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REVIEW ARTICLE

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Childhood obesity and metabolic syndrome: a systematic review

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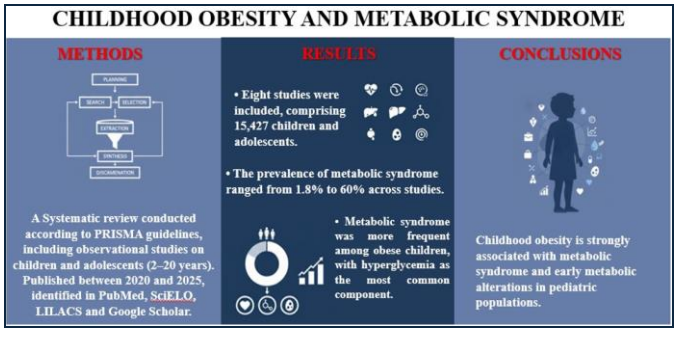
Abstract

Childhood obesity holds great relevance in the global health panorama, being a problem that continues to rise. Such a condition is directly associated with metabolic disorders, triggering **metabolic syndrome (MS)**, which results in several factors such as insulin resistance, dyslipidemia, arterial hypertension, and an increased risk of other comorbidities, such as type 2 diabetes and cardiovascular diseases. This systematic review aims to analyze factors such as prevalence, diagnostic criteria, and main risk factors, using scientific databases to select literature consistent with the proposed theme.

Keywords: Childhood obesity. Overweight. Prevalence.

Graphical Abstract



Source: Own authorship.

Introduction

Childhood Obesity (CO) is classified according to the World Health Organization (WHO) as an increase in body weight in children that does not adequately follow the growth curve, according to health guidelines, presents a Body Mass Index (BMI) higher than expected on the Z-score, which determines body weight according to the age and height of the child and adolescent **[1]**.

This is associated with complications referred to as Metabolic Syndrome (MS), that is, a set of factors that dysregulates the proper functioning of human systems, such as alterations in glycemic control, which leads to insulin resistance up to type 2 diabetes, associated with at least two factors: hypertension, dyslipidemia, central obesity, and microalbuminuria, and has presented alarming numbers and constant growth, both in countries that retain great economic power **[2]**, such as the United States, which, in recent decades, recorded an increase in the proportion of children and adolescents who suffer from extreme obesity and consequent metabolic dysfunctions, which entail high cardiometabolic risk in pediatric populations **[3]**.

As for countries with lower socioeconomic development, this is what recent studies show, in which the surveys presented reveal a presence in various areas of the globe, which present alarming numbers of overweight and/or obesity in small age ranges, pointing to children and adolescents as the

target of this occurrence, associating them inevitably with metabolic syndrome **[4-6]**.

It is important to analyze the relevance of studying this topic, since early metabolic alterations are strongly linked, clinically and epidemiologically, to increased adiposity from the first years of life until the beginning of the next phase, approximately 20 years of age, which may continue into adulthood and contribute to cardiometabolic morbidities soon for the individual with childhood obesity **[7-8]**.

For the medical problem to be mitigated, the need for clinical guidelines is emphasized, which are based on the identification and subsequent early management of pediatric obesity, through routine care, in order to reduce the chances of the problem being effectively related to metabolic syndrome, in addition to decreasing the risk of developing future comorbidities related to increased weight in youth **[6]**. Analyses including Brazil and other countries reveal, in large cohort studies as well as regional ones, that lifestyle and anthropometric markers are highly interconnected with the metabolic syndrome phenotype in young people; while emerging indices and biomarker-based approaches have been evaluated regarding their predictive utility in pediatric obesity **[9-12]**.

To change the current context, it is necessary to understand the studies conducted in endocrionopediatric patients, which show the correlation of children and adolescents who are victims of metabolic syndrome, or, to a lesser degree, metabolic dysfunctions related to increased weight, present in various contexts, highlighting the importance of guiding preservation and conducting a retention of damage, using an epidemiological synthesis to achieve such a feat **[10-12]**.

Metabolic syndrome, better explained, refers to the accumulation of correlated cardiometabolic abnormalities, in addition to increased triglycerides, central adiposity, dyslipidemia, reduction of high-density lipoprotein cholesterol, and elevation of blood pressure **[8,10]**. In pediatrics, the grouping of dysfunctions becomes essential to understand the mechanism of metabolic syndrome; thus, the components become more evident than when analyzed in isolation **[7,11]**.

Pediatric studies conducted in Brazilian territory described a recognizable MS phenotype among adolescents, with prevalence estimates varying according to the definition and the population **[12,13]**. Subsequently, research showed that a pattern similar to MS can be detected before adulthood, important for measuring and driving efforts with the purpose of reducing risks in children and adolescents with obesity **[14]**.

Despite all advances in science with studies related to the topic, important gaps still exist, for example, that the comparability of estimates of pediatric MS and its relationship with obesity is limited by the heterogeneity of diagnostic criteria and operational definitions, including the ongoing debate about "the real" definition of MS in children and adolescents and about the adequacy of consensus criteria across different phases of development **[10,11]**.

Another example is the heterogeneity regarding the classification of obesity, which presents different margins to determine overweight or obesity, both in the absence of identification of a universal standard and by using different methods to construct the ideal curve, which is seen in studies in which BMI can be determined by the WHO with the Z-score or with the international cutoffs of the International Obesity Task Force (IOTF) **[1]**; thus, individuals with the same BMI, age, and sex may be classified divergently, fitting or not fitting with weight above what is expected. This reality ends up interfering negatively in literature reviews, hindering comparability and the construction of more concrete facts, the comparison between subgroups, and combined estimates **[15-18]**, resulting in difficulty in constructing a curve that references subsequent pediatric studies related to MS. Thus, methodological requirements are not met, postponing an idealization of analysis standards between population and age **[19,20]**. Therefore, this inconsistency contributes to the prevalence of the situation and limits the practice of resolutive public policies **[4,5,14]**.

It is important to recall that, although the study in question contributes to science, possible prevention and treatment, there are still gaps that deserve attention, such as heterogeneities and definitions regarding the classification of obesity, differences in study designs, and regional variability in underlying risk profiles **[10,11,15-20]**.

This review aimed to investigate the association between childhood obesity and the development of metabolic syndrome**,** and to analyze the prevalence and clinical impact of this association in different pediatric populations.

Methods

Guidelines

This systematic literature review was conducted following the criteria established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), available at: https://www.prisma-statement.org/, with database searches carried out between July and August 2025.

Search Strategy

The studies included were searched in the following databases: PubMed, SciELO, Latin American and Caribbean Health Sciences Literature (LILACS), and Google Scholar, covering the years 2020 to 2025. The search terms used in Portuguese, Spanish, and English referred to obesity and its prevalence in childhood and were: "childhood obesity", "overweight" "Overweight in children", "overweight in adolescents", "prevalence". The descriptors were adapted according to each database. Eligible studies were observational ones involving children and adolescents of any age, which included the prevalence of excess weight in this age group assessed through anthropometric evaluation. The selection of studies by title and abstract was carried out by three independent reviewers.

Eligibility Criteria

The guiding question of this review was formulated based on the **PICO strategy**, as follows:

- **Population:** Children and adolescents
- **Intervention:** Obesity assessed through Body Mass Index (BMI) calculation
- **Comparison:** Children with normal weight
- **Outcome:** Presence of metabolic syndrome

Qualitative studies, case reports, review articles, randomized clinical trials, instrument validation studies, and studies without an assessment of overweight prevalence in children and adolescents were excluded. The analyzed article characteristics included sample size, design, location, survey, and age range.

Data Extraction

The articles found in the databases were exported to the Rayyan reference manager. After exportation, three independent reviewers removed duplicates and screened titles and abstracts to decide on inclusion or exclusion from the sample.

Bias Analysis

The JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data was used to assess the risk of bias of the included studies. Available at: https://jbi.global/critical-appraisaltools. Accessed on: August 2025. This tool consists of nine questions:

1. Was a representative sample of the population included?
2. Was the sample recruited appropriately?
3. Was the sample size adequate?
4. Were the study participants and setting described in detail?
5. Was the data analysis conducted with sufficient coverage of the sample?
6. Were valid methods used for the identification of the condition?
7. Was the condition measured in a standard and reliable way for all participants?
8. Was appropriate statistical analysis used?
9. Were the study objectives clearly addressed?

The possible answers were "yes," "no," "unclear," and "not applicable." The overall quality of the included studies was judged based on criteria recommended by Porritt et al. (2014). Each "yes" answer scored one point, while "no," "unclear," and "not applicable" scored zero. The total score determined the risk of bias as follows:

- **0–3 points:** high risk of bias
- **4–6 points:** moderate risk of bias
- **7–9 points:** low risk of bias

As this review used only previously published data, it did not involve human subjects or personal information and therefore did not require approval by an ethics committee.

Results

Initially, 268 studies were identified in the databases, of which 41 were excluded due to duplication. Of the remaining 245, 213 were excluded after reading the titles in full, leaving 32, of which 24 were excluded after full-text reading. Thus, 8 articles were finally included after applying inclusion and exclusion criteria, as demonstrated in the PRISMA flow diagram (Figure 1).

The figure shows the steps of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), divided into identification (starting with 286 publications), screening (decreases to 32 articles) and included (narrows down to 8 studies).

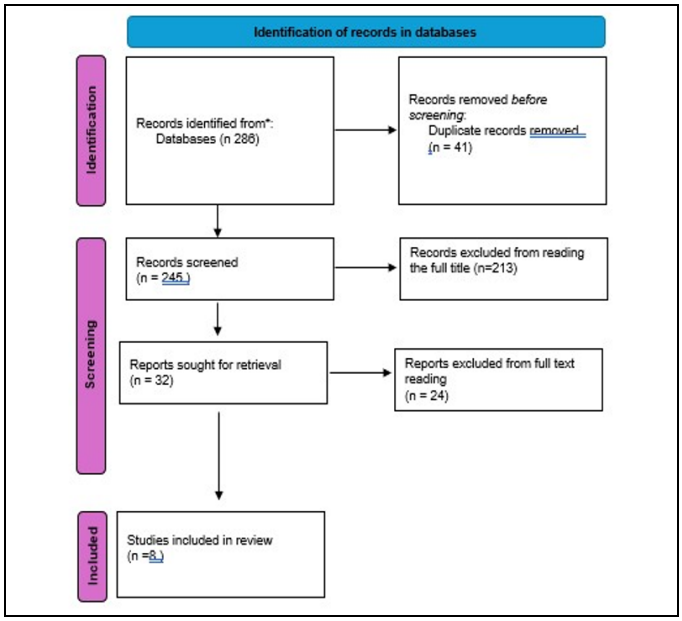


Figure 1. Flow Diagram of Study Selection Process. Source: Own authorship.

Based on the database search, eight articles addressing the association between childhood obesity and metabolic syndrome were included in this review. Most of the studies had a cross-sectional design, with only one being retrospective. The publication years ranged from 2014 to 2025. The studies covered Latin American countries (Brazil, Chile, Mexico) and European countries (Sweden, Germany, Hungary, Cyprus, Spain, Belgium, Estonia, and Poland), as shown in the table below.

The target population of the included studies comprised children and adolescents of both sexes, aged between 2 and 20 years. The sample sizes ranged from 120 to 12,319 participants per study. Among them, there were 1,063 girls, 1,028 boys, and 13,336 participants of unidentified sex, totaling a sample of 15,427 children and adolescents. Some studies included obese participants as part of the inclusion criteria (Table 1).

Regarding the diagnostic criteria for obesity, the studies showed convergence in using parameters from the IOTF (International Obesity Task Force) and the WHO 2007 classification. Additionally, some studies applied the Quelet formula and the WHO growth charts, using Body Mass Index (BMI) as the main reference for assessment. For metabolic syndrome, the diagnostic criteria used included IDEFICS, IDF, NCEP-ATP III, and the modified ATP III for children and adolescents (Table 1).

Across the studies, obesity and overweight were prevalent in most of the analyzed populations. The prevalence of metabolic syndrome varied widely among studies, ranging from 1.8% to 60%. Hyperglycemia was the most frequent component, and the syndrome was shown to be more strongly associated with obese individuals (Table 1). The main factors associated with obesity and metabolic syndrome, as analyzed in the studies, were age, sex, obesity, birth weight, blood glucose, insulin resistance, low intake of fruits and vegetables, visceral circumference, and high cholesterol levels.

The confounding variables identified were related to age, sex, type of stratified analysis, age group, weight, and BMI. Another relevant aspect in the selected studies was the methodological quality, assessed using the JBI/STROBE (Joanna Briggs Institute / Strengthening the Reporting of Observational Studies in Epidemiology) tools. Among the included studies, two were classified as high quality, while seven were of moderate quality.

In Table 1, on each line of the x-axis, the data from each study included in the article are selected. The y-axis presents the analysis categories, such as: year, authors and country of the study, study design (mostly cross-sectional studies), target population (children and adolescentes between 2 and 17 years old), sample size, diagnostic criteria for obesity (mainly IOTF), percentual prevalence of obesity and metabolic syndrome (variable in each study), main associated factors (such as age, obesity and sex), statistical adjustments (body mass index, economic status, among others) and the methodological quality analysed by JBI/STROBE checklist (all presented moderate or high quality).

Table 1. Data extraction from the included studies.

FIRST VARIABLES					
Year /author	**Country/ Location**	**Study design**	**Target population (age, sex)**	**Sample size (n)**	**Diagnostic criteria for obesity**
Ahrens et al., 2014 (IDEFICS)	Sweden, Germany, Hungary, Italy, Cyprus, Spain, Belgium, Estonia	Cross-sectional study	Children age 2-10 years, both sexes	≈18,169 (IDEFICS); complete analyses n=12,319	IOTF
Oliveira and Guedes, 2019	Brazil, Panama	Cross-sectional study	Adolescents aged 12–20 years, both sexes	1,035 (565 girls, 470 boys)	IOTF (BMI by age and sex)
Ávila-Curiel et al., 2018	Mexico, State of Mexico	Cross-sectional study	Children aged 6– 12 years, both sexes	1,017 (109 normal weight, 137 overweight, 771 obese)	IOTF (BMI by age and sex) WHO 2007 (BMI-forage, Zscore)
Jankowska et al., 2021	Poland, Gdańsk	Cross-sectional study	Obese children aged 10–12 years, both sexes	591 (275 girls, 316 boys)	≥95th BMI percentile on Polish (WHO) growth charts
Enrique Romero Valverde et al,.2015	Mexico	Cross-sectional study	Obese children aged 7–13 years, both sexes	120 (72 boys, 48 girls)	Body Mass Index (BMI) > 2.0 standard deviations (SD) for age and sex using the WHO (2007) reference standard
Valle-Leal Jaime, et al. 2016	Mexico	Cross-sectional study	Children aged 6– 12 years	223 (117 boys, 106 girls)	BMI Quetelet formula
Cesar Osorio-Fuentealba, et al. 2025	Chile	Retrospective study	Children aged 7– 17 years	122 (69 girls, 53 boys)	not cited
SECOND VARIABLES					
Diagnostic criteria for metabolic syndrome	**Prevalence of obesity (%)**	**Prevalence of MS (%)**	**Main associated factors**	**Statistical adjustments (confounding variables)**	**Methodological quality (JBI/ STROBE)**
Cook et al. (adapted NCEPATP III), Viner et al., pediatric IDF, and new IDEFICS proposal (≥3 components above p90/p95)	Variable (classification by percentiles, single value not provided); overweight/obesity grouped	0.4% (IDF) to 5.5% (new IDEFICS definition); 1.8% (conservative definition)	Age, sex, obesity, BP percentiles, glucose, lipids; MS more common in obese individuals	Age, sex, weight, stratified analyses	High
IDF (pediatric criteria: waist circumference + 2 other metabolic factors)	Not detailed in the article (but obesity associated with risk of MS, OR = 1.62)	4.5% (95% CI: 3.8–5.4)	Older age, higher economic status, long screen time, low fruit/vegetable intake, obesity	Age, sex, economic status, BMI	High
Cook et al. 2003 modified for children/adolescents NCEP-ATP III)	≈76% (771 out of 1,017 were obese)	43.9% (54.6% among obese individuals)	Obesity (OR = 8.62), insulin resistance, atherogenic risk	Age, sex, and age group	Moderate
IDF: waist circumference >90th percentile + ≥2 metabolic factors (HDL, TG, glucose, BP)	32.1% obese; 67.9% overweight	12.9% (76/591 obese children)	Male sex, parental obesity, low birth weight, skipping breakfast/ dinner	Sex; nonparametric tests	Moderate
Modified ATP III for children and adolescents (three or more) Modified WHO for children and adolescents (three or more) International Diabetes Federation (IDF) (waist circumference ≥ 90th percentile and two or more)	Boys: 60.3% overweight, 26.3% obese Girls: 26% overweight, 53% obese	Using WHO and ATP III, prevalence ranged from 40–48% in men and 50–60% in women. According to IDF, it was 33% in men and 42% in women.	High birth weight and the presence of insulin resistance	Sex, birth weight, BMI	Moderate

Unicel DXC 600, Beckman Coulter	52% obese	Percentile >85: 100%: hyperglycemia 93%: hypercholesterole mia 76%: hypertriglyceride mia	Obesity, hypertriglyceridemia, hyperglycemia, hypercholesterolemia, and abdominal circumference	Sex, age, weight, BMI	Moderate
Cook et al. 2003	Overweight: 34 Obese: 57 Severe obesity: 31	40.1% (36.6% in obese and 77.6% in severe obesity)	Visceral adipose tissue accumulation, cholesterol, fasting insulin	Age, weight, height, BMI, waist circumferen ce, blood pressure, HDL	Moderate

Source: Own Authorship.

Discussion

Childhood obesity has become one of the main global public health problems, presenting a close relationship with the early development of metabolic syndrome (MS). The analysis of the studies included in this review reveals that the prevalence of obesity and MS among children and adolescents varies widely across populations, reflecting methodological, cultural, and socioeconomic differences.

The findings by Ahrens et al. (2014) **[14]**, from the multicenter European IDEFICS study, showed a prevalence of metabolic syndrome ranging from 0.4% to 5.5%, depending on the diagnostic criteria used, with higher frequencies observed among obese children. This highlights the decisive influence of excess weight on metabolic components and reinforces the need for standardized diagnostic criteria for the pediatric age group.

Similarly, Oliveira and Guedes (2019) **[21]** found a significant association between obesity, longer screen time, low fruit and vegetable intake, and an increased risk of MS in Brazilian adolescents. The observed prevalence of 4.5% confirms the growing trend of the problem in emerging countries, especially in urban populations with greater access to ultra-processed foods and sedentary habits.

In the Latin American context, studies conducted in Mexico **[22-24]** reported high prevalences of MS (33% to 60%), mainly associated with insulin resistance, dyslipidemia, and central obesity. These results suggest that genetic and environmental factors, such as hypercaloric diets and low physical activity levels, contribute to worsening the metabolic condition in obese children.

In Poland, Jankowska et al. (2021) **[25]** found a prevalence of 12.9% among obese children, with higher risk for males and for those with a family history of obesity and poor eating habits, such as skipping meals. These data reinforce the influence of behavioral and familial factors in the genesis of obesity and its metabolic complications.

The Chilean study by Osorio-Fuentealba et al. (2025) **[26]** reported a prevalence of 40.1%, showing a strong relationship with visceral adiposity, elevated fasting insulin, and dyslipidemias. The high frequency among individuals with severe obesity (77.6%) confirms the progressive association between the degree of adiposity and metabolic dysfunction.

Overall, most studies used a cross-sectional design, which limits causal inference. However, the consistency of findings regarding the association between obesity and metabolic syndrome across different populations strengthens the robustness of the evidence. In addition, there is notable heterogeneity in diagnostic criteria, such as IOTF, WHO 2007, IDF, and modified NCEP-ATP III, which makes direct comparison and global prevalence estimation difficult **[27-34]**.

Therefore, the analyzed studies indicate that childhood obesity is an important risk factor for the development of metabolic syndrome, influenced by biological, behavioral, and socioeconomic determinants. Early interventions promoting healthy eating habits, physical activity, and screen time control are essential to reduce the progression of this condition and its long-term repercussions.

Limitations

With regard to the methodological aspects of the present study, the study has limitations inherent to the design of a systematic review. Thus, no primary data were collected, so the results depend on the methodological quality of the included studies. In addition, heterogeneity was observed among the articles regarding the age groups of the children, the diagnostic criteria for obesity and metabolic syndrome, the assessment methods, and the geographical contexts, which limits the comparability of the findings and the generalization of the results. Furthermore, the sample size corresponds to the number of studies included after applying the search strategy and eligibility criteria. Therefore, no statistical calculation of sample size was performed, as this procedure does not apply to this type of study. The adequacy of the sample was determined by the methodological rigor of the selection process, conducted in accordance with PRISMA guidelines, ensuring a comprehensive and critical synthesis of the available evidence.

Conclusion

This review highlights childhood excess weight as a major risk factor for early metabolic disorders, with strong associations to insulin resistance, dyslipidemia, hypertension, and visceral adiposity. Behavioral, genetic, and socioeconomic factors significantly influence these metabolic alterations. Despite methodological variability across studies, the findings

emphasize the need for standardized pediatric diagnostic criteria and the implementation of public health strategies focused on healthy lifestyles to prevent future metabolic complications.

CRediT

Author contributions: **Conceptualization -** Vitória de Oliveira Pagani, Isabela Monçalvarga, Juliana Salles Cantadori, Isabella Zolin de Almeida Lopes, Livia de Camargo Biasi, Mariana de Lima Sanches; **Data curation -** Vitória de Oliveira Pagani, Isabela Monçalvarga, Juliana Salles Cantadori, Isabella Zolin de Almeida Lopes; **Formal analysis-** Livia de Camargo Biasi, Mariana de Lima Sanches; **Investigation-** Vitória de Oliveira Pagani, Isabela Monçalvarga, Juliana Salles Cantadori, Isabella Zolin de Almeida Lopes, Livia de Camargo Biasi, Mariana de Lima Sanches; **Methodology-** Vitória de Oliveira Pagani, Isabela Monçalvarga; **Project administration-** Vitória de Oliveira Pagani; **Supervision-** Vitória de Oliveira Pagani; **Writing - original draft -** Vitória de Oliveira Pagani, Isabela Monçalvarga, Juliana Salles Cantadori, Isabella Zolin de Almeida Lopes, Livia de Camargo Biasi, Mariana de Lima Sanches; and **Writing-review & editing-** Vitória de Oliveira Pagani, Isabela Monçalvarga, Juliana Salles Cantadori, Isabella Zolin de Almeida Lopes, Livia de Camargo Biasi, Mariana de Lima Sanches.

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Ethical Approval

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Informed Consent

Not applicable.

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Data Sharing Statement

No additional data are available.

Conflict of Interest

The author declares no conflict of interest.

Similarity Check

It was applied by Ithenticate®.

Application of Artificial Intelligence (AI)

Not applicable.

Peer Review Process

It was performed.

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