criteria.

2.3. Information sources

PubMed, Cochrane Library and Scopus. Search conducted through December 2025. The works for the screening process were downloaded on 04.01.2026.

2.4. Search strategy

A comprehensive search strategy combining controlled vocabulary and free-text keywords was developed to capture three core concepts: the pediatric population, the COVID-19 pandemic and related restrictions, and weight-related outcomes. Search terms included combinations of children, adolescents, pediatric, obesity, overweight, BMI, weight gain, COVID-19, pandemic, lockdown, school closure, and post-pandemic, combined using database-specific Boolean operators and, where available, controlled vocabulary terms such as MeSH or Emtree descriptors. Searches were limited to studies involving human pediatric populations, and completeness was enhanced through backward citation searching of included studies and relevant reviews.

2.5. Study selection

The study selection process was performed independently by two reviewers (Z.W. and M.Š.) using the Rayyan web-based platform for blinded screening according to the predefined eligibility criteria. Disagreements regarding study inclusion were resolved by consensus or, when required, through consultation with a third independent reviewer (J.J.), who applied the same predefined criteria to ensure consistency and minimize selection bias.

2.6. Data extraction

Data extraction was performed using a standardized digital form to ensure consistency across authors. The extraction process was shared equally among all authors, with each author responsible for a comparable proportion of the eligible studies. For each included study, the following information was extracted: record number, title, authors, year of publication, country, study design, data source or setting, sample size, age range, study population description, timing of measurements, restriction or school-closure context where reported, form of weight measurement, type of analyses performed, weight-related outcomes, study conclusions, statistical adjustments, reported limitations, and any additional relevant information.

In accordance with the eligibility criteria, particular attention was paid to whether each study reported weight-related outcomes at the three required time points: before the pandemic or major restrictions, during lockdown, school closure or another major restriction period, and at least six months after full school reopening or the easing or lifting of major restrictions. Where available, the timing of school reopening or restriction lifting was checked against the reported timing of post-restriction measurements. When specific information was not reported in the original article, it was recorded as not available rather than inferred. Any uncertainties or discrepancies identified during extraction were resolved through discussion among the authors and, where necessary, by consensus.

2.7. Methodological quality and risk-of-bias considerations

No formal risk-of-bias assessment was conducted using standardized tools such as the Newcastle–Ottawa Scale, RoB 2, ROBINS-I, or JBI critical appraisal checklists. This decision was based on the narrative and descriptive character of the review, the heterogeneity of included study designs, and the absence of a quantitative meta-analysis or formal certainty-of-evidence grading. Instead, the interpretation of the findings was performed cautiously, with attention to key methodological characteristics of the included studies, including study design, study setting, sample size, age range, timing of BMI assessment, definition of COVID-19 restriction periods, and completeness of reported pre-, during-, and post-restriction BMI data.

The absence of a formal risk-of-bias assessment should be considered a methodological limitation of this review. Therefore, the findings should be interpreted as a structured narrative synthesis of the available evidence rather than as conclusions derived from a full systematic review with formal quality appraisal.

2.8. Data synthesis plan

Given the anticipated heterogeneity in study design, data sources, study settings, measurement timing, restriction or school-closure contexts, forms of weight assessment, and analytical approaches, findings were synthesized narratively. Quantitative pooling was not performed. Instead, the extracted data were used to compare studies descriptively according to country, study design, data source or setting, sample size, age range, study population, timing of measurements, restriction context, form of weight measurement, statistical approach, adjustment strategy, and reported weight-related outcomes.

The synthesis focused on weight-related outcomes reported across the three eligibility-defined periods: before the pandemic or major restrictions, during lockdown, school closure or another major restriction period, and after school reopening or the easing or lifting of major restrictions. Particular attention was paid to whether post-restriction measurements were obtained at least six months after reopening or the lifting/easing of major restrictions, where this could be established from the original study or contextual information. The main interpretative focus was whether pandemic-associated changes in weight status persisted, declined, stabilized, or progressed after restrictions ended.

Where data permitted, patterns were explored across age groups, countries, study settings, measurement methods, restriction contexts, and statistical adjustment strategies. Because of substantial variability in outcome definitions, measurement intervals, study populations, and analytical methods, the results were interpreted as a structured narrative synthesis rather than as pooled effect estimates. Tables and simple visual summaries were used to support comparison of study characteristics and outcome patterns.

3. Results

3.1. Study selection

The initial search identified 1496 records (479 from PubMed, 60 from the Cochrane Library and 957 from Scopus). After duplicate removal, 1039 records were screened. Following title and abstract screening, 985 records were excluded for not meeting the eligibility criteria. Full-text assessment was performed for 54 articles, of which 4 could not be retrieved and from the remaining 50, further 40 were excluded. Ultimately, 10 studies were selected for this systematically informed narrative review. Figure 1 presents the PRISMA flow diagram of the study selection process.

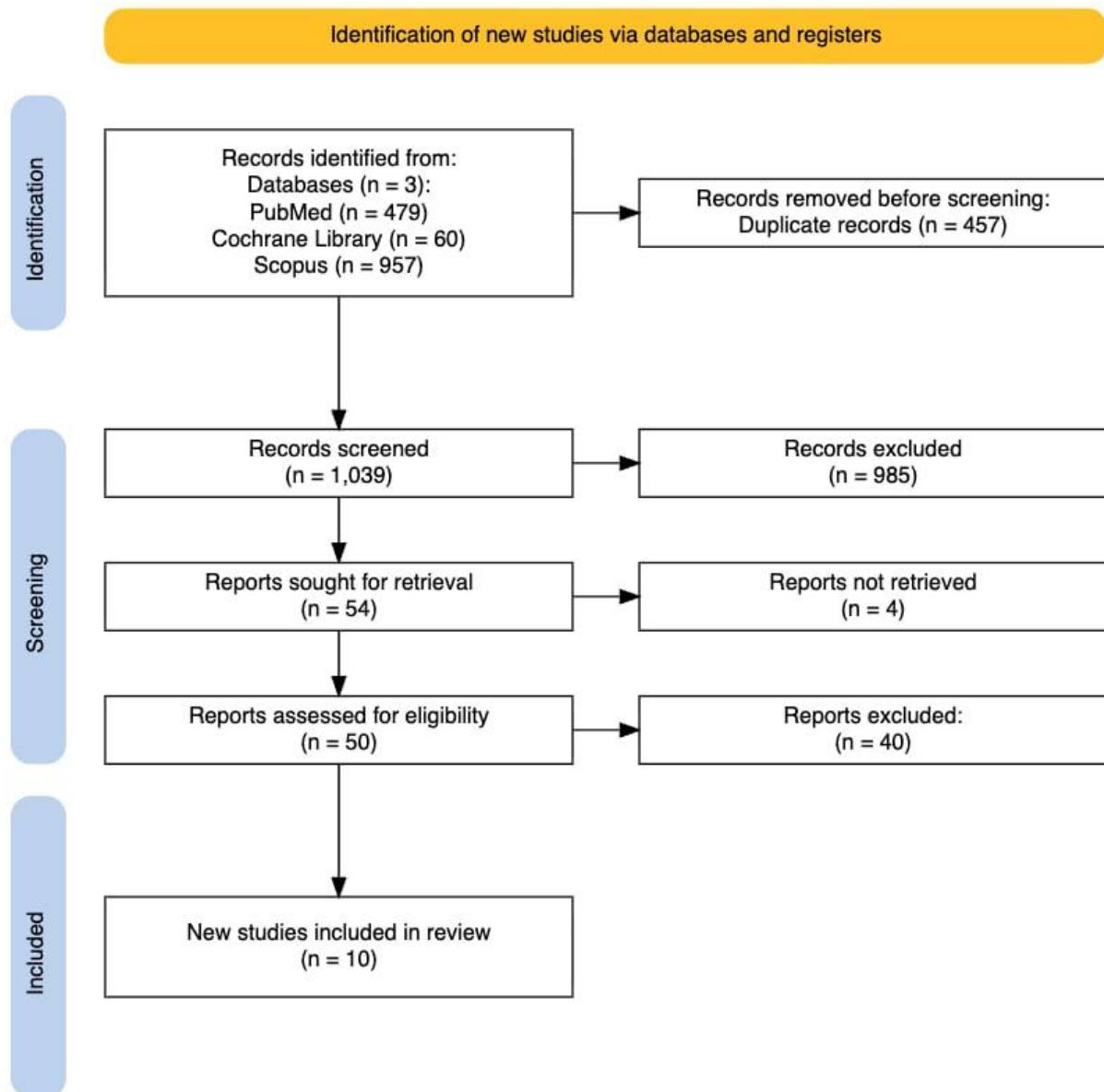


Fig. 1. PRISMA flow diagram of the study selection process (Haddaway et al., 2022)

3.2 Study characteristics

Ten studies published between 2023 and 2025 were included in the review. Their main characteristics are presented in Table 1 (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023). The studies were conducted in nine countries across Europe, East Asia, and the Middle East. Two studies were conducted in Sweden (Fäldt et al., 2024; Nylander et al., 2025). The remaining studies were conducted in Japan (Takaya et al., 2023), Germany (Berisha et al., 2025), Saudi Arabia (Alhakami et al., 2025), the United Kingdom (Basterfield et al., 2024), China (Cheng et al., 2024), Austria (Irschik et al., 2023), Israel (Shalitin et al., 2024), and South Korea (Ha, 2025).

Study designs varied considerably. Four studies assessed within-child changes using repeated measurements of the same children (Alhakami et al., 2025; Basterfield et al., 2024; Irschik et al., 2023; Shalitin et al., 2024), whereas five primarily examined repeated cross-sectional or annual population-level trends (Berisha et al., 2025; Cheng et al., 2024; Ha, 2025; Nylander et al., 2025;

Takaya et al., 2023). One study explicitly combined both methodological approaches. Fäldt et al. conducted population-level comparisons alongside longitudinal follow-up of children with repeated growth measurements (Fäldt et al., 2024). The Austrian study was described as a cross-sectional survey, although changes in anthropometric outcomes were assessed using measurements recorded in the same children before, during, and after restrictions (Irschik et al., 2023). Conversely, although the Chinese study was described by the authors as longitudinal, the reported methods and analyses were more consistent with annual population-level comparisons than with within-child follow-up (Cheng et al., 2024).

Four studies used school-based health records, physical-fitness surveillance systems, or anthropometric measurements collected directly in schools (Basterfield et al., 2024; Cheng et al., 2024; Ha, 2025; Takaya et al., 2023). Six studies used healthcare-based records or routine pediatric surveillance data, including hospital and outpatient medical records, a specialized auxological database, a large integrated healthcare database, and child health surveillance systems (Alhakami et al., 2025; Berisha et al., 2025; Fäldt et al., 2024; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024). The scope of the datasets ranged from national or large multicenter data sources (Berisha et al., 2025, 2025; Ha, 2025; Nylander et al., 2025) to multiregional and regional databases (Cheng et al., 2024; Fäldt et al., 2024; Takaya et al., 2023). Three studies were conducted at a single site, including one hospital (Alhakami et al., 2025), one pediatric practice (Irschik et al., 2023), and one school (Basterfield et al., 2024).

Sample sizes varied substantially, ranging from 90 children in the single-school study from North East England (Basterfield et al., 2024) to 591,330 children contributing 1,495,401 clinical visits to the German CrescNet database (Berisha et al., 2025). Five studies included more than 100,000 participants (Berisha et al., 2025; Ha, 2025; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023), while two additional studies included approximately 30,000–50,000 participants (Cheng et al., 2024; Fäldt et al., 2024). The remaining studies were substantially smaller and were conducted in single-school, single-hospital, or single-practice settings (Alhakami et al., 2025; Basterfield et al., 2024; Irschik et al., 2023). Participants ranged from infancy to 18 years, although most studies focused on school-age children or adolescents. Two studies examined preschool children (Fäldt et al., 2024; Nylander et al., 2025). Two included school-age populations, ranging from elementary-school students to children aged 15 years (Basterfield et al., 2024; Takaya et al., 2023), while two focused specifically on adolescents (Cheng et al., 2024; Ha, 2025). Four studies included broader pediatric age ranges spanning early childhood through adolescence (Alhakami et al., 2025; Berisha et al., 2025; Irschik et al., 2023; Shalitin et al., 2024). Exact sample sizes and participant age ranges for each study are provided in Table 1.

Definitions of the pre-pandemic, pandemic, and post-restriction periods varied across studies. All ten studies reported at least one pre-pandemic or pre-restriction measurement, a measurement during the pandemic or major restriction period, and at least one subsequent assessment (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023). Alhakami et al. formed three partially overlapping cohorts according to measurement availability, with only one cohort providing data from all three periods (Alhakami et al., 2025). In most studies, pre-pandemic or pre-restriction baseline measurements were obtained in 2018 or 2019, although in some studies the baseline periods extended into early 2020 (Alhakami et al., 2025; Basterfield et al., 2024; Cheng et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023). Fäldt et al. included data collected from 2015 onward (Fäldt et al., 2024), while Berisha et al. assessed pre-pandemic trends from 2002 to 2019 (Berisha et al., 2025). The timing of pandemic-period assessments varied across studies and included both measurements taken during defined restriction periods and those assigned to broader pandemic-era time windows that partially or fully overlapped with major restrictions (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et

al., 2024; Takaya et al., 2023). The latest measurement year was 2021 in the study by Takaya et al. (Takaya et al., 2023), 2022 in five studies (Alhakami et al., 2025; Basterfield et al., 2024; Cheng et al., 2024; Irschik et al., 2023; Nylander et al., 2025), 2023 in three studies (Berisha et al., 2025; Fäldt et al., 2024; Shalitin et al., 2024), and 2024 in the study by Ha (Ha, 2025).

The nature and duration of pandemic-related restrictions differed considerably across study settings. Sweden did not impose a formal national lockdown, and preschools and schools generally remained open (Fäldt et al., 2024; Nylander et al., 2025). Other countries implemented varying combinations of school closures, remote learning and broader public health restrictions (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Ha, 2025; Irschik et al., 2023; Shalitin et al., 2024; Takaya et al., 2023). Consequently, pandemic-period assessments reflected heterogeneous restriction contexts and were not directly comparable across studies.

All studies used directly measured or routinely recorded height and weight rather than self- or parent-reported measurements (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023). Nine studies evaluated weight status using BMI-derived outcomes, including raw BMI, BMI z-scores or BMI standard deviation scores, age- and sex-adjusted BMI percentiles, and the prevalence of overweight, obesity, or severe obesity (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024). Takaya et al. instead assessed weight status using percentage of overweight (POW) relative to age- and sex-specific standard body weight (Takaya et al., 2023). The reference standards used to define weight status varied and included International Obesity Task Force thresholds, World Health Organization and Centers for Disease Control and Prevention growth references, and country-specific pediatric growth references and weight-status classification criteria. Statistical approaches varied according to study design and included mixed-effects models, repeated-measures analyses, regression-based trend analyses, analyses of variance, paired comparisons, and comparisons of prevalence across time periods (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023).

Given the heterogeneity in study design, participant populations, restriction contexts, outcome definitions, and duration of follow-up, findings were synthesized narratively. Where appropriate, within-child longitudinal changes were distinguished from repeated cross-sectional population-level trends.

Table 1. Characteristics of included studies

Reference	Country	Study design	Setting and data source	Sample size (N)	Population and age range	Measurement periods	Restriction context	Anthropometric outcomes and reference standards
Fäldt et al., 2024	Sweden	Combined repeated cross-sectional and longitudinal study	Swedish Child Health Services Register (BHVQ); data from Dalarna, Jönköping, and Sörmland	N=50 833	Preschool children aged 3–5 years	Overall study period: May 2015–May 2023; pre-pandemic: before 1 May 2020; early pandemic: 1 May 2020–31 May 2021; late pandemic: 1 June 2021–1 April 2022; post-pandemic: after 1 April 2022	No formal national lockdown; reduced preschool attendance and access to nutritious food and regular outdoor activities.	BMI and weight status; sex-specific BMI-for-age classified using International Obesity Task Force (IOTF) cut-offs: overweight (26–29) and obesity (≥ 30)
Takaya et al., 2023	Japan	Repeated cross-sectional study	Annual school physical examination data from public elementary and junior high schools in Osaka	N=143,758	Public school students aged 6–12 years (elementary school), 12–15 years (junior high school)	Pre-pandemic: 2018, 2019; lockdown: 2020; post-lockdown: 2021	Nationwide school closures from March to May 2020; schools reopened in June with online classes; regular in-person attendance resumed after the summer vacation.	Percentage of overweight (POW) based on Japanese age- and sex-specific standard weight-for-height from the 2000 School Health Statistics; mild, moderate, and severe obesity: $\text{POW} \geq 20\%$ to $<30\%$, $\geq 30\%$ to $<50\%$, and $\geq 50\%$, respectively
Berisha et al., 2025	Germany	Repeated cross-sectional trend analysis	CrescNet auxological network; data from 505 pediatric outpatient clinics nationwide	N=591,330 (1,495,401 visits)	Children and adolescents aged 4–16 years attending pediatric outpatient clinics; children with chronic diseases and long-term medication affecting growth/weight were excluded	Overall study period: 1 January 2002–31 December 2023; pre-pandemic trends: 2002–2019; pandemic and post-pandemic trends: 2020–2023, with 2019 as the reference year	School closures and broader social restrictions, with reduced social activities and disruptions to routine pediatric visits were described; no specific restriction timeline provided.	BMI-SDS using German age- and sex-specific reference values: overweight ($1.28 < \text{BMI-SDS} \leq 1.88$), obesity ($1.88 < \text{BMI-SDS} \leq 2.58$) and severe obesity ($\text{BMI-SDS} > 2.58$); excess weight (W-E) and excess BMI (BMI-E) percentiles also assessed

Reference	Country	Study design	Setting and data source	Sample size (N)	Population and age range	Measurement periods	Restriction context	Anthropometric outcomes and reference standards
Alhakami et al., 2025	Saudi Arabia	Longitudinal cohort study	Electronic health records from pediatric outpatient clinics at King Abdullah bin Abdulaziz University Hospital (KAAUH), Riyadh	Cohort 1: N=934; Cohort 2: N=1,129; Cohort 3: N=203	Children aged 2–18 years divided into three partially overlapping cohorts. Cohort 1: with pre-lockdown and lockdown measurements; Cohort 2: lockdown and post-lockdown measurements; Cohort 3: measurements at all three periods.	Pre-lockdown: September 2019–February 2020; lockdown: September 2020–September 2021; post-lockdown: July–December 2022	Lockdown first enforced on 25 March 2020; restrictions included school closures and social isolation. By the post-lockdown assessment, schools and normal daily activities had resumed for at least 6 months.	BMI and age- and sex-adjusted BMI percentile based on World Health Organization (WHO) Child Growth Standards; Centers for Disease Control and Prevention (CDC) categories: overweight (≥ 85 th to < 95 th percentile) and obesity (≥ 95 th percentile)
Basterfield et al., 2024	United Kingdom	Longitudinal cohort study	Single primary school in Newcastle upon Tyne, North East England	N=90 at T0; N=87 at T1–T3	Primary school children aged 8–9 years at baseline; most lived in areas within the most deprived quintile.	Pre-pandemic: October 2019 (T0); during the second national lockdown: November 2020 (T1); follow-up: November 2021 (T2), June 2022 (T3)	First lockdown (16 March–June/July 2020): schools closed; second lockdown (5 November–2 December 2020): stay-at-home orders, schools remained open, sports activities were restricted; third lockdown (6 January–8 March 2021): schools closed.	BMI and age- and sex-normalized BMI z-score based on UK 1990 reference data; UK population-sensitive cut-offs: overweight (≥ 85 th to < 95 th centile), obesity (≥ 95 th to < 99.6 th centile) and severe obesity (≥ 99.6 th centile)
Cheng et al., 2024	China	Annual population-level study, described by the authors as longitudinal	National Physical Fitness Survey data from schools in Jinan, Shandong Province	N=29,813	Adolescents aged 12–14 years	Pre-pandemic: 2019; pandemic: 2020; follow-up: 2021, 2022	The opening of in-person classes was delayed and online learning was introduced. Adolescents spent prolonged periods at home with reduced outdoor activity; no specific restriction timeline provided.	BMI and BMI z-score; BMI classified according to WHO criteria (< 18.5 , 18.5 – 23.9 , 24 – 27.9 and ≥ 28 kg/m ²) and BMI z-score WHO growth curve for children and adolescents: overweight (BMI-z > 1), obesity (BMI-z > 2)
Irschik et al., 2023	Austria	Within-child repeated-measures study, described by	Single pediatric practice in Vienna; parental socioeconomic and lifestyle survey	N=388	Children aged 1 week–14.4 years at the initial assessment	Pre-restriction: 6 months before March 2020, extended to 1 year if prior BMI was	Restrictions from 15 March 2020 to 5 March 2022 included lockdowns, school and preschool	BMI percentiles and BMI z-scores based on Kromeyer–Hauschild reference values; 2019 German pediatric obesity

Reference	Country	Study design	Setting and data source	Sample size (N)	Population and age range	Measurement periods	Restriction context	Anthropometric outcomes and reference standards
		the authors as a cross-sectional survey				stable; during restrictions: March 2020–March 2022; post-restriction: August–November 2022	closures, and prohibition of team sports.	guidelines cut-offs: overweight (>90th percentile) and obesity (>97th percentile)
Shalitin et al., 2024	Israel	Longitudinal cohort study	Electronic database of Clalit Health Services (CHS)	N=106,871	Children aged 2–16 years at the first measurement; those with obesity-related genetic or endocrine disorders, chronic illnesses, eating disorders, bariatric surgery, or taking weight-affecting medications were excluded.	Pre-pandemic: 1 January 2018–28 February 2020; pandemic: 1 March 2020–30 March 2021; post-pandemic: 1 January 2022–30 September 2023	Three lockdowns occurred: March–May 2020, September–October 2020, and December 2020–March 2021. Nurseries and schools were closed or operated partially for most of 2020; social distancing was recommended.	BMI and BMI-SDS based on the 2000 CDC growth charts; overweight (85th–95th percentiles; $1.036 < \text{BMI-SDS} \leq 1.645$), obesity (≥ 95 th percentile; $\text{BMI-SDS} > 1.645$); BMI-SDS change ≥ 0.25 considered significant
Nylander et al., 2025	Sweden	Repeated cross-sectional study	Swedish Child Health Services (CHS); aggregated regional data	N=303,843 (representing 87% of children born in Sweden in 2014, 2016, and 2018)	Children aged 4 years attending their 4-year health visit	Pre-pandemic: 2018; pandemic: 2020; post-pandemic: 2022	Preschools and schools remained mainly open; social distancing from older adults was encouraged.	Age- and sex-adjusted BMI; IOTF definitions: overweight (IOTF-BMI >25) and obesity (IOTF-BMI >30)
Ha, 2025	South Korea	Repeated cross-sectional trend study	National Physical Activity Promotion System (PAPS); annual school-based assessments	N=171,705	Middle and high school students aged 13–18 years	Pre-pandemic: 2018, 2019; pandemic: 2020, 2022; post-pandemic: 2023, 2024; data from 2021 were excluded due to incomplete measurements	Nationwide school closures and remote learning were implemented. Physical education classes, recess, after-school sports, and school clubs were suspended or restricted; no specific restriction timeline provided.	BMI classified using grade- and sex-specific Physical Activity Promotion System (PAPS) cut-offs for underweight, normal weight, overweight, mild obesity and severe obesity, based on Korean anthropometric data and WHO/ Korean Society for the Study of Obesity (KSSO) recommendations

3.3 Weight changes during restrictions

Most studies reported increases in BMI-derived measures or in the prevalence of overweight and obesity during the pandemic or restriction period, although changes were not uniform across age and baseline weight groups. Across the four studies examining within-child changes, BMI-related outcomes generally increased during restrictions (Alhakami et al., 2025; Basterfield et al., 2024; Irschik et al., 2023; Shalitin et al., 2024). In the Saudi Arabian cohort assessed across all three periods, mean age- and sex-adjusted BMI percentile increased from 0.40 before lockdown to 0.53 during lockdown. A supplementary analysis of the larger cohort with measurements before and during lockdown showed a mean increase of 0.06 (SD 0.24) (Alhakami et al., 2025). In the English school cohort, mean BMI z-score increased from 0.71 before the pandemic to 0.97 in November 2020, while the proportion of children with overweight or obesity rose from 32% to 46% ($p = 0.003$) (Basterfield et al., 2024). In the Austrian study, BMI z-score and obesity prevalence both peaked during restrictions, with mean BMI z-score increasing by 0.403 from baseline and obesity prevalence rising from 6.4% to 15.2% (Irschik et al., 2023). The large Israeli cohort similarly showed an increase in BMI-SDS during the pandemic, while the prevalence of overweight increased from 13.4% to 14.3% and obesity from 12.8% to 15.4% (Shalitin et al., 2024). Population-level analyses similarly demonstrated adverse changes during the pandemic. Fäldt et al. reported that the prevalence of overweight among 3-year-olds increased from 11.6% before the pandemic to 13.2% during early COVID-19, while obesity increased from 2.4% to 3.4%. Among 4-year-olds, overweight increased from 10.3% to 11.7% and obesity from 2.6% to 3.7%, whereas no significant changes were observed among 5-year-olds (Fäldt et al., 2024). In the national Swedish cohorts of 4-year-olds, the combined prevalence of overweight or obesity increased from 11.4% in 2018 to 13.3% in 2020 (Nylander et al., 2025). Berisha et al. reported that the pre-existing increase in severe obesity accelerated during the pandemic and peaked in 2021 across all age and sex groups, with severe obesity odds ratios of 1.3–1.7 compared with 2019 (Berisha et al., 2025). In the Chinese adolescent sample, mean BMI z-score increased from 0.48 (SD 0.74) in 2019 to its highest value of 0.58 (SD 0.80) in 2020 (Cheng et al., 2024). The South Korean study similarly found a significant increase in mean BMI during the pandemic period, with values peaking in 2022 (Ha, 2025). Takaya et al. observed opposing trends in elementary- and junior-high-school students, with increases in several obesity categories among elementary-school children but weight loss and generally lower obesity rates among junior-high-school students in 2020 (Takaya et al., 2023). Taken together, the evidence indicated a general shift toward higher BMI and greater obesity prevalence during the pandemic, although the direction and magnitude of change varied across age groups and study populations.

3.4 Post-restriction changes

Post-restriction trajectories of weight-related outcomes were heterogeneous. Most studies showed at least partial reversal of pandemic-associated increases, although a full return to pre-pandemic levels was observed only for certain outcomes or subgroups. Among studies with within-child follow-up, in the Saudi Arabian cohort assessed across all three periods, mean age- and sex-adjusted BMI percentile was 0.53 during lockdown and 0.56 after lockdown, remaining above the pre-lockdown value of 0.40 (Alhakami et al., 2025). In the English school cohort, mean BMI z-score declined from 0.97 in November 2020 to 0.89 in June 2022 but remained above the pre-pandemic value of 0.71. In contrast, the proportion of children with overweight or obesity remained elevated and reached 48% at the final assessment. This did not differ significantly from the 46% observed in November 2020 but remained significantly higher than the pre-pandemic prevalence (Basterfield et al., 2024). In the Austrian study, BMI z-score declined after restrictions were lifted but remained 0.19 above the pre-pandemic baseline, while obesity prevalence decreased from its restriction-period peak of 15.2% to 12.1% remaining above the pre-pandemic prevalence of 6.4% (Irschik et al., 2023).

Similarly, in the Israeli cohort, BMI-SDS decreased after the pandemic but remained above pre-pandemic levels. Overweight prevalence returned to approximately its pre-pandemic level, decreasing from 14.3% during the pandemic to 13.3% afterward, compared with 13.4% before the pandemic, whereas obesity remained elevated at 15.0% after the pandemic compared with 12.8% before it (Shalitin et al., 2024). Population-level studies showed greater evidence of normalization in some younger populations. Fäldt et al. reported that the prevalence of overweight and obesity among Swedish children aged 3 and 4 years returned to pre-pandemic levels during subsequent follow-up, after increasing during the pandemic (Fäldt et al., 2024). Similarly, among national cohorts of Swedish 4-year-olds, the combined prevalence of overweight or obesity decreased from 13.3% in 2020 to 11.4% in 2022, returning to the level observed in 2018 (Nylander et al., 2025). In the Japanese study, obesity rates among elementary-school children generally remained elevated or increased further in 2021, although most changes from 2020 were not statistically significant. Among junior-high-school students, obesity rates rebounded after the decreases observed during lockdown, with significant increases in several obesity categories from 2020 to 2021 (Takaya et al., 2023). Among Chinese adolescents, mean BMI z-score declined from 0.58 in 2020 to 0.57 in 2021 and 0.53 in 2022, approaching but remaining numerically above the 2019 value of 0.48 (Cheng et al., 2024). In the German CrescNet study, severe obesity declined after its 2021 peak and returned to pre-pandemic levels among children aged 4–8 years by 2023, whereas it remained elevated among children older than 8 years. Overweight and obesity generally returned to pre-pandemic or lower levels by 2023, except among girls aged 12–16 years. Similarly, excess-weight percentiles returned to pre-pandemic levels among children aged 4–8 years but generally remained elevated in older age groups (Berisha et al., 2025). In the South Korean adolescent sample, mean BMI declined gradually in 2023 and 2024 after peaking in 2022 (Ha, 2025). Across studies, pandemic-associated increases in BMI-related measures and the prevalence of overweight or obesity often diminished during follow-up, but complete return to pre-pandemic levels was inconsistent. Residual elevations persisted in several study populations, and further increases were observed in some subgroups.

3.5 Differences by age and sex

Age-related differences were evident both in the initial pandemic-associated changes and in subsequent post-restriction outcomes, whereas sex-specific findings were less consistent. Fäldt et al. observed increases in overweight and obesity during early COVID-19 among children aged 3 and 4 years but not among 5-year-olds. During subsequent follow-up, the prevalence of overweight and obesity among 3- and 4-year-olds returned to pre-pandemic levels, while weight status among 5-year-olds remained relatively stable throughout the study period. In the longitudinal analysis, the incidence of BMI increase declined from the early COVID-19 period to the post-COVID-19 period across all age groups (Fäldt et al., 2024). Takaya et al. reported opposing age-related patterns during lockdown, with weight gain among elementary-school children and weight loss among junior-high-school students. In 2021, obesity rates among elementary-school children generally remained elevated or increased further, whereas the lockdown-associated decreases among junior-high-school students were followed by a rebound (Takaya et al., 2023). In the Israeli cohort, although BMI-SDS was lower among children aged 2–6 years throughout the study period, the pandemic-associated increase was greater than among children aged 6.1–16 years. BMI-SDS subsequently declined among younger children but remained above the pre-pandemic level, whereas it continued to increase after the pandemic among older children (Shalitin et al., 2024). Similarly, in the German CrescNet study, post-pandemic recovery was greater among younger children. By 2023, severe obesity and excess-weight percentiles had returned to pre-pandemic levels among children aged 4–8 years but generally remained elevated in older age groups. In contrast, overweight and obesity returned to pre-pandemic or lower levels across most age- and sex-specific groups, except among girls aged 12–16 years, in whom the prevalence of both outcomes remained higher in 2023 than in 2019 (Berisha et al., 2025). Sex-specific findings frequently depended on age. In the Japanese study, lockdown-associated

increases were particularly evident among elementary-school boys, while the subsequent rebound among junior-high-school students was observed in both sexes (Takaya et al., 2023). In the Israeli cohort, BMI-SDS declined after the pandemic in both sexes, with a greater decrease among females, but remained above pre-pandemic levels (Shalitin et al., 2024). In the German study, adverse post-pandemic patterns were particularly evident among girls aged 8–16 years, among whom severe obesity increased from 2022 to 2023. Among boys in the same age range, severe obesity remained above pre-pandemic levels but did not show a comparable renewed increase (Berisha et al., 2025). These findings suggest that younger children frequently experienced greater initial pandemic-associated changes but also showed more evidence of subsequent recovery, whereas persistent or renewed elevations were more apparent in some older children and adolescents. Sex-specific patterns were less uniform and often varied according to age group.

3.6 Differences by baseline weight status and socioeconomic or geographic characteristics

Differences according to baseline weight status were examined in three longitudinal studies (Alhakami et al., 2025; Irschik et al., 2023; Shalitin et al., 2024). In the Saudi Arabian study, increases in adjusted BMI percentile during lockdown were greater among children with underweight or healthy weight at baseline, whereas decreases were observed among those with overweight or obesity. A similar pattern was observed after lockdown, with further increases among children classified as underweight or healthy weight during lockdown and decreases among those with overweight or obesity (Alhakami et al., 2025). In the Israeli cohort, BMI-SDS increased most among children with pre-pandemic underweight, increased to a lesser extent among those with normal weight, and decreased among those with overweight or obesity during both the pandemic and post-pandemic periods. Nevertheless, at the post-pandemic assessment, 9.4% of children with pre-pandemic normal weight were classified as overweight and 4.5% as having obesity, while 25.7% of those with pre-pandemic overweight were classified as having obesity. Among children with pre-pandemic obesity, 66.0% remained in the obesity category (Shalitin et al., 2024). A different post-restriction pattern was observed in the Austrian study, where BMI z-score declined among children with normal weight or overweight but continued to increase among those with pre-existing obesity, who showed no evidence of post-restriction normalization (Irschik et al., 2023). Baseline weight status therefore appeared to modify both pandemic-associated changes and subsequent recovery, although the direction of these differences was not consistent across studies.

Three studies examined associations between socioeconomic characteristics and weight-related outcomes, while one additional study evaluated geographic disparities (Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024). In the Austrian study, higher parental education was associated with a smaller increase in BMI z-score during restrictions, whereas household income was not significantly associated with BMI z-score change. Access to an outdoor area and participation in organized sport were associated with lower BMI before the pandemic but did not appear to protect against restriction-period weight gain. However, returning to organized sport after restrictions were lifted was associated with more favorable weight changes (Irschik et al., 2023). In the Israeli cohort, BMI-SDS was consistently highest among children in the lowest socioeconomic-position cluster. BMI-SDS increased during the pandemic across all socioeconomic-position clusters and subsequently declined slightly in the low- and medium-position groups while remaining above pre-pandemic levels. In contrast, it increased slightly further in the high-position group (Shalitin et al., 2024). In the Swedish study, regions with lower education and income levels and higher proportions of single-parent households generally had a higher prevalence of overweight or obesity before, during, and after the pandemic. Greater childhood poverty was associated with a higher prevalence during and after the pandemic. These regional socioeconomic inequalities remained evident in 2022, despite the national prevalence returning to its pre-pandemic level (Nylander et al., 2025). The South Korean study identified consistently higher BMI among adolescents in rural and non-capital regions. Rural areas showed the most pronounced increase up to 2022, while the difference between capital and non-

capital regions peaked during 2020–2022. Although BMI subsequently declined across all regional groups, these geographic disparities remained evident through 2024 (Ha, 2025). Overall, findings from the limited number of studies examining these characteristics suggest that socioeconomic and geographic factors were associated with differences in weight-related outcomes, although associations with pandemic-related changes and post-restriction recovery were inconsistent.

3.7 Heterogeneity across studies

The included studies showed substantial clinical and methodological heterogeneity. Study populations differed in age, baseline weight status, geographic setting, and, where reported, socioeconomic characteristics, while sample sizes ranged from a small single-school cohort to national and large multicenter datasets. Study designs included both within-child longitudinal assessments and repeated cross-sectional population-level comparisons. The timing and definition of the pandemic and post-restriction periods also differed, reflecting variation in the onset, intensity, and duration of restrictions across countries. Follow-up duration ranged considerably, with final assessments conducted between 2021 and 2024. Weight-related outcomes were reported using raw BMI, BMI z-scores or BMI-SDS, BMI percentiles, percentage of overweight, and categorical definitions of overweight, obesity, or severe obesity. Variation in growth references, statistical methods, and subgroup analyses further limited direct comparisons. Accordingly, studies differed in the magnitude and direction of reported weight-related changes and in the extent to which outcomes returned to pre-pandemic levels. Consequently, quantitative pooling was not considered appropriate, and the findings were synthesized narratively, with emphasis on broader patterns and consistency across studies rather than direct comparison of numerical estimates.

4. Discussion

4.1 Pediatric weight trajectories during and after COVID-19 restrictions

Across the ten included studies, BMI-related measures and the prevalence of overweight or obesity generally increased during the pandemic or associated restriction periods, although changes varied across populations. After restrictions eased, most studies showed attenuation or partial recovery, but complete normalization was inconsistent, with residual or renewed elevations in several populations and subgroups. (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023) These longer-term findings provide important context for earlier studies that documented accelerated weight gain during restrictions but lacked post-restriction follow-up (Jarnig et al., 2021; Lange et al., 2021; Vogel et al., 2022).

Early studies conducted while restrictions were in place or shortly after their introduction consistently reported accelerated increases in BMI among children and adolescents (Jarnig et al., 2021; Lange et al., 2021; Vogel et al., 2022). However, these studies were not included in the primary synthesis because they lacked longer-term follow-up. As their final assessments were conducted predominantly in 2020, they mainly captured the immediate response to lockdown and could not determine whether the observed changes persisted after schools reopened and restrictions were lifted (Jarnig et al., 2021; Lange et al., 2021; Vogel et al., 2022).

Studies with follow-up extending beyond the restriction period subsequently placed these early findings in a broader temporal context. In many cohorts, the lifting of restrictions was followed by an attenuation of the adverse trend and a partial or complete return of weight-related measures towards pre-pandemic levels (Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024). This suggests that the initial increase in BMI did not invariably represent a sustained shift in growth trajectories. Nevertheless, the subsequent improvement cannot be attributed solely to the lifting of restrictions, as

all included studies were observational and differed in the timing of assessments and the course of the pandemic across countries (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023).

The extent of normalization varied considerably between populations. A more complete return to pre-pandemic levels was more frequently reported in studies involving younger children (Berisha et al., 2025; Fäldt et al., 2024; Nylander et al., 2025), whereas persistent adverse changes were observed in some older age groups and in certain cohorts of children with obesity, particularly severe obesity (Berisha et al., 2025; Ha, 2025; Irschik et al., 2023). However, the association with baseline weight status was not consistent across studies (Alhakami et al., 2025; Irschik et al., 2023; Shalitin et al., 2024). The persistence of pandemic-related changes may therefore have been shaped not only by age and baseline BMI but also by socioeconomic and environmental factors (Alhakami et al., 2025; Berisha et al., 2025; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024).

Early studies therefore captured the marked deterioration in weight-related measures during the restriction period, whereas longer-term follow-up showed that these changes partially or completely regressed in many children. At the same time, the persistence of elevated measures in selected subgroups indicates that the impact of the pandemic was neither uniform nor fully reversible (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Jarnig et al., 2021; Lange et al., 2021; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023; Vogel et al., 2022).

4.2 Factors associated with increased body weight among children during COVID-19 restrictions

The heterogeneity of the observed weight trajectories indicates that both the initial pandemic-related changes and subsequent recovery varied across subgroups of children and adolescents. Age-related patterns were prominent but inconsistent. Among Swedish preschoolers, early-pandemic increases in overweight and obesity occurred mainly among children aged 3 and 4 years and subsequently returned towards pre-pandemic levels, whereas no significant change was observed among 5-year-olds (Fäldt et al., 2024). In Japan, obesity increased during school closures among elementary school children, particularly boys; among junior high school students, obesity and underweight tended to decrease in 2020 and then increased again in 2021 (Takaya et al., 2023). German data showed a return towards pre-pandemic levels among children aged 4–8 years by 2023, whereas excess weight and severe obesity remained elevated in older age groups, particularly among girls aged 8–16 years (Berisha et al., 2025). In Israel, BMI standard deviation score (BMI-SDS) increased during the pandemic in both sexes and age groups. Younger children experienced a larger initial increase followed by a partial decline, whereas BMI-SDS continued to rise among older children in the post-pandemic period (Shalitin et al., 2024). Chinese adolescents showed broadly similar temporal BMI patterns across age and sex groups, while Korean adolescents had consistently higher mean BMI values among males and residents of rural or non-capital regions (Cheng et al., 2024; Ha, 2025). Overall, the evidence does not identify either sex as consistently more susceptible, and the relevance of age appears to depend on the population and follow-up period (Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Shalitin et al., 2024; Takaya et al., 2023).

None of the ten studies in the primary synthesis jointly measured diet, physical activity, screen time, and sleep alongside repeated anthropometric assessments, and behavioral factors were not evaluated consistently across the evidence base (Alhakami et al., 2025; Basterfield et al., 2024; Berisha et al., 2025; Cheng et al., 2024; Fäldt et al., 2024; Ha, 2025; Irschik et al., 2023; Nylander et al., 2025; Shalitin et al., 2024; Takaya et al., 2023). Potential behavioral pathways must therefore be considered using supplementary studies that were not included in the primary synthesis. In the parent-reported COV-EAT study, reduced physical activity and more frequent consumption of breakfast,

salty snacks, and snacks overall were associated with reported weight gain (Androutsos et al., 2021). Among Italian children and adolescents with obesity, sports participation decreased and screen time increased during lockdown (Pietrobelli et al., 2020). An accelerometer-based study also showed a decrease in moderate-to-vigorous physical activity and an increase in sedentary time, particularly among girls, although body weight was not assessed (Ganzar et al., 2022). These observations are consistent with the Structured Days Hypothesis, according to which school attendance supports regular patterns of eating, physical activity, sedentary behavior, and sleep (Brazendale et al., 2022). They do not, however, demonstrate that behavioral changes mediated the observed BMI trajectories. A more favorable pre-pandemic home environment was associated with less acceleration in BMI growth during the early pandemic period, but not during the later period (McCabe et al., 2024). Within the primary synthesis, improvements in shuttle-run and standing broad-jump performance were associated with greater reductions in BMI z-score in England (Basterfield et al., 2024). In Austria, children who had participated in organized sport before the restrictions and resumed participation afterwards reduced their BMI z-score, whereas those who discontinued participation continued to gain weight after restrictions were lifted (Irschik et al., 2023). The observational nature of these associations precludes conclusions about causal direction.

Baseline weight status was not a consistent predictor of subsequent change. In the larger Saudi Arabian cohorts based on two-period comparisons, adjusted BMI percentile increased among children with underweight or healthy weight but decreased among those with overweight or obesity. In the smaller cohort assessed across all three periods, the adjusted BMI percentile remained essentially stable in the obesity group (Alhakami et al., 2025). A similar pattern was observed in Israel, where BMI-SDS increased among children with pre-pandemic underweight or normal weight and decreased among those with overweight or obesity (Shalitin et al., 2024). In Austria, obesity at baseline was not associated with a significantly greater BMI gain during the restrictions; nevertheless, unlike children in the other weight categories, children with obesity continued to gain weight after restrictions were lifted and showed no evidence of normalization (Irschik et al., 2023). Conversely, the US ECHO study found that baseline obesity was associated with a higher risk of excessive BMI gain during the pandemic (Knapp et al., 2022). These discrepancies may reflect differences in age distribution, study setting, outcome standardization, follow-up duration, and regression to the mean (Alhakami et al., 2025; Irschik et al., 2023; Knapp et al., 2022; Shalitin et al., 2024).

Socioeconomic and geographic associations were similarly context-dependent. In Austria, higher parental education was associated with less weight gain during the restrictions, whereas household income was not associated with BMI change (Irschik et al., 2023). In Israel, BMI-SDS remained highest in the lowest socioeconomic-position group, although post-pandemic trajectories did not follow a simple socioeconomic gradient: BMI-SDS decreased slightly in the low- and medium-position groups but increased slightly in the high-position group (Shalitin et al., 2024). In Sweden, aggregated regional indicators of lower education, lower income, and a higher prevalence of single-parent households were associated with a higher combined prevalence of overweight or obesity in all three cohorts. Regional childhood poverty was associated with a higher prevalence during and after the pandemic, but not before it; because the analysis was ecological, these findings cannot be interpreted as individual-level associations (Nylander et al., 2025). Geographic inequalities also persisted in South Korea, where adolescents living in rural and non-capital regions had consistently higher mean BMI values (Ha, 2025).

Supplementary studies further emphasize the importance of pre-existing inequality. Higher household income was associated with a lower risk of excessive BMI gain in the ECHO cohort (Knapp et al., 2022), whereas in the ABCD cohort the association between lower family income and greater pandemic-related weight gain was observed among girls but not boys (Betts et al., 2023). Larger increases in obesity prevalence were also found among racially and ethnically minoritized children living in neighborhoods characterized by greater social vulnerability and lower collective efficacy (Min et al., 2024). These patterns are more plausibly interpreted as reflecting unequal access

to material, social, and environmental resources than intrinsic biological susceptibility of particular groups.

Overall, pandemic-related changes in weight status may have reflected interactions among age, baseline weight status, disruption of daily structure, the home environment, and socioeconomic and geographic inequalities. However, none of these factors consistently explained the differences across all populations. The observational design and methodological heterogeneity of the available evidence, together with the lack of concurrent behavioral and anthropometric measurements in several studies, preclude firm causal conclusions (Alhakami et al., 2025; Androutsos et al., 2021; Basterfield et al., 2024; Berisha et al., 2025; Betts et al., 2023; Brazendale et al., 2022; Cheng et al., 2024; Fäldt et al., 2024; Ganzar et al., 2022; Ha, 2025; Irschik et al., 2023; Knapp et al., 2022; McCabe et al., 2024; Min et al., 2024; Nylander et al., 2025; Pietrobelli et al., 2020; Shalitin et al., 2024; Takaya et al., 2023).

4.3 Health problems associated with pediatric obesity

Childhood obesity frequently persists into adolescence and adulthood. Longitudinal data indicate that children and adolescents with obesity are approximately five times more likely to remain obese as adults than their normal-weight peers, and this tracking effect strengthens with both the severity and duration of excess weight during childhood (Simmonds et al., 2016). Beyond the persistence of adiposity itself, childhood BMI has been shown to predict a range of obesity-related morbidities later in life, including a moderately increased incidence of adult diabetes and coronary heart disease, even though the majority of individual cases of adult disease originate outside the pediatric overweight group (Llewellyn et al., 2016).

The metabolic consequences of pediatric obesity are, however, already measurable well before adulthood. Pediatric obesity markedly increases the risk of impaired glucose metabolism, including insulin resistance, prediabetes, and type 2 diabetes. Meta-analytic evidence indicates that the prevalence of type 2 diabetes among children and adolescents with obesity is approximately thirteen times higher than among their normal-weight peers, accompanied by a three-fold higher prevalence of prediabetes and consistently elevated fasting insulin, HbA1c, and HOMA-IR values (He et al., 2022). In addition, childhood obesity is frequently accompanied by dyslipidemia, characterized by elevated triglyceride concentrations, reduced high-density lipoprotein cholesterol, and increased levels of atherogenic lipoproteins, further amplifying long-term cardiovascular risk (Mosca et al., 2022). These metabolic abnormalities rarely occur in isolation. Rather, they represent interconnected manifestations of cardiometabolic dysfunction, with childhood obesity serving as the principal driver of pediatric metabolic syndrome. In 2020, metabolic syndrome was estimated to affect approximately 3% of children and 5% of adolescents worldwide, corresponding to 25.8 million children and 35.5 million adolescents globally (Noubiap et al., 2022).

Elevated blood pressure follows a similar pattern. Pediatric obesity is consistently identified as one of the strongest correlates of childhood hypertension in global epidemiological data, and the two conditions frequently co-occur well before either becomes clinically apparent (Song et al., 2019). Excess adiposity contributes to elevated blood pressure through multiple mechanisms, including insulin resistance, chronic low-grade inflammation, activation of the sympathetic nervous system, and dysregulation of the renin–angiotensin–aldosterone system (Brady, 2017).

Finally, the liver is among the organs most sensitive to excess adiposity in youth. Current estimates place the prevalence of non-alcoholic fatty liver disease at roughly one in four children with obesity, making it the most common chronic liver condition in this population and a growing driver of pediatric hepatology referrals (Shapiro et al., 2021). Importantly, NAFLD is now recognized as the hepatic manifestation of metabolic dysfunction and may progress to steatohepatitis, fibrosis, and, in rare cases, cirrhosis, even during adolescence (Brecelj & Orel, 2021).

4.4 Clinical implications

Despite substantial heterogeneity across the included studies, several practical implications emerge. Persistent elevation of BMI-related measures in some populations suggests that pandemic-associated weight gain should not be assumed to resolve spontaneously. Routine growth monitoring should therefore remain a priority, particularly for older children and adolescents, children with established obesity, and those from socioeconomically or geographically disadvantaged populations, although these associations were not consistent across all studies.

Children with a sustained unfavorable BMI trajectory should be evaluated according to established pediatric overweight and obesity guidelines. This should include assessment of blood pressure, lifestyle factors, family history, and signs of obesity-related complications. Metabolic testing, including assessment of glucose metabolism, lipid profile, and liver function, may be appropriate when indicated by age, obesity severity, clinical findings, and additional cardiometabolic risk factors. However, previous exposure to pandemic restrictions alone should not be considered an indication for laboratory screening.

The findings also support monitoring physical activity and fitness alongside body weight. Resumption of organized sport in the Austrian study was associated with a more favorable post-restriction BMI trajectory, while the English and Chinese studies showed that recovery of physical fitness accompanied more favorable BMI-related outcomes (Brady, 2017; Noubiap et al., 2022; Song et al., 2019). These observational findings should be interpreted cautiously but support encouraging a return to regular structured and outdoor activity after prolonged periods of inactivity.

Finally, socioeconomic and geographic differences indicate that universal interventions may not reach all children equally. Future public-health responses should aim to preserve access to school meals, structured physical activity, outdoor time, and regular daily routines during disruptions. Targeted recovery programs may be particularly important in underserved communities and for children whose excess weight or reduced fitness persists after normal schooling and activities resume.

4.5 Strengths and limitations

Several methodological features strengthen the interpretation of the present review. It addresses an important clinical and public health question regarding whether pandemic-associated weight gain in children represents a transient disturbance or a more persistent alteration in growth trajectories. Unlike many previous reviews that focused primarily on weight changes during lockdown, the present review required evidence from three predefined time points (pre-pandemic, during restrictions, and after restriction easing), allowing evaluation of post-restriction trajectories rather than short-term changes alone. The literature search covered three major databases (PubMed, Scopus, and the Cochrane Library), followed predefined PICO-based eligibility criteria, and was supplemented by backward citation searching. Study selection was performed independently by two reviewers, with disagreements resolved by a third reviewer, thereby reducing the risk of selection bias. In addition, all included studies were based on directly measured or routinely recorded height and weight rather than self- or parent-reported anthropometric data, improving the reliability of the reported weight-related outcomes.

Several limitations should also be considered when interpreting the findings. The review was not prospectively registered, and no formal risk-of-bias assessment (e.g., Newcastle-Ottawa Scale, RoB 2, ROBINS-I, or JBI critical appraisal tools) was performed. Although data extraction followed a standardized protocol, it was distributed among members of the author team rather than independently duplicated for every included study. Considerable heterogeneity in study design, data sources, follow-up duration, outcome definitions, and the growth references used to classify weight status (IOTF, WHO, CDC, and country-specific standards) precluded quantitative synthesis. Furthermore, all included studies were observational; therefore, residual confounding cannot be excluded and causal inferences regarding the effects of pandemic-related restrictions on pediatric

weight trajectories cannot be established. The available evidence originated predominantly from high-income countries, with only one upper-middle-income country (China) represented, limiting the generalizability of the findings to lower-resource settings. In addition, the minimum required follow-up of six months after restriction easing may still be insufficient to distinguish sustained changes in growth trajectories from delayed normalization. Finally, publication bias remains possible, as studies reporting persistent adverse outcomes may have been more likely to reach publication than studies demonstrating complete recovery.

4.6 Research recommendations

Given the limitations identified in this review, future research should focus on several key areas. First, longitudinal cohort studies with extended follow-up periods, going beyond the first 2–3 years after the pandemic, are needed to determine whether the observed weight gain among children and adolescents persists over time, resolves spontaneously, or continues to worsen during adolescence and early adulthood. Second, the majority of currently available evidence originates from the lockdown period and its immediate aftermath, while studies reflecting present, more stabilized social and educational conditions (including lasting changes in leisure-time organization and screen-use habits) are lacking. Comparative studies encompassing the pre-pandemic, pandemic, and current periods, employing consistent methodology, would therefore be valuable. Third, standardization of the definitions of overweight and obesity (e.g., through consistent application of WHO, CDC, or IOTF criteria) and of age- and sex-adjusted BMI z-score cut-off points is needed to improve comparability across studies and enable robust future meta-analyses. Finally, future research should be based on large, population-representative samples encompassing diverse socioeconomic and geographic groups, including data from low- and middle-income countries, which remain significantly underrepresented in the current literature.

5. Conclusions

This systematically informed narrative review of ten studies from nine countries indicates that the COVID-19 pandemic and related disruptions were generally associated with increases in BMI-related measures and the prevalence of overweight or obesity among children and adolescents. However, the magnitude and direction of change varied according to age, baseline weight status, sex, and socioeconomic or geographic context. Post-restriction trajectories were also heterogeneous. Some populations returned partially or fully to pre-pandemic levels, whereas persistent or renewed elevations were observed in others, particularly among some older children, adolescents, and children with established obesity.

Because the included studies differed substantially in design, population, outcome definitions, restriction context, and follow-up duration, the findings should be interpreted as evidence of association rather than direct causation, and quantitative pooling was not appropriate. Nevertheless, the recurrence of unfavorable weight-related changes across diverse settings supports continued monitoring of pediatric growth and weight status, with particular attention to children showing persistent adverse trajectories and to populations facing socioeconomic or geographic disadvantage.

Further longitudinal studies using standardized definitions and extended follow-up are needed to determine whether these changes persist into later adolescence and adulthood and to guide responses to future public-health disruptions affecting children.

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