Research Article

Prevalence of Metabolic Syndrome among Children and Adolescents in High-Income Countries: A Systematic Review and Meta-Analysis of Observational Studies

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Introduction. Metabolic syndrome (MetS) is an assemblage of interconnected cardiovascular risk factors that are prevalent among children and adolescents in high-income countries (HICs). Despite the presence of several studies on the issue, the study findings are incongruent due to the absence of a gold standard diagnostic method of MetS in children. Thus, the findings of the original studies are inconclusive for policy makers and other stakeholders. This systematic review and meta-analysis is aimed at giving conclusive evidence about MetS among children and adolescents in HICs. Methods. We conducted searches using electronic databases (PubMed, Scopus, Web of Science, CINAHL (EBSCOhost), EMBASE (Elsevier), and Medline (EBSCOhost)) and other sources (Google Scholar and Google) up to September 2020. Observational studies reporting the prevalence of MetS were eligible in this study. The pooled estimates were computed in fixed and random effect models using six diagnostic methods (IDF, ATP III, de Ferranti et al., WHO, Weiss et al., and Cruz and Goran). Publication bias was verified using funnel plots and Egger’s regression tests. Subgroup and sensitivity analysis were performed in case of higher heterogeneities among the included studies. Results. In this study, 77 studies with a total population of 125,445 children and adolescents were used in the final analysis. Metabolic syndrome among the overweight and obese population was computed from 28 studies with the pooled prevalence of 25.25%, 24.47%, 39.41%, 29.52%, and 33.36% in IDF, ATP III, de Ferranti et al., WHO, Weiss et al., and Cruz and Goran, respectively. Likewise, 49 studies were eligible to compute the pooled prevalence of MetS in the general population of children and adolescents. Hence, MetS was found in 3.70% (IDF), 5.40% (ATP III), 14.78% (de Ferranti et al.), 3.90% (WHO), and, 4.66% (Cruz and Goran) of study participants. Regarding the components of MetS, abdominal obesity in the overweight and obese population, and low HDL-C in the general population were the most common components. Besides, the prevalence of Mets among males was higher than females. Conclusion. This study demonstrates that MetS among children and adolescents is undoubtedly high in HICs. The prevalence of MetS is higher among males than females. Community-based social and behavioral change communications need to be designed to promote healthy eating behaviors and physical activities. Prospective cohort studies could also help to explore all possible risk factors of MetS and to design specific interventions accordingly.
1. Introduction

Metabolic syndrome (MetS) is an assemblage of interconnected cardiovascular risk factors of metabolic origin [1]. Elevated triglycerides (TG), altered glucose metabolism, reduced high-density lipoprotein cholesterol (HDL-C), and elevated blood pressure (BP) and adiposity are the main risk factors [2]. It is primarily caused by insulin resistance due to abnormal cellular metabolism, leading to diabetes mellitus, increased uric acid level, hepatic steatosis, polycystic ovary syndrome, and obstructive sleep apnea [3–8].

The definition of MetS in children and adolescents remains unclear due to the absence of gold standard diagnostic criteria of MetS for the pediatric population [9]. Some of the diagnostic criteria used by studies include the International Diabetes Federation (IDF) criteria [10], the World Health Organization (WHO) criteria [11], the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) criteria modified for age [12], the de Ferranti et al. criteria [13], the Weiss et al. criteria [14], and the Cruz and Goran criteria [15].

Globally, an estimated 3.3% with a range of 0.2% to 38.9% of children and adolescents were expected to live with MetS. The prevalence was considerably higher in the overweight (11.9%) and obese (29.2%) population [9, 16, 17]. Likewise, the prevalence of MetS is remarkably higher in high-income countries (HICs) due to increasing trends of childhood obesity rates [18]. The rise in obesity in the past four decades could be primarily associated with related lifestyle factors such as routine consumption of fructose in the form of soft drinks, juice, and baked goods [19–22]. Thus, obesity increased MetS in children and adolescents from 6% to 39% [23].

Metabolic syndrome has been a global pandemic affecting children and adults [24]. The burden is significantly higher in the developed world posing a high economic burden on the health care system [25]. Cardiovascular and other metabolic complications are also common consequences of MetS in children [26]. In addition, MetS also negatively impacts the mental status and over all cognitive performance of children and adolescents [27]. In spite of the fact that multiple treatment strategies were designed and implemented, the prevalence of MetS remained high in most high-income countries with a remarkable variation among countries [28, 29]. Primary studies substantiated this by showing that the prevalence of MetS in the general population ranged from 0.4% [30] to 24% [31]. Similarly, the prevalence in the obese population ranged from 6% [32] to as high as 55.8% [33]. There is also considerable variation among the diagnostic methods of MetS in the pediatric population [34].

Though comprehensive systematic reviews and meta-analyses are vital for evidence-based decision making, they are scant in HICs where the burden of MetS is undoubtedly higher. Hence, this systematic review and meta-analysis is aimed at determining the pooled prevalence of MetS among children and adolescents in HICs and at giving conclusive evidence about its burden in these countries. The findings will be vital for policy makers and program planners in crafting preventive and treatment measures. The current findings will be supplementary for assessing the progress of sustainable development goals, specifically, ending all forms of malnutrition by 2030 [35]. In addition, the findings of this study will have a pivotal implication to conduct original studies on a multitude of factors related to high-burden MetS among the pediatric population.

2. Methods

2.1. Data Sources and Eligibility Criteria. Studies performed in HICs with the aim of identifying MetS among children and adolescents were included in this systematic review and meta-analysis. The eligibility of the studies was verified prior to inclusion to this study using study area, study setups, title, abstract, and full texts. The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guideline [36] was followed in the write-up process of the whole document. We explored national surveys and published and unpublished studies conducted in English. The reference lists of selected articles were also cross-checked for additional articles that were not found using search strings. Studies conducted until September 2020 were searched. Finally, observational studies reporting the prevalence of MetS among children and adolescents conducted both in clinical and community-based setups were included.

Conversely, studies with incomplete or unclear diagnostic methods and studies without full texts were excluded. We communicated with the corresponding authors using email before making the decision to exclude studies without full texts. Letters to editors, conference proceedings, and qualitative studies were also excluded. The EndNote X8 reference manager was used to manage the retrieved articles.

2.2. Search Strategies and Study Selection Process. A comprehensive search was performed by three investigators (ZWB, ZT, and TW), independently. Literature searches were conducted for studies published up to September 2020 using databases such as PubMed, Scopus, Web of Science, CINAHL (EBSCOhost), EMBASE (Elsevier), and Medline (EBSCOhost) as well as other sources (Google Scholar and Google). The following key terms were used for searching: (a) population (children, child, school age, and adolescent), (b) exposure (associated factors and risk factors), (c) outcome (metabolic syndrome, MetS, components of metabolic syndrome, and cardiovascular risk factors), (d) study design (cohort studies, cross-sectional studies, epidemiological, observational studies, and national health surveys), (e) study setting (school, community-based, surveys, and health institutions), and (f) location (high-income countries, HICs, developed countries, and names of high-income countries). The Boolean search operators “OR” and “AND” were used during the searching process, and the appropriateness of the key terms were checked before conducting the search in each of the explored databases. An example of a search string in PubMed is shown in Table 1.

2.3. Data Extraction Process. Data extraction was done by three authors (ZWB, AA, and TW) independently using a standardized data extraction checklist. The extraction
checklist was prepared using Microsoft Excel 2016. The checklist included the name of the author(s), publication year, study country, sample size, age of the study population, gender distribution of MetS, prevalence of MetS with different diagnostic methods, and components. Discrepancies between the three investigators in the extraction process were resolved through discussion and consensus. The other author (AA) cross-checked the studies and solved inconsistencies accordingly.

2.4. Quality Assessment of Studies. The qualities of the included studies were assessed by two authors (ZWB and AA), independently. Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Observational Studies was used for quality assessment [37]. The tool has four options (yes, no, unknown, and not applicable). One is given for yes, and zero was given for the other options. The scores were added up and changed to percentages. The minimum score was zero, and the maximum score was eight. Studies with >50% quality scores were included in this meta-analysis (Additional file 1).

The interrater agreement was computed by an author (ZT) after the critical appraisals and prior to the final decision of inclusion. The interrater agreement was computed using Cohen’s kappa coefficient (κ). The findings revealed that there was substantial agreement [38] between the two raters (κ = 0.784; p ≤ 0.001).

2.5. Summary Measures. Metabolic syndrome among children and adolescents in HICs with different diagnostic methods is the primary outcome of this study. The pooled prevalence of MetS was calculated in the general population and overweight and obese adolescents, separately. The general population included overweight, normal weight, overweight, and obese children and adolescents. The other outcomes were components of MetS and the pooled prevalence of MetS among the male and female population. The recent list of HICs was obtained from the World Bank database [39]. The prevalence was calculated by dividing the total number of events (MetS) to the total sample size and multiplying it by 100. The binomial distribution formula was used to compute the standard error for each original study. The pooled estimates were computed from prevalence and standard error of prevalence using the “metan” commands in the STATA (version 15) software. The pooled estimates were presented with their 95% CIs. The effect sizes were prevalence of MetS in HICs and the respective components.

Regarding the diagnostic criteria, the pooled estimates of MetS in HICs were computed using six diagnostic methods. The respective definitions are presented as follows. In the IDF diagnostic criteria, MetS is diagnosed if children aged between 10 and 16 years have central adiposity (≥90th centile) and two of the following: triglycerides (TG) ≥ 150 mg/dl, HDL − C < 40 mg/dl, systolic blood pressure (BP) ≥ 130 mmHg or diastolic BP ≥ 85 mmHg, and fasting plasma glucose (FG) ≥ 100 mg/dl or previously diagnosed type 2 diabetes [10]. Based on the WHO criteria, MetS is diagnosed when three or more of the following criteria are met: body mass index (BMI) > 95th percentile, hyperinsulinemia or impaired fasting glucose or impaired glucose tolerance, BP > 95th percentile, TG > 105/136 mg/dl (1.2/1.5 mmol/l) for children aged <10 and >10 years, respectively, and HDL − C < 35 mg/dl (0.9 mmol/l) [11]. Based on the NCEP-ATP

### Table 1: Search string used for searching articles from PubMed.

| Population | Outcome |
|------------|---------|
| (Children) OR (school children) OR ("Child\[Mesh\]) OR ("Adolescent\[Mesh\]) |
| ("Prevalence\[Mesh\] AND "epidemiology\[Subheading\]" AND ("Metabolic Syndrome\[Mesh\] (Subheading) AND ("Metabolic Syndrome\[Mesh\]) AND ("Child\[Mesh\]) OR (children) AND ("Adolescent\[Mesh\]) AND ("Developed Countries\[Mesh\]) OR ("high income countries\) OR ("Andorra\[Mesh\]) OR ("Antigua and Barbuda\[Mesh\]) OR ("Aruba\[Mesh\]) OR ("Australia\[Mesh\]) OR ("Austria\[Mesh\]) OR ("Bahamas\[Mesh\]) OR ("Bahrain\[Mesh\]) OR ("Barbados\[Mesh\]) OR ("Belgium\[Mesh\]) OR ("Bermuda\[Mesh\]) OR ("British Virgin Islands\[Mesh\]) OR ("Brunei\[Mesh\]) OR ("Canada\[Mesh\]) OR ("West Indies\[Mesh\]) OR ("Channel Islands\[Mesh\]) OR ("Chile\[Mesh\]) OR ("Croatia\[Mesh\]) OR ("Curacao\[Mesh\]) OR ("Cyprus\[Mesh\]) OR ("Czech Republic\[Mesh\]) OR ("Denmark\[Mesh\]) OR ("Estonia\[Mesh\]) OR ("Finland\[Mesh\]) OR ("France\[Mesh\]) OR ("Polynesia\[Mesh\]) OR ("Germany\[Mesh\]) OR ("Gibraltar\[Mesh\]) OR ("Greece\[Mesh\]) OR ("Greenland\[Mesh\]) OR ("Guam\[Mesh\]) OR ("Hong Kong\[Mesh\]) OR ("Hungary\[Mesh\]) OR ("Iceland\[Mesh\]) OR ("Ireland\[Mesh\]) OR ("Israel\[Mesh\]) OR ("Italy\[Mesh\]) OR ("Japan\[Mesh\]) OR ("Republic of Korea\[Mesh\]) OR ("Kuwait\[Mesh\]) OR ("Latvia\[Mesh\]) OR ("Liechtenstein\[Mesh\]) OR ("Lithuania\[Mesh\]) OR ("Luxembourg\[Mesh\]) OR ("Macau\[Mesh\]) OR ("Malta\[Mesh\]) OR ("Mauritius\[Mesh\]) OR ("Monaco\[Mesh\]) OR ("Micronesia\[Mesh\]) OR ("Netherlands\[Mesh\]) OR ("New Caledonia\[Mesh\]) OR ("New Zealand\[Mesh\]) OR ("Norway\[Mesh\]) OR ("Oman\[Mesh\]) OR ("Palau\[Mesh\]) OR ("Panama\[Mesh\]) OR ("Poland\[Mesh\]) OR ("Portugal\[Mesh\]) OR ("Puerto Rico\[Mesh\]) OR ("Romania\[Mesh\]) OR ("Qatar\[Mesh\]) OR ("San Marino\[Mesh\]) OR ("Saudi Arabia\[Mesh\]) OR ("Seychelles\[Mesh\]) OR ("Singapore\[Mesh\]) OR ("Slovakia\[Mesh\]) OR ("Slovenia\[Mesh\]) OR ("Spain\[Mesh\]) OR ("Saint Kitts and Nevis\[Mesh\]) OR ("Sint Maarten\[Mesh\]) OR ("Sweden\[Mesh\]) OR ("Switzerland\[Mesh\]) OR ("Taiwan\[Mesh\]) OR ("Tajikistan\[Mesh\]) OR ("United Kingdom\[Mesh\]) OR ("United States\[Mesh\]) OR ("Uruguay\[Mesh\]) OR ("United States Virgin Islands\[Mesh\]) Filters: Abstract, Observational Study, in the last 10 years, Humans, English, Child: 6-12 years, Adolescent: 13-18 years | Filters: free full text, observational study, in the last 10 years, humans, English, child: 6-12 years, adolescent: 13-18 years |
III criteria modified for age, MetS is diagnosed when three of the following criteria are met: TG ≥ 110 mg/dl; HDL – C ≤ 40 mg/dl; systolic BP or diastolic BP ≥ 90th percentile, waist circumference ≥ 90th percentile for age and gender, and FG ≥ 110 mg/dl [12]. According to de Ferranti et al., MetS is a clustering of at least three of the following criteria: FG ≥ 110 mg/dl; HDL – C ≤ 50 mg/dl (except in boys aged 15 to 19 years in whom the cut-off point is 45 mg/dl); TG ≥ 100 mg/dl; systolic BP > 90th percentile for gender, age, and height; and WC > 75th percentile for age and gender [13]. According to Cruz and Goran, MetS is defined as the presence of at least three of the following abnormalities: abdominal obesity (WC > 90th percentile for age and gender), hypertriglyceridemia (TG > 90th percentile for age and gender), low HDL-C (HDL – C < 10th percentile for age and gender), hypertension (systolic or diastolic blood pressure > 90th percentile adjusted for height, age, and gender), and impaired glucose tolerance [15]. Furthermore, Weiss et al. diagnosed MetS when three or more of the following are obtained: obesity (BMI ≥ 50 mg/dl; elevated BP (BP > 95th centile), low HDL-C (HDL – C < 5th centile), and high TG (TG > 95th centile) [14].

2.6. Statistical Methods and Analysis. In this meta-analysis, STATA version 15 (STATA Corporation, College Station Texas) software was used to calculate the pooled estimates. The pooled estimates were computed using both random and fixed effect models. In the presence of high heterogeneity among studies, the pooled estimates were computed using random effect models and were weighted using the inverse variance method. Subgroup analyses were performed using different parameters. The pooled estimates in the general and overweight and obese population were presented separately. For the subgroup analysis, data were extracted based on study continent, study country, and gender of study subjects. The appropriateness of each datum was verified before the analyses. Forest plots, summery tables, and texts were used to present the findings of this study.

2.7. Publication Bias and Heterogeneity. Publication bias was assessed using the funnel plot and Egger’s regression test at a 5% significant level [40]. Heterogeneity among included studies was explored using the forest plot, the $I^2$ test, and the Cochrane Q statistics [41]. The $I^2$ values of 25%, 50%, and 75% were interpreted as low, medium, and high heterogeneity, respectively [42]. In the present meta-analysis, significant heterogeneity was considered when the $I^2$ value was ≥50%, with a p value < 0.05. The possible sources of significant heterogeneity were addressed through subgroup and sensitivity analyses.

3. Results

3.1. Selection of Eligible Studies. We found 5514 studies in our initial search from reputable databases and grey literature sources. Primarily, 765 studies were duplicated files. A total of 4749 studies were screened using titles and abstracts, and 4648 were removed due to the fact that most of the results were unrelated to our objective. Finally, the full texts of 101 studies were assessed for eligibility criteria. Of 101 studies, 24 were excluded due to inconsistency of results [43–59], incompleteness of results [60–64], and publications not in English language [65, 66]. Seventy seven studies were included in the current systematic review and meta-analysis, of which 49 [13, 30, 31, 67–112] were used in computing the pooled prevalence of MetS in the general population and 29 [14, 15, 32, 33, 113–136] were used for estimating the pooled prevalence of MetS in overweight and obese study subjects (Figure 1).

3.2. Characteristics of the Included Studies. All studies included in this study were cross-sectional studies. Out of the total 77 studies, 49 studies were conducted among the general population of children and adolescents [13, 30, 31, 67–112]. The remaining 28 studies were performed in the overweight and obese population [14, 15, 32, 33, 113–136]. In this review, 125,445 study participants were included, of which 113,742 were from the general population and 11,703 were from the overweight and obese population. In the overweight and obese population, the sample size ranged from 97 [136] to 1241 [119] children. Likewise, the sample size in the general population ranged from 234 [111] to 12,147 [30]. The age range of study subjects in both groups was between 2 and 19 years. Regarding geographic distribution of studies, 34 studies were conducted in Europe, while 23, 16, 2, and 2 studies were conducted in Asia, USA, Canada, and Latin America, respectively. The quality of articles was also assessed using the JBI checklists. Thus, 48 studies were classified under medium quality, and 29 studies had high quality (Tables 2 and 3).

3.3. Metabolic Syndrome among Overweight and Obese Children and Adolescents. The pooled prevalence of MetS was estimated using five diagnostic methods (IDF, ATP III, de Ferranti, Weiss, and WHO). In the IDF diagnostic method, thirteen studies [32, 33, 119, 126, 128–132, 134–136] were used to compute the pooled prevalence of MetS (25.25%; 95% CI: 19.31, 31.19; $I^2 = 97.5%$; $p ≤ 0.001$). Regarding the components, abdominal obesity was found to be the most common component (65.62%; 95% CI: 47.09, 84.15; $I^2 = 99.4%$; $p ≤ 0.001$), and high FG level was the least common component (7.64%; 95% CI: 4.81, 10.46; $I^2 = 97.3%$; $p ≤ 0.001$). According to the ATP III method, the pooled prevalence of MetS was computed using 15 eligible studies [32, 113, 115, 116, 118–121, 123–127, 129, 133]. One quarter (24.47%; 95% CI: 19.87, 29.08; $I^2 = 94.9%$; $p ≤ 0.001$) of study subjects were diagnosed with MetS. Regarding the components, MetS, abdominal obesity was the most common component (79.8%; 95% CI: 67.39, 92.23; $I^2 = 99.5%$; $p ≤ 0.001$), and high FG level was the most infrequent component (7.77%; 95% CI: 5.53, 10.02; $I^2 = 96.3%$; $p ≤ 0.001$). The highest pooled prevalence of MetS (39.41%; 95% CI: 34.62, 44.22; $I^2 = 78.3%$; $p ≤ 0.001$) among the overweight and obese population was recorded in the de Ferranti diagnostic criteria, using three eligible studies [32, 115, 119]. Three quarters (75.72%; 95% CI: 67.29, 84.15; $I^2 = 96%$; $p ≤ 0.001$) of children and adolescents were found to have abdominal
obesity and only 1.61% (0.34, 2.88, 84.1%; p ≤ 0.01) of them had high FG level. According to the WHO diagnostic criteria, MetS was found in 29.52% (95%: 16.69, 42.35; $I^2 = 99.1%$; $p ≤ 0.001$) of the study population and it was computed from seven eligible studies [32, 114, 117, 119, 121, 83, 84, 86, 88, 93, 94, 98–101, 103, 104, 106, 108, 112]. Regarding the components of MetS, low HDL-C was the most prevalent component (23.41%; 95% CI: 14.71, 32.11; $I^2 = 99.8%; p ≤ 0.001$), whereas high TG level was the least prevalent component (7.10%; 95% CI: 4.72, 9.48; $I^2 = 98.4%; p ≤ 0.001$). Coming to the ATP III diagnostic method, the pooled prevalence of MetS was found to be 6.08% (95% CI: 5.08, 7.07; $I^2 = 98.2%; p ≤ 0.001$), and it was estimated from 33 studies [30, 31, 67–72, 74, 76–80, 83, 84, 86, 89–92, 95–98, 100–102, 105, 107–109, 111]. In this diagnostic method, elevated BP was the most common component (21.43%; 95% CI: 16.60, 26.25; $I^2 = 99.6%; p ≤ 0.001$) and high FG level (7.16%; 95% CI: 5.22, 9.11; $I^2 = 99.4%; p ≤ 0.001$) was the least common component. The highest (14.78%; 95% CI: 11.02, 18.54; $I^2 = 96.5; p ≤ 0.001$) pooled prevalence of MetS was recorded in the de Ferranti diagnostic criteria, which was computed from four eligible studies [13, 31, 78, 106]. In accordance with the Cruz and Goran diagnostic criteria, the pooled prevalence of MetS was computed from two studies [75, 78], and it was found to be 4.66% (95% CI: 3.29, 6.03; $I^2 = 76.6%; p ≤ 0.01$). Elevated BP was the most prevalent component (27.50%; 95% CI: 12.12, 42.89; $I^2 = 99.0; p ≤ 0.001$) of MetS, and abdominal obesity was the most infrequent component (10.06%; 95% CI: 7.12, 13.00; $I^2 = 89.6%; p ≤ 0.01$). Besides, the pooled prevalence of MetS was estimated using the WHO diagnostic method from three studies [68, 79, 110]. Accordingly, 3.90% (95% CI: 0.60, 7.20; $I^2 = 97.2; p ≤ 0.001$) of the study subjects were found to have MetS. The highest component

3.4. Metabolic Syndrome among the General Population of Children and Adolescents. In the general population of children and adolescents, the pooled prevalence of MetS was computed using the IDF, ATP III, de Ferranti, Cruz and Goran, and WHO diagnostic criteria. The pooled prevalence of MetS was estimated to be 3.70% (95% CI: 2.96, 4.44; $I^2 = 97.5%; p ≤ 0.001$) with the IDF diagnostic criteria, which was computed from 23 original studies [30, 73, 74, 77, 79, 81–83, 85, 87, 88, 93, 94, 98–101, 103, 104, 106, 108, 112]. The pooled prevalence of MetS was in the Weiss criteria, MetS was found in 29.52% (95%: 16.69, 42.35; $I^2 = 99.1%$; $p ≤ 0.001$) of the study population and it was computed from seven eligible studies [32, 114, 117, 119, 121, 122, 129]. In this diagnostic criteria, abdominal obesity (73.41%; 95% CI: 62.73, 84.09; $I^2 = 99.8%; p ≤ 0.001$) was the frequent component, whereas high FG was the infrequent one (11.12%; 95% CI: 3.67, 18. 57; $I^2 = 98.7%; p ≤ 0.001$). Only three studies [14, 15, 32] were used to compute the pooled prevalence of MetS (33.36%; 95% CI: 25.06, 41.65; $I^2 = 89.9%; p ≤ 0.001$) in the Weiss diagnostic criteria. Similar to the other diagnostic methods, abdominal obesity (71.48%; 95%: 53.87, 89.10; $I^2 = 93.8%; p ≤ 0.001$) and high FG level (15.53%; 95% CI: -7.01, 38.07; $I^2 = 99.1%; p ≤ 0.001$) were the most and least frequent components, respectively, in the Weiss criteria.

The pooled prevalence of MetS was also estimated among males and females. The prevalence of MetS was relatively higher in males (26.62%) than in females (20.18%) in the IDF method. However, the pooled prevalence was nearly similar among males (24.75%) and females (24.97%) in accordance with the ATP III diagnostic method (Figure 2 and Table 4).

**Figure 1:** PRISMA flow chart showing study selection process.
Table 2: Characteristics of studies used to compute the prevalence of metabolic syndrome in HICs in overweight and obese adolescents.

| Author, year         | Country | Sample size | Gender distribution | MetS with diagnostic methods (%) | Ab. obesity | Components of MetS (%) | Quality scores |
|----------------------|---------|-------------|---------------------|----------------------------------|-------------|------------------------|---------------|
|                      |         |             | M (%) F (%)         | Age                              |             | Low HDL    | High TGL | High FG | High BP |
|                    |         |             |                     | MetS with diagnostic methods (%) |             |_de F.      |_Weiss |_WHO |_scores |   |
| Cruz et al., 2004   | USA     | 126         | 73 53               | 8-13                            | —           | —          | —      | 30.2 | —       | 62 | 67 | 26 | 4 | 27 | 6 |
| Weiss et al., 2004  | USA     | 470         | — —                 | 4-20                            | —           | —          | —      | 40.6 | —       | — | — | — | — | — | 5 |
| Yoshinaga et al., 2005 | Japan  | 471         | 309 (13.6) 162 (16) | 6-12                            | 14.1        | —          | —      | 91.5 | 6.8      | 31 | 1.9 | 20.2 | 6 |
| Atabek et al., 2006 | Turkey  | 169         | 76 93               | 7-18                            | —           | —          | —      | 99.8 | 16.5     | 35.5 | 10 | 21.8 | 6 |
| Bueno et al., 2006  | Spain   | 103         | 54 (33.4) 49 (26.5) | 7-13                            | 29.9        | 50         | —      | —    | —        | — | — | — | — | — | 5 |
|                     |         |             | 54 (59.3) 49 (51)   |                                  |             | —          | —      | —    | —        | — | — | — | — | — |      |
| Druet et al., 2006  | France  | 308         | 142 (14.1) 166 (17.5) | 7-17                            | 15.9        | —          | —      | 95.8 | 22.1     | 22.4 | 1 | 2.6 | 6 |
| Invitti et al., 2006 | Italy  | 588         | 291 297             | 6-16                            | —           | —          | —      | 100  | 27.7     | 13.2 | 3.8 | 8.8 | 6 |
| Lo´pez-Capape´ et al., 2007 | Spain | 429         | 220 209             | 4-18                            | 18          | —          | —      | 27.7 | 16       | 4.6  | 23 | 5 |
| Reinehr et al., 2007 | Germany | 1205        | 554 651             | 4-16                            | 14          | —          | —      | 56   | 43        | 21   | 1 | 2.3 | 5 |
|                     |         |             | —                  | 13                              | —           | —          | —      | 64   | 10       | 48.5 | 13 | 1.2 | 5 |
|                     |         |             | 20 18               | 39                              | 80          | 52         | 1      | 42   | 11       | 27   | 12 | 29 | 22 |       |
| Bokor et al., 2008  | Europe  | 1241        | 560 681             | 10-16                           | 16.4        | —          | —      | 71.4 | 27.6     | 15.1 | 8.6 | 38.1 | 6 |
|                     |         |             | —                  | 20.3                            | 71.4        | 15.1       | 6.4    | 38.1 | 8.5      | 2.3  | 38.1 | 6 |
|                     |         |             | 38                 | 35.7                            | 71.4        | 48.5       | 2.3    | 38.1 | 8.5      | 2.3  | 38.1 | 6 |
|                     |         |             | 31.4               | 71.4                            | 13          | 15.1       | 2.3    | 38.1 | 8.5      | 2.3  | 38.1 | 6 |
| Cakaterra et al., 2008 | Italy  | 191         | 93 98               | 6-15                            | 19.4        | —          | —      | 32.5 | 5.8       | 14   | 27.2 | 6 |
| Cizemcioğlu et al., 2008 | Turkey | 112         | 46 66               | 2-18                            | 24          | —          | —      | 89   | 23.2      | 24.1 | 8.9 | 42.9 | 8 |
| Sen et al., 2008    | Turkey  | 352         | 180 (48.3) 172 (34.9) | 2-19                            | —           | —          | —      | 41.8 | —         | —    | — | — |      |
| Taha et al., 2009   | S. Arabia | 57         | 33 24               | 6-14                            | 29.7        | —          | —      | —    | —         | —    | 15.4 | 25.6 | 26 | 42 | 6 |
| Wickham et al., 2009 | USA     | 165         | 63 102              | 11-18                           | 30.3        | —          | —      | —    | —         | —    | 26.7 | 29.1 | 2.4 | 54.5 | 6 |
| Bustos et al., 2010 | Chile   | 461         | 197 (43.7) 264 (33) | 10-18                           | 37.5        | —          | —      | 88.2 | 25.3     | 39.4 | 29.4 | 8 |
| Druet et al., 2010  | France  | 300         | 139 161             | 7-18                            | 6.3         | —          | —      | 93.5 | 23.4      | 8.9  | 10.3 | 5 |
|                     |         |             | —                  | 15.7                            | —           | —          | —      | 94.9 | 23.4      | 21.5 | —    | 28.4 | 6 |
| Eapen et al., 2010  | UAE     | 260         | 153 107             | 11-18                           | 44          | —          | —      | 88.2 | 25.3      | 39.4 | 29.4 | 8 |
| Lafortuna et al., 2010 | Italy  | 665         | 271 394             | 12-18                           | 23.3        | —          | —      | —    | —         | —    | 13.4 | 10.8 | 6.4 | 44.7 | 6 |
| Lafortuna et al., 2010 | Germany | 661         | 261 400             | 12-18                           | 40.4        | —          | —      | —    | —         | —    | 39.5 | 24.5 | 7.6 | 66.1 | 8 |
| Sangun et al., 2011 | Turkey  | 614         | 307 307             | 7-18                            | 33          | —          | —      | —    | —         | —    | 38  | 14.8 | — |      | 6 |
| de Armas et al., 2012 | Spain  | 133         | 67 66               | 5-19                            | 19.6        | —          | —      | —    | —         | —    | 100 | 15.9 | 7.97 | 26.08 | 6 |
| Pelin & Mătăsăru, 2012 | Romania | 120         | 59 61               | 7-18                            | 55.8        | —          | —      | 69.2 | 77.5      | 26.6 | 10 | 27.5 | 6 |
| Pastucha et al., 2013 | [33]  | 274         | 128 (43.8) 146 (31.5) | 9-17                            | 37          | —          | —      | —    | —         | —    | — | — | — | 7 |      |
| Author, year                        | Country          | Sample size | Gender distribution | MetS with diagnostic methods (%) | Components of MetS (%) | Quality scores |
|------------------------------------|------------------|-------------|---------------------|-----------------------------------|------------------------|----------------|
| Santoro et al., 2013 [132]         | Italy            | 1080        | M (30.6) F (27.9)   | Age 29.2                         | Low Ab. HDL 30.2       | 8              |
| Suazo et al., 2013 [133]           | Chile            | 259         | M (21.1) F (32.2)   | Age 26.3                         | Low HDL 31.8           | 5              |
| Šimunovic et al., 2016 [134]        | Croatia          | 201         | M (104) F (97)      | Age 30.3                         | Low HDL 31.8           | 5              |
| Szabelska-Zakrzewska et al., 2018  | Poland           | 591         | M (14.6) F (10.9)   | Age 12.9                         | Low HDL 27.1           | 6              |
| Davidsson et al., 2020 [136]       | Kuwait           | 97          | M (17.5) F (10)     | Age 14.4                         | Low HDL 11.8           | 8              |
| Author, year | Country | Sample size | Sample size males (%) | Sample size females (%) | Prevalence in males (%) | Prevalence in females (%) | Age | MetS with diagnostic method (%) | Ab. obesity | HDL | TGL | FG | BP | Quality score |
|--------------|---------|-------------|-----------------------|------------------------|------------------------|-------------------------|-----|-------------------------------|-------------|-----|-----|----|----|----------------|
| Cook et al., 2003 [67] | USA | 2430 | 1150 (6.1) | 1280 (2.1) | 12-19 | — | 4.2 | — | — | 9.8 | 23.3 | 23.4 | 1.5 | 4.9 | 6 |
| de Ferranti et al., 2004 [13] | USA | 1960 | 9.5 | 8.9 | 12-19 | — | 9.2 | — | — | — | — | — | — | — | 6 |
| Goodman et al., 2004 [68] | USA | 1513 | 755 (3.8) | 758 (4.7) | — | — | 4.2 | — | — | 8.2 | 14.5 | 4.9 | 1.7 | 4.9 | 5 |
| Agirbasli et al., 2006 [69] | Turkey | 1385 | 690 (3.3) | 695 (1.0) | 10-17 | — | 2.2 | — | — | — | 4.9 | 13.4 | 26.7 | 0.5 | 15.7 | 5 |
| Dubose et al., 2006 [70] | USA | 375 | 182 (5) | 193 (5) | 7-9 | — | 5 | — | — | 10 | 5 | 18 | 1 | 37 | 8 |
| Cook et al., 2008 [72] | USA | 1826 | 13.2 | 5.3 | 12-17 | 4.5 | — | — | — | 28.6 | 22.6 | 8.9 | 10.6 | 3.5 | 8 |
| Goodman et al., 2004 [68] | USA | 1513 | 755 (3.8) | 758 (4.7) | — | — | 4.2 | — | — | 8.2 | 14.5 | 4.9 | 1.7 | 4.9 | 5 |
| Agirbasli et al., 2006 [69] | Turkey | 1385 | 690 (3.3) | 695 (1.0) | 10-17 | — | 2.2 | — | — | — | 4.9 | 13.4 | 26.7 | 0.5 | 15.7 | 5 |
| Dubose et al., 2006 [70] | USA | 375 | 182 (5) | 193 (5) | 7-9 | — | 5 | — | — | 10 | 5 | 18 | 1 | 37 | 8 |
| Cook et al., 2008 [72] | USA | 1826 | 13.2 | 5.3 | 12-17 | 4.5 | — | — | — | 28.6 | 22.6 | 8.9 | 10.6 | 3.5 | 8 |
| Goodman et al., 2004 [68] | USA | 1513 | 755 (3.8) | 758 (4.7) | — | — | 4.2 | — | — | 8.2 | 14.5 | 4.9 | 1.7 | 4.9 | 5 |
| Agirbasli et al., 2006 [69] | Turkey | 1385 | 690 (3.3) | 695 (1.0) | 10-17 | — | 2.2 | — | — | — | 4.9 | 13.4 | 26.7 | 0.5 | 15.7 | 5 |
| Dubose et al., 2006 [70] | USA | 375 | 182 (5) | 193 (5) | 7-9 | — | 5 | — | — | 10 | 5 | 18 | 1 | 37 | 8 |
| Cook et al., 2008 [72] | USA | 1826 | 13.2 | 5.3 | 12-17 | 4.5 | — | — | — | 28.6 | 22.6 | 8.9 | 10.6 | 3.5 | 8 |
| Goodman et al., 2004 [68] | USA | 1513 | 755 (3.8) | 758 (4.7) | — | — | 4.2 | — | — | 8.2 | 14.5 | 4.9 | 1.7 | 4.9 | 5 |
| Agirbasli et al., 2006 [69] | Turkey | 1385 | 690 (3.3) | 695 (1.0) | 10-17 | — | 2.2 | — | — | — | 4.9 | 13.4 | 26.7 | 0.5 | 15.7 | 5 |
| Dubose et al., 2006 [70] | USA | 375 | 182 (5) | 193 (5) | 7-9 | — | 5 | — | — | 10 | 5 | 18 | 1 | 37 | 8 |
| Cook et al., 2008 [72] | USA | 1826 | 13.2 | 5.3 | 12-17 | 4.5 | — | — | — | 28.6 | 22.6 | 8.9 | 10.6 | 3.5 | 8 |
| Author, year                  | Country    | Sample size | Prevalence in males (%) | Prevalence in females (%) | Age | MetS with diagnostic method (%) | Components of MetS (%) | Quality score |
|------------------------------|------------|-------------|-------------------------|----------------------------|-----|--------------------------------|------------------------|---------------|
| Carlson et al., 2011 [86]    | USA        | 2128        | 1085                    | 1043                       | 12-19 | —                              | —                      | 6             |
| Estathiou et al., 2012 [87]  | Greece     | 1091        | —                       | —                          | 12-15 | 7.9                            | —                      | 8             |
| Papoutsakis et al., 2012 [88]| Greece     | 1128        | 528 (0.75)              | 600 (0.67)                 | 9.8-13.8 | 0.7                            | —                      | 4.8 12.3 4.7 | 33 | 7 |
| Setayeshgar et al., 2012 [89]| Canada     | 2173        | —                       | —                          | 12-19 | 3.5                            | —                      | —             | — | 5 |
| Turchiano et al., 2012 [90]  | USA        | 1185        | 538 (12.3)              | 647 (7.1)                  | 14-19 | 9.5                            | —                      | 35.5 26.2 15 | 1.0 | 23.2 | 6 |
| Chung et al., 2013 [91]      | Korea Rep  | 5652        | 2964 (9.4)              | 2688 (7.3)                 | 10-18 | 8.4                            | —                      | 11.6 20.9 24.9 | 6.7 | 32.7 | 6 |
| Lee et al., 2013 [92]        | Korea Rep  | 1660        | 891 (6.5)               | 758 (6.4)                  | —     | 6.4                            | —                      | 13.6 5.8 17.6 | 0.7 | 57.2 | 7 |
| Mehairi et al., 2013 [93]    | UAE        | 1018        | 525 (21)                | 493 (4)                    | 12-18 | 13                             | —                      | 13.3 81.2 2.9 | 9.6 | 6.5 | 8 |
| Park et al., 2013 [94]       | Korea Rep  | 1554        | 821 (2.7)               | 733 (2.1)                  | 10-19 | 2.3                            | —                      | 11.3 23.6 10.1 | 6.1 | 3.4 | 6 |
| Ahrens et al., 2014 [30]     | Europe     | 12147       | 6100 (0.4)              | 6047 (0.3)                 | 2-10.9 | 0.4                           | —                      | —              | — | — | — |
| Lee and Park, 2014 [95]      | Korea Rep  | 1187        | 630 (7.0)               | 557 (5.4)                  | 12-18 | 6.3                            | —                      | —              | — | — | — |
| Miller et al., 2014 [96]     | USA        | 3495        | 1624 (13)               | 1871 (6.9)                 | 12-19 | 10.1                           | —                      | 40.8 16.1 20.6 | 16.5 | 4.9 | 7 |
| Monzani et al., 2014 [97]    | Italy      | 489         | 258 (10.1)              | 231 (9.5)                  | 6.7-13 | 9.8                            | —                      | 41.1 4.7 21.3 | 9.8 | 21.9 | 8 |
| Galera-Martinez et al., 2015 | Spain      | 379         | 220 (5.2)               | 159 (1.9)                  | 12-16.9 | 3.8                           | 5.7                    | —              | — | — | — |
| Gonzalez-Jimenez et al., 2015| Spain      | 976         | 457 (5.38)              | 519 (3.85)                 | 10-15 | 4.4                            | —                      | 24.8 14 3.3 | 6.7 | 26.2 | 6 |
| Kim et al., 2016 [100]       | Korea Rep  | 3313        | 1756 (1.4)              | 1557 (1.8)                 | 10-18 | 1.6                            | —                      | —              | — | — | — |
| Kim and So et al., 2016 [101]| Korea Rep  | 2330        | 1249 (1.9)              | 1081 (2.2)                 | 10-18 | 2.1                            | —                      | 9.4 13.6 7.8 | 11.4 | 2.4 | 7 |
| Lee et al., 2016 [102]       | USA        | 5117        | 10.9                    | 6.29                       | 12-19 | 9.83                           | —                      | 9.7 11.6 21.2 | 11.4 | 20.4 | 6 |
| MacPherson et al., 2016 [103]| Canada     | 1228        | 632                     | 596                        | 10-18 | 2.1                            | —                      | 21.6 19.1 7.9 | 1.7 | — | 8 |
| Cho et al., 2017 [104]       | USA        | 1036        | 488 (4.5)               | 548 (6.8)                  | 7-13  | 5.7                            | —                      | —              | — | — | — |

Table 3: Continued.
| Author, year       | Country     | Sample size | Prevalence in males (%) | Prevalence in females (%) | Age       | MetS with diagnostic method (%) | Components of MetS (%) | Quality score |
|-------------------|-------------|-------------|-------------------------|--------------------------|-----------|---------------------------------|------------------------|---------------|
| Choi et al., 2017 [105] | Korea Rep  | 3057        | 1625 (7.0)              | 1432 (5.2)               | 10-19     | 6.2                             | 8.9, 14.5, 19.7, 0.5 | 25.6          |
| Haroun et al., 2017 [112] | UAE        | 596         | 308 (12)                | 288 (10)                 | 10-15.9   | 3.7                             | 17.9, 15.1, 15.1, 15.1 | 8             |
| Kim et al., 2018 [106]   | Korea Rep  | 2314        | —                       | —                        | 12-18     | 7.8                             | —                     | 8             |
| Stevens et al., 2018 [107] | USA       | 7464        | 7.9                     | 4.9                      | 12-15     | 6.5                             | —                     | 8             |
| Bacopoulou et al., 2019 [108] | Greece    | 1578        | 671 (3.4)               | 907 (2)                  | 12-17     | 2.6                             | 9.5, 10.7, 2.3, 25.9 | 21.8          |
| DeBoer et al., 2019 [109]  | USA        | 4600        | 2429 (9.9)              | 2171 (5.5)               | 12-19     | 7.7                             | 20.9, 14.6, 21.8 | 14.9          |
| Elitok et al., 2019 [110] | Turkey     | 353         | —                       | —                        | 10-14     | 0.85                            | 14.1, 2.5, 7.4, 1.4 | 2             |
| Shah et al., 2020 [111]   | UAE        | 234         | 113 (7.9)               | 121 (9.9)                | 6-11      | 8.9                             | 15, 47.4, 6.8, 1.7 | 20.5          |
Figure 2: The pooled prevalence of MetS among overweight and obese children and adolescents in high-income countries, 2020.
(14.42%; 95% CI: 12.82, 16.02) was abdominal obesity, and the lowest one was high FG level (1.63%; 95% CI: 1.06, 2.21), with no heterogeneity among the included studies.

The gender-based distribution of MetS in the general population was also estimated in all diagnostic methods. The pooled prevalence of MetS among males was higher than females in the IDF (3.80%, 2.37%), ATP III (6.61%, 4.65%), and Cruz and Goran (5.53%, 4.22%) diagnostic methods. On the contrary, the pooled prevalence of MetS was lower among males than among females in the de Ferranti (16.49%, 16.76%) and WHO (2.66%, 3.03%) diagnostic criteria (Figure 3 and Table 5).

3.5. Subgroup Analysis of the Pooled Prevalence of MetS in the General Population. The subgroup analyses were performed for the two diagnostic methods (IDF and ATP III) using continents where the original studies were performed. In the IDF diagnostic method, the pooled prevalence of MetS was estimated in three continents (North America, Asia, and Europe). Accordingly, the highest prevalence was recorded
in Asia, where 4.72% (95% CI: 3.40, 6.04; $I^2 = 96.7%$, $p \leq 0.001$) of the children and adolescents were found to have MetS. Likewise, the pooled prevalence of MetS in North America and that in Europe were 3.95% (95% CI: 1.95, 5.96; $I^2 = 90.9%$, $p \leq 0.001$) and 2.54% (95% CI: 1.64, 3.44; $I^2 = 97%$, $p \leq 0.001$), respectively (Figure 4).

Similarly, the pooled prevalence of MetS was computed for three eligible continents (North America, Asia, and Europe) using the ATP III diagnostic criteria. Thus, 6.79% (95% CI: 5.40, 8.18; $I^2 = 96.9%$, $p \leq 0.001$) of the study subjects in North America were diagnosed to have MetS. In Asia, the pooled prevalence of MetS was 6.32% (95% CI: 5.05, 7.58; $I^2 = 94.9%$, $p \leq 0.001$), and it was 3.84% (95% CI: 2.83, 4.85; $I^2 = 94.9%$, $p \leq 0.001$) in Europe (Figure 4).

The heterogeneity among the included studies remained significant after subgroup analysis. Hence, the possible sources of heterogeneity were further explored for the two diagnostic methods (IDF and ATP III). Thus, the funnel plots...
both diagnostic methods. This was done to evaluate if the
criteria were presented (Figure 5). The
asymmetry of the plots was objectively verified by Egger’s
regression test, and there was publication bias among the
articles included in computing the pooled prevalence of MetS
in the IDF ($p \leq 0.001$) and ATP III ($p \leq 0.001$) diagnostic
methods. Moreover, sensitivity analyses were performed for
both diagnostic methods. This was done to evaluate if the
pooled estimates were altered by the exclusion of any single
study. However, none of the studies had signifi-

Finally, the Duval and Tweedie trim and fill analysis, a
nonparametric method of accounting for publication bias
in meta-analysis, was employed to estimate the pooled prev-

| Variables                  | Characteristics     | # of included articles | Pooled prevalence (95% CI)       | Heterogeneity $I^2$ (%) | $p$ value | Model |
|----------------------------|---------------------|------------------------|----------------------------------|------------------------|---------|-------|
| Diagnostic criteria        | de Ferranti         | 4                      | 14.78 (11.02, 18.54)             | 96.5, $p \leq 0.001$   | REM     |
|                           | WHO                 | 3                      | 3.90 (0.60, 7.20)                | 97.2, $p \leq 0.001$   | REM     |
|                           | Cruz and Goran      | 2                      | 4.66 (3.29, 6.03)                | 76.6, $p = 0.039$      | REM     |
| Gender distribution of MetS (IDF) | Male          | 19                     | 3.80 (2.90, 4.70)                | 96.1, $p \leq 0.001$   | REM     |
|                           | Female              | 20                     | 2.37 (1.77, 2.96)                | 92.3, $p \leq 0.001$   | REM     |
|                           | Male                | 27                     | 6.61 (5.10, 8.13)                | 98.4, $p \leq 0.001$   | REM     |
| Gender distribution of MetS (ATP III) | Female          | 28                     | 4.65 (3.75, 5.54)                | 98.6, $p \leq 0.001$   | REM     |
|                           | Male                | 3                      | 16.49 (12.80, 20.17)             | 88.4, $p \leq 0.001$   | REM     |
| Gender distribution of MetS (de F.) | Female         | 3                      | 16.76 (12.11, 21.41)             | 92.4, $p \leq 0.001$   | REM     |
|                           | Male                | 2                      | 2.66 (0.61, 4.72)                | 86.0, $p = 0.008$      | REM     |
| Gender distribution of MetS (WHO) | Female          | 2                      | 3.03 (-0.11, 6.16)               | 93.0, $p \leq 0.001$   | REM     |
|                           | Male                | 2                      | 5.53 (3.09, 7.98)                | 82.8, $p = 0.016$      | REM     |
| Gender distribution of MetS (Cruz and Goran) | Female        | 2                      | 4.22 (3.27, 5.17)                | 21.1, $p = 0.260$      | REM     |
| Abdominal obesity         | 14                  |                        | 16.13 (11.47, 20.79)             | 99.3, $p \leq 0.001$   | REM     |
| Low HDL-C                 | 14                  |                        | 23.41 (14.71, 32.11)             | 99.8, $p \leq 0.001$   | REM     |
| Components MetS (IDF)     | High TG             | 13                     | 7.10 (4.72, 9.48)                | 98.4, $p \leq 0.001$   | REM     |
|                           | High FG             | 13                     | 10.62 (6.64, 14.59)              | 99.0, $p \leq 0.001$   | REM     |
|                           | Elevated BP         | 12                     | 14.56 (10.52, 18.59)             | 99.2, $p \leq 0.001$   | REM     |
| Abdominal obesity         | 21                  |                        | 16.28 (13.03, 19.53)             | 99.1, $p \leq 0.001$   | REM     |
| Low HDL-C                 | 21                  |                        | 17.45 (14.43, 20.47)             | 98.9, $p \leq 0.001$   | REM     |
| Components MetS (ATP III) | High TG             | 21                     | 19.05 (14.84, 23.26)             | 99.4, $p \leq 0.001$   | REM     |
|                           | High FG             | 21                     | 7.16 (5.22, 9.11)                | 99.4, $p \leq 0.001$   | REM     |
|                           | Elevated BP         | 21                     | 21.43 (16.60, 26.25)             | 99.6, $p \leq 0.001$   | REM     |
| Abdominal obesity         | 2                   |                        | 14.42 (12.82, 16.02)             | 0.00, $p = 0.846$      | REM     |
| Low HDL-C                 | 2                   |                        | 3.78 (1.43, 6.13)                | 82.8, $p = 0.016$      | REM     |
| Components MetS (WHO)     | High TG             | 2                      | 5.82 (3.46, 8.19)                | 64.2, $p = 0.094$      | REM     |
|                           | High FG             | 2                      | 1.63 (1.06, 2.21)                | 0.00, $p = 0.672$      | REM     |
|                           | Elevated BP         | 2                      | 3.49 (0.65, 6.34)                | 89.7, $p = 0.002$      | REM     |
| Abdominal obesity         | 2                   |                        | 10.06 (7.12, 13.00)              | 89.6, $p = 0.002$      | REM     |
| Low HDL-C                 | 2                   |                        | 10.47 (7.93, 13.02)              | 85.3, $p = 0.009$      | REM     |
| Components MetS (Cruz and Goran) | High TG         | 2                      | 11.15 (10.25, 12.06)             | 0.00, $p = 0.583$      | REM     |
|                           | High FG             | 2                      | 16.65 (-5.99, 39.28)             | 99.8, $p \leq 0.001$   | REM     |
|                           | Elevated BP         | 2                      | 27.50 (12.12, 42.89)             | 99.0, $p \leq 0.001$   | REM     |

* Others: underweight and normal weight; REM: random effect model; FM: fixed effect model.
| Study ID | MetS (IDF) | ES (95% CI) |
|----------|------------|-------------|
| N.America |            |             |
| Ford et al., 2008 | 4.50 (3.60, 5.40) |         |
| Park et al., 2010 | 5.50 (3.85, 7.15) |         |
| MacPherson et al., 2016 | 2.10 (1.30, 2.90) |         |
| subtotal (I² = 90.9%, p = 0.000) | 3.95 (1.95, 5.96) |         |
| Asia |            |             |
| Kong et al., 2008 | 1.20 (0.67, 1.73) |         |
| Park et al., 2009 | 2.60 (2.11, 3.09) |         |
| Al-lus et al., 2010 | 14.80 (11.45, 18.15) |         |
| Park et al., 2010 | 2.50 (1.30, 3.70) |         |
| Mehari et al., 2013 | 13.00 (10.94, 15.06) |         |
| Park et al., 2013 | 3.50 (2.56, 3.04) |         |
| Kim et al., 2016 | 1.60 (1.17, 2.03) |         |
| Kim & So et al., 2016 | 2.10 (1.51, 2.69) |         |
| Choe et al., 2017 | 5.70 (4.29, 7.11) |         |
| Hanoun et al., 2017 | 3.70 (2.19, 5.21) |         |
| Kim et al., 2018 | 7.80 (6.70, 8.90) |         |
| subtotal (I² = 96.7%, p = 0.000) | 4.72 (3.40, 6.04) |         |
| Europe |            |             |
| Pirkola et al., 2008 | 2.40 (2.01, 2.79) |         |
| Cizmecioglu et al., 2009 | 2.30 (1.71, 2.89) |         |
| Noto et al., 2009 | 0.60 (0.23, 0.97) |         |
| Editha et al., 2012 | 7.90 (6.29, 9.51) |         |
| Papoutsakis et al., 2012 | 0.70 (0.21, 1.19) |         |
| Ahrens et al., 2014 | 0.40 (0.28, 0.52) |         |
| Galera-Martinez et al., 2015 | 3.80 (1.88, 5.72) |         |
| Gonzalez-Simenez et al., 2015 | 4.40 (3.11, 5.69) |         |
| Bacoopolou et al., 2019 | 2.60 (1.82, 3.38) |         |
| subtotal (I² = 97.0%, p = 0.000) | 2.54 (1.64, 3.44) |         |
| Overall (I² = 97.3%, p = 0.000) | 3.70 (2.96, 4.44) |         |

Note: weights are from random effect analysis

| Study ID | MetS (ATP III) | ES (95% CI) |
|----------|----------------|-------------|
| N.America |                |             |
| Cook et al., 2003 | 4.20 (3.40, 5.00) |         |
| Goodman et al., 2004 | 4.20 (3.18, 5.22) |         |
| Dudose et al., 2006 | 5.00 (2.79, 7.21) |         |
| Cook et al., 2008 | 9.40 (6.07, 10.73) |         |
| Pan et al., 2009 | 3.50 (2.95, 4.05) |         |
| Johnson et al., 2009 | 8.60 (7.48, 9.72) |         |
| Carlson et al., 2011 | 6.40 (5.36, 7.44) |         |
| Settavangh et al., 2012 | 3.50 (2.74, 4.36) |         |
| Turchiano et al., 2012 | 9.50 (7.83, 11.17) |         |
| Miller et al., 2014 | 10.10 (9.10, 11.10) |         |
| Lee et al., 2016 | 9.83 (9.01, 10.65) |         |
| Stevens et al., 2018 | 6.50 (5.93, 7.07) |         |
| DeBoer et al., 2019 | 7.70 (6.94, 8.46) |         |
| subtotal (I² = 96.9%, p = 0.000) | 6.79 (5.40, 8.18) |         |
| Europe |                |             |
| Agirbasli et al., 2006 | 2.20 (1.44, 2.96) |         |
| Pirkola et al., 2008 | 2.10 (1.73, 2.47) |         |
| Cizmecioglu et al., 2009 | 2.40 (1.79, 3.01) |         |
| Di Bonito et al., 2010 | 11.00 (8.73, 13.27) |         |
| Ahrens et al., 2014 | 1.40 (1.18, 1.62) |         |
| Monzani et al., 2014 | 9.80 (7.17, 12.43) |         |
| Galera-Martinez et al., 2015 | 5.70 (3.37, 8.03) |         |
| Bacoopolou et al., 2019 | 2.90 (2.08, 3.72) |         |
| subtotal (I² = 94.9%, p = 0.000) | 3.84 (2.83, 4.85) |         |
| Asia |                |             |
| Kim et al., 2007 | 7.80 (6.66, 8.94) |         |
| Kong et al., 2008 | 2.10 (1.39, 2.81) |         |
| See et al., 2008 | 6.10 (5.30, 6.90) |         |
| Al-lus et al., 2011 | 9.10 (6.38, 11.82) |         |
| Lee et al., 2010 | 6.70 (5.09, 8.31) |         |
| Chung et al., 2013 | 8.40 (6.77, 9.13) |         |
| Lee et al., 2013 | 6.40 (5.22, 7.58) |         |
| Lee & Park, 2014 | 6.30 (4.91, 7.69) |         |
| Kim et al., 2015 | 4.10 (3.43, 4.77) |         |
| Kim & So et al., 2017 | 5.70 (4.76, 6.64) |         |
| Choi et al., 2017 | 6.20 (5.34, 7.06) |         |
| Shah et al., 2020 | 8.90 (5.25, 12.55) |         |
| subtotal (I² = 94.6%, p = 0.000) | 6.32 (5.05, 7.58) |         |
| Overall (I² = 98.2%, p = 0.000) | 6.08 (5.08, 7.07) |         |

Note: weights are from random effect analysis

Figure 4: Pooled prevalence of MetS based on continent in two diagnostic methods (IDF and ATP III).
of missing studies, and adjust the meta-analysis to incorporate the theoretical missing studies. Nevertheless, the pooled prevalence of MetS remained the same (3.70%) using the IDF criteria. However, the pooled prevalence of MetS among the general population of children and adolescents was reduced to 5.40% (95% CI: 4.47, 6.32) in the ATP III diagnostic criteria.

Eventually, the trend of MetS in the general population of children and adolescents in HICs was plotted in a scatter plot based on the prevalence of cases with publication year (2003 to 2020). The trend line implied that there is an increasing trend of cases in three diagnostic methods (IDF, ATP III, and de Ferranti) (Figure 7).

4. Discussion

This is a comprehensive systematic review and meta-analysis, determining the prevalence of metabolic syndrome among children and adolescents in high-income countries. The pooled prevalence of MetS was computed using six diagnostic methods: IDF, ATP III, de Ferranti et al., WHO, Weiss et al., and Cruz and Goran. In the current meta-analysis, 77 studies with a total of 125,445 study participants were included. Of the total studies, 49 were conducted among the general population of study subjects, and 28 were conducted among overweight and obese population.

This study revealed that the prevalence of MetS among overweight and obese study participants is considerably higher than its prevalence in the general population. The pooled prevalence of MetS in the overweight and obese children and adolescents is as follows: IDF = 25.25%; ATP III = 24.47%; de Ferranti et al. = 39.41%; WHO = 29.52%; and Weiss et al. = 33.36%. Likewise, the pooled prevalence in the general population was 3.70%, 6.08%, 14.78%, 3.90%, 4.66% with the IDF, ATP III, de Ferranti, WHO, and Cruz and Goran diagnostic criteria, respectively. The prevalence in the general population is comparable with findings of a systematic review from Iran, where the prevalence of MetS was 0-8%, 3-16%, and 0-22% in the IDF, ATP III, and de Ferranti criteria, respectively [137]. But, Iranian findings are remarkably lower than the current pooled prevalence of MetS among the overweight and obese population. A possible reason for this disparity may be explained by the fact that overweight and obese children are at greater risk of developing metabolic syndrome as compared to children with normal weight [19]. Furthermore, the higher prevalence of obesity
in HICs may account for this discrepancy. The current findings are in line with the findings of previous reviews which reported that the prevalence of MetS in the pediatric population ranged from 1.2 to 22.6% in [138] and from 0 to 19.2% in [16]. The median prevalence of MetS in the whole world was 3.3% in 2007 to 2009, which is lower than all the pooled estimates in this meta-analysis [16]. This indicates that the prevalence of MetS is on the rise in the developed world. Besides, the present findings are higher than the findings of a meta-analysis in China, where 1.8% (IDF) and 2.6% (ATP III) of the children and adolescents had MetS [139]. The findings of the recent systematic review also revealed that the prevalence of MetS in the pediatric population ranged from 0.3 to 26.4%, with the lower prevalence recorded in the IDF.
criteria (0.3–9.5%). But, the prevalence was relatively higher in the de Ferranti et al. criteria (4–26.4%) [140]. Thus, the current findings are in line with the findings in this study. However, the meta-analyses results of the current study are higher than most of the previous findings, which depict that MetS is having an upsurge primarily in the developed world, and it is supported by the findings of the previous reviews [9, 141, 142]. In general, the pooled prevalence of MetS among the obese population is higher in HICs as compared to the low- and middle-income countries, but comparable with the general population [143].

In this study, the pooled prevalence of the components of MetS was also computed using different diagnostic criteria. Abdominal obesity was the most prevalent component of MetS in the overweight and obese population ranging from 65.62% in the IDF criteria to 79.81% in the ATP III criteria. On the other hand, a high level of FG level was the most infrequent component of MetS in the overweight and obese population. The pooled prevalence ranges from 1.61% (de Ferranti et al.) to 15.53% (Weiss et al.). Similarly, the frequent and infrequent components of MetS were computed in the general population. Thus, the most prevalent components include elevated BP (27.50%), low HDL-C (23.41%), high TG level (19.05%), and abdominal obesity (14.42) with the Cruz and Goran, IDF, ATP III, and WHO diagnostic methods, respectively. However, the high FG level is the least frequent component in the ATP III (7.16%) and WHO (1.63%) criteria. Likewise, abdominal obesity and high TG level were the least prevalent components in the Cruz and Goran (10.06%) and IDF (7.10%) criteria. In general, the prevalence of MetS amongst the general population is similar between high-income and low-income countries, whereas the prevalence is not the same amongst obese children in HICs and low-income countries. The pooled prevalence of MetS in the overweight and obese population was considerably higher among children in HICs. The possible elucidation could be due to a multitude of factors like consumption of unhealthy diets such as diets low in fruit, vegetables, and grains [144, 145]. Moreover, sedentary behavior and lack of physical exercise may also contribute to the rise of MetS in these countries [146].

In most of the diagnostic methods, the prevalence of MetS in males is relatively higher than that in females. The pooled prevalence of MetS in the overweight and obese males is 26.62% (IDF) and 24.75% (ATP III). Likewise, it is 20.18% (IDF) and 24.97% (ATP III) among females. The pooled prevalence of MetS in the general population was computed in both genders using five diagnostic methods. Thus, the pooled prevalence of MetS among males was higher than that among females in the IDF (3.80%, 2.37%), ATP III (6.61%, 4.65%), and Cruz and Goran (5.53%, 4.22%) diagnostic criteria. In contrast, the pooled prevalence of MetS among males was lower compared to that of females in the de Ferranti et al. (16.49%, 16.76%) and WHO (2.66%, 3.03%) diagnostic criteria. In general, males are more highly at risk to have MetS than females both in the original studies and pooled estimates of most diagnostic methods. The current findings are in line with the findings of a meta-analysis in China which showed that males are more highly liable to have MetS than females [139]. The possible justification for gender disparities may be associated with a higher prevalence of obesity in males than females. A higher prevalence of obesity among male children and adolescents may be related to excessive energy intake due to self- and family-imposed perception of being underweight and underestimation of their weight. On the other hand, females control their weight through diet and physical activity due to a self-perception of being overweight [147].

Moreover, the pooled prevalence of MetS in HICs was computed in three continents (Asia, North America, and Europe). Thus, 4.72%, 3.95%, and 2.54% of the study subjects in Asia, North America, and Europe, respectively, are found to have MetS in the IDF criteria. Similarly, the pooled prevalence of MetS in the ATP III criteria is 6.79% (North America), 6.32% (Asia), and 3.84% (Europe). These findings pinpointed that MetS is considerably higher in HICs. This could be associated with a high burden of childhood obesity and consumption of unhealthy diets in these countries [148, 149]. Childhood obesity is not only associated with childhood MetS, but with MetS in adults [150].

Eventually, the number of cases was plotted against the publication year (2003 to 2020), using five diagnostic methods. The trend line revealed that the prevalence of MetS has increased from 2003 to 2020 in all diagnostic criteria. This implies that the prevalence of MetS is increasing in a sustainable manner in the developed world.

The findings of this study may be used by program planners and policy makers to design preventive and treatment strategies against morbidities and mortalities related to MetS. These findings will also help researchers who intend to conduct original researches on multiple factors contributing to a higher burden of MetS in those high-income countries. Nonetheless, there is no specific diagnostic method for MetS,
and this could affect the actual prevalence of MetS in HICs. The other limitation of this study was the exclusion of the following: studies written in non-English language, studies with no full texts, and studies conducted in different study designs and with a different study population. This could cause either under- or overestimation of the pooled prevalence of MetS.

5. Conclusion

In conclusion, the current study revealed that the prevalence of MetS among children and adolescents is high in high-income countries with higher proportions among the overweight and obese population. The prevalence is considerably higher in overweight and obese children of Asian countries. Similarly, MetS in the general population of children and adolescents is high in North America. Male children and adolescents are also at greater risk of MetS than females. Metabolic syndrome was diagnosed in underweight, normal weight, overweight, and obese children and adolescents. This implies that MetS is a nonselective problem of children and adolescents in high-income countries. Community-based social and behavioral change communications need to be designed to promote healthy eating behaviors and physical activities. Prospective cohort studies could also help to explore all possible risk factors of MetS and to design specific interventions accordingly.

Abbreviations

| Abbreviation | Definition |
|--------------|------------|
| HDL-C        | High-density lipoprotein cholesterol |
| MetS         | Metabolic syndrome |
| IDF          | International Diabetic Federation |
| TG           | Triglyceride |
| BP           | Blood pressure |
| FG           | Fasting glucose |
| WHO          | World Health Organization |
| BMI          | Body mass index |
| NCEP-ATP III | National Cholesterol Education Program Adult Treatment Panel III |
| WC           | Waist circumference |
| HICs         | High-income countries |
| JBI          | Juana Brigg’s Institute |

Data Availability

The data that support the review findings of this study are included in the manuscript and supporting files.

Conflicts of Interest

There are no competing interests.

Authors’ Contributions

ZWB and AA were responsible for analysis, visualization, and writing of the manuscript; ZWB, ZT, AA, and TW made substantial contributions to data acquisition; ZWB, AA, and EGA participated in the data interpretation and made substantial revisions in the first draft; ZWB and TW contributed to the reception and the design of the work. All authors read and approved the final manuscript.

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Supplementary Materials

Critical appraisal of cross-sectional studies. (Supplementary Materials)

References

[1] “Third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report,” Circulation, vol. 106, no. 25, pp. 3143–3421, 2002.
[2] G. Reaven, “Metabolic syndrome: pathophysiology and implications for management of cardiovascular disease,” Circulation, vol. 106, no. 3, pp. 286–288, 2002.
[3] J. A. Morrison, L. A. Friedman, P. Wang, and C. J. Glueck, “Metabolic syndrome in childhood predicts adult metabolic syndrome and type 2 diabetes mellitus 25 to 30 years later,” The Journal of Pediatrics, vol. 152, no. 2, pp. 201–206, 2008.
[4] P. Muntner, A. Menke, S. Srinivasan, D. A. Patel, W. Chen, and G. Berenson, “Impact of childhood metabolic syndrome components on the risk of elevated uric acid in adulthood: the Bogalusa Heart Study,” The American Journal of the Medical Sciences, vol. 335, no. 5, pp. 332–337, 2008.
[5] T. S. Burgert, S. E. Taksali, J. Dziura et al., “Alanine aminotransferase levels and fatty liver in childhood obesity: associations with insulin resistance, adiponectin, and visceral fat,” The Journal of Clinical Endocrinology and Metabolism, vol. 91, no. 11, pp. 4287–4294, 2006.
[6] A. D. Coviello, R. S. Legro, and A. Dunai, “Adolescent girls with polycystic ovary syndrome have an increased risk of the metabolic syndrome associated with increasing androgen levels independent of obesity and insulin resistance,” The Journal of Clinical Endocrinology and Metabolism, vol. 91, no. 2, pp. 492–497, 2006.
[7] K. A. Waters and S. Sitha, “Follow-up on metabolic markers in children treated for obstructive sleep apnea,” American Journal of Respiratory and Critical Care Medicine, vol. 174, no. 4, pp. 455–460, 2006.
[8] M. D. DeBoer, “Assessing and managing the metabolic syndrome in children and adolescents,” Nutrients, vol. 11, no. 8, p. 1788, 2019.
[9] D. Al-Hamad and V. Raman, “Metabolic syndrome in children and adolescents,” Translational Pediatrics, vol. 6, no. 4, pp. 397–407, 2017.
[10] K. G. M. Alberti, P. Zimmet, and J. Shaw, “The metabolic syndrome—a new worldwide definition,” The Lancet, vol. 366, no. 9491, pp. 1059–1062, 2005.
[11] Organization WH, Definition, diagnosis and classification of diabetes mellitus and its complications: report of a WHO consultation. Part 1. Diagnosis and classification of diabetes mellitus, World Health Organization, 1999.
heterogeneity may mislead," *BMC Medical Research Methodology*, vol. 8, no. 1, p. 79, 2008.

[42] J. P. Higgins and S. G. Thompson, "Quantifying heterogeneity in a meta-analysis," *Statistics in Medicine*, vol. 21, no. 11, pp. 1539–1558, 2002.

[43] M. Agirbasli, N. B. Agaoglu, N. Orak et al., "Sex hormones and metabolic syndrome in children and adolescents," *Metabolism*, vol. 58, no. 9, pp. 1256–1262, 2009.

[44] T.-F. Chan, W.-T. Lin, H.-L. Huang et al., "Consumption of sugar-sweetened beverages is associated with components of the metabolic syndrome in adolescents," *Nutrients*, vol. 6, no. 5, pp. 2088–2103, 2014.

[45] J. Co, J. Jeffrey, M. Emmett, A. Modak, and S. B. Sondike, "Obesity, hypertension and metabolic syndrome in children in West Virginia," *The West Virginia Medical Journal*, vol. 111, no. 4, pp. 20–24, 2015.

[46] M. Espiau, D. Yeste, A. Nogueira-Julian et al., "Metabolic syndrome in children and adolescents living with HIV," *The Pediatric Infectious Disease Journal*, vol. 35, no. 6, pp. e171–e176, 2016.

[47] C. Girvalaki, C. Vardavas, C. Papandrueou et al., "Trends in metabolic syndrome risk factors among adolescents in rural Crete between 1989 and 2011," *Hormones*, vol. 13, no. 2, pp. 259–267, 2014.

[48] H. Y. Jin, "Prevalence of subclinical hypothyroidism in obese children or adolescents and association between thyroid hormone and the components of metabolic syndrome," *Journal of Paediatrics and Child Health*, vol. 54, no. 9, pp. 975–980, 2018.

[49] M. L. Pollestad Kolsgaard, L. F. Andersen, S. Tonstad, C. Brunborg, T. Wangensteen, and G. Joner, "Ethnic differences in metabolic syndrome among overweight and obese children and adolescents: the Oslo Adiposity Intervention Study," *Acta Paediatrica*, vol. 97, no. 11, pp. 1557–1563, 2008.

[50] C. Li, E. S. Ford, T. T.-K. Huang, S. S. Sun, and E. Goodman, "Patterns of change in cardiometabolic risk factors associated with the metabolic syndrome among children and adolescents: the Fels Longitudinal Study," *The Journal of Pediatrics*, vol. 155, no. 3, pp. 55.e9–55.e16, 2009.

[51] H. Lim, H. Xue, and Y. Wang, "Association between obesity and metabolic co-morbidities among children and adolescents in South Korea based on national data," *BMC Public Health*, vol. 14, no. 1, p. 279, 2014.

[52] F. Martino, P. E. Puddu, G. Pannarale et al., "Metabolic syndrome among children and adolescents from Southern Italy: contribution from the Calabrian Sierras Community Study (CSCS)," *International Journal of Cardiology*, vol. 177, no. 2, pp. 455–460, 2014.

[53] O. Pinhas-Hamiel, N. Levek-Motola, K. Kaidar et al., "Prevalence of overweight, obesity and metabolic syndrome components in children, adolescents and young adults with type 1 diabetes mellitus," *Diabetes/Metabolism Research and Reviews*, vol. 31, no. 1, pp. 76–84, 2015.

[54] T. Reinehr, "Metabolic syndrome in children and adolescents: a critical approach considering the interaction between pubertal stage and insulin resistance," *Current Diabetes Reports*, vol. 16, no. 1, p. 8, 2016.

[55] B. H. Sanders, L. M. Lubsch, and D. S. West, "Prevalence and treatment of metabolic syndrome in adolescents with type 2 diabetes," *The Annals of Pharmacotherapy*, vol. 40, no. 9, pp. 1517–1521, 2006.

[56] A. Sartorio, F. Agosti, A. De Col, D. Mornati, M. P. Francescato, and S. Latzer, "Prevalence of the metabolic syndrome in Caucasian obese children and adolescents: comparison between three different definition criteria," *Diabetes Research and Clinical Practice*, vol. 77, no. 2, pp. 341–342, 2007.

[57] S. Serap, B. Mevlit, C. Inanç, and S. Endor, "Metabolic syndrome in childhood obesity," *Indian Pediatrics*, vol. 44, no. 9, pp. 657–662, 2007.

[58] D. Thivel, R. M. Malina, L. Isacco, J. Aucouturier, M. Meyer, and P. Duché, "Metabolic syndrome in obese children and adolescents: dichotomous or continuous?", *Metabolic Syndrome and Related Disorders*, vol. 7, no. 6, pp. 549–556, 2009.

[59] T. Urakami, J. Suzuki, A. Yoshida et al., "Prevalence of components of the metabolic syndrome in schoolchildren with newly diagnosed type 2 diabetes mellitus," *Pediatric Diabetes*, vol. 10, no. 8, pp. 508–512, 2009.

[60] W. Kiess, S. Blüher, T. Kapellen, and A. Körner, "Metabolic syndrome in children and adolescents: prevalence, public health issue, and time for initiative," *Journal of Pediatric Gastroenterology and Nutrition*, vol. 49, no. 3, pp. 268–271, 2009.

[61] G. Poriadina, "Obesity and metabolic syndrome in children and adolescents (outpatient study results in Moscow)," *Eksperimental’naia i klinicheskaiia gastroenterologiia= Experimental & clinical gastroenterology*, vol. 7, no. 7, p. 123, 2010.

[62] B. Falkner and N. D. Cossrow, "Prevalence of metabolic syndrome and obesity-associated hypertension in the racial ethnic minorities of the United States," *Current Hypertension Reports*, vol. 16, no. 7, p. 449, 2014.

[63] C. M. Hatzis, C. Papandreou, D. Sifaki-Pistolla, C. Jilideh, and A. G. Kafatos, "The metabolic syndrome among preschool and school age children and adolescents in Crete in the first decade of the 21st century," *Hormones*, vol. 13, no. 4, pp. 588–590, 2014.

[64] W. Kiess, J. Kratzsch, E. Sergeyev et al., "Metabolic syndrome in childhood and adolescence," *Clinical Biochemistry*, vol. 47, no. 9, p. 695, 2014.

[65] Y.-G. Cho, H.-J. Song, and J.-H. Kang, "Prevalence of the metabolic syndrome in Korean children and adolescents according to the International Diabetes Federation definition in children and adolescents," *Korean Journal of Family Medicine*, vol. 30, no. 4, p. 261, 2009.

[66] M. A. Guizarro de Armas, S. Monereo Megías, M. Merino Viveros, P. Iglesias Bolaños, and B. Vega Piñero, "Prevalence of metabolic syndrome in a population of obese children and adolescents," *Endocrinología y Nutrición: organo de la Sociedad Española de Endocrinología y Nutrición*, vol. 59, no. 3, pp. 155–159, 2012.

[67] S. Cook, M. Weitzman, P. Auinger, M. Nguyen, and W. H. Dietz, "Prevalence of a metabolic syndrome phenotype in adolescents: findings from the Third National Health and Nutrition Examination Survey, 1988-1994," *Archives of Pediatrics & Adolescent Medicine*, vol. 157, no. 8, pp. 821–827, 2003.

[68] E. Goodman, S. R. Daniels, J. A. Morrison, B. Huang, and L. M. Dolan, "Contrasting prevalence of and demographic disparities in the World Health Organization and National Cholesterol Education Program Adult Treatment Panel III definitions of metabolic syndrome among adolescents," *The Journal of Pediatrics*, vol. 145, no. 4, pp. 445–451, 2004.
Clinical and Experimental, vol. 55, no. 8, pp. 1002–1006, 2006.

[70] K. D. DuBose, E. E. Stewart, S. R. Charbonneau, M. S. Mayo, and J. E. Donnelly, “Prevalence of the metabolic syndrome in elementary school children,” Acta Paediatrica, vol. 95, no. 8, pp. 1005–1011, 2006.

[71] H. M. Kim, J. Park, H. S. Kim, and D. H. Kim, “Prevalence of the metabolic syndrome in Korean adolescents aged 12-19 years from the Korean National Health and Nutrition Examination Survey 1998 and 2001,” Diabetes Research and Clinical Practice, vol. 75, no. 1, pp. 111–114, 2007.

[72] S. Cook, P. Auinger, C. Li, and E. S. Ford, “Metabolic syndrome rates in United States adolescents, from the National Health and Nutrition Examination Survey, 1999-2002,” The Journal of Pediatrics, vol. 152, no. 2, pp. 165–170.e2, 2008.

[73] E. S. Ford, C. Li, G. Zhao, W. S. Pearson, and A. H. Mokdad, “Prevalence of the metabolic syndrome among U.S. adolescents using the definition from the International Diabetes Federation,” Diabetes Care, vol. 31, no. 3, pp. 587–589, 2008.

[74] A. P. Kong, G. T. Ko, R. Ozaki, G. W. Wong, P. C. Tong, and J. C. Chan, “Metabolic syndrome by the new IDF criteria in Hong Kong Chinese adolescents and its prediction by using body mass index,” Acta Paediatrica, vol. 97, no. 12, pp. 1738–1742, 2008.

[75] M. Linardakis, G. Bertias, K. Sarri, A. Papadaki, and A. Kafatos, “Metabolic syndrome in children and adolescents in Crete, Greece, and association with diet quality and physical fitness,” Journal of Public Health, vol. 16, no. 6, pp. 421–428, 2008.

[76] Y. Pan and C. A. Pratt, “Metabolic syndrome and its association with diet and physical activity in US adolescents,” Journal of the American Dietetic Association, vol. 108, no. 2, pp. 276–286, 2008.

[77] J. Pirkola, T. Tammelin, A. Bloigu et al., “Prevalence of metabolic syndrome at age 16 using the International Diabetes Federation paediatric definition,” Archives of Disease in Childhood, vol. 93, no. 11, pp. 945–951, 2008.

[78] S. J. Seo, H. Y. Lee, and S. W. Lee, “The prevalence of the metabolic syndrome in Korean children and adolescents: comparisons of the criteria of Cook et al., Cruz and Goran, and Ferranti et al.,” Yonsei Medical Journal, vol. 49, no. 4, pp. 563–572, 2008.

[79] F. M. Cizmecioglu, N. Etiler, O. Hamzaoglu, and S. Hatun, “Prevalence of metabolic syndrome in schoolchildren and adolescents in Turkey: a population-based study,” The Journal of Pediatric Endocrinology, vol. 22, no. 8, p. 703, 2009.

[80] W. D. Johnson, J. J. Kroon, F. L. Greenway, C. Bouchard, D. Ryan, and P. T. Katzmarzyk, "Prevalence of risk factors for metabolic syndrome in adolescents: National Health and Nutrition Examination Survey (NHANES), 2001-2006," Archives of Pediatrics & Adolescent Medicine, vol. 163, no. 4, pp. 371–377, 2009.

[81] D. Noto, T. Niglio, A. B. Cefalú et al., “Obesity and the metabolic syndrome in a student cohort from Southern Italy,” Nutrition, Metabolism, and Cardiovascular Diseases: NMCD, vol. 19, no. 9, pp. 620–625, 2009.

[82] M. J. Park, B. A. Boston, M. Oh, and S. H. Jee, "Prevalence and trends of metabolic syndrome among Korean adolescents: from the Korean NHANES survey, 1998-2005," The Journal of Pediatrics, vol. 155, no. 4, pp. 529–534.e1, 2009.

[83] A. Al-Isa, A. O. Akanji, and L. Thalib, “Prevalence of the metabolic syndrome among female Kuwaiti adolescents using two different criteria,” The British Journal of Nutrition, vol. 103, no. 1, pp. 77–81, 2010.

[84] Y. J. Lee, Y. H. Shin, J. K. Kim, J. Y. Shim, D. R. Kang, and H. R. Lee, “Metabolic syndrome and its association with white blood cell count in children and adolescents in Korea: the 2005 Korean National Health and Nutrition Examination Survey,” Nutrition, Metabolism, and Cardiovascular Diseases: NMCD, vol. 20, no. 3, pp. 165–172, 2010.

[85] J. Park, D. C. Hilmers, J. A. Mendoza, J. E. Stuff, Y. Liu, and T. A. Nicklas, “Prevalence of metabolic syndrome and obesity in adolescents aged 12 to 19 years: comparison between the United States and Korea,” Journal of Korean Medical Science, vol. 25, no. 1, pp. 75–82, 2010.

[86] J. J. Carlson, J. C. Eisenmann, G. J. Norman, K. A. Ortiz, and P. C. Young, “Dietary fiber and nutrient density are inversely associated with the metabolic syndrome in US adolescents,” Journal of the American Dietetic Association, vol. 111, pp. 1688–1695, 2011.

[87] S. P. Efstathiou, I. I. Skeva, E. Georgiou, and T. D. Mountokalakis, “Metabolic syndrome in adolescence,” Circulation, vol. 125, no. 7, pp. 902–910, 2012.

[88] C. Papoutsakis, M. Yannakoulia, I. Ntalla, and G. V. Dedousis, “Metabolic syndrome in a Mediterranean pediatric cohort: prevalence using International Diabetes Federation-derived criteria and associations with adiponectin and leptin,” Metabolism, Clinical and Experimental, vol. 61, no. 2, pp. 140–145, 2012.

[89] S. Setayeshgar, S. J. Whiting, and H. Vatanparast, “Metabolic syndrome in Canadian adults and adolescents: prevalence and associated dietary intake,” ISRN Obesity, vol. 2012, 8 pages, 2012.

[90] M. Turchiano, V. Sweat, A. Fierman, and A. Convit, “Obesity, metabolic syndrome, and insulin resistance in urban high school students of minority race/ethnicity,” Archives of Pediatrics & Adolescent Medicine, vol. 166, no. 11, pp. 1030–1036, 2012.

[91] J. Y. Chung, H. T. Kang, Y. H. Shin, H. R. Lee, B. J. Park, and Y. J. Lee, “Prevalence of metabolic syndrome in children and adolescents—the recent trends in South Korea,” Journal of Pediatric Endocrinology & Metabolism, vol. 26, no. 1-2, pp. 105–110, 2013.

[92] S. Lee, S. M. Kim, H. Park et al., “Serum 25-hydroxyvitamin D levels, obesity and the metabolic syndrome among Korean children,” Nutrition, Metabolism, and Cardiovascular Diseases, vol. 23, no. 8, pp. 785–791, 2013.

[93] A. E. Mehairi, A. A. Khouri, M. M. Naqbi et al., “Metabolic syndrome among Emirati adolescents: a school-based study,” PloS One, vol. 8, no. 2, article e56159, 2013.

[94] S. H. Park, J. H. Park, J. W. Kang, H. Y. Park, J. Park, and K. J. Shin, “Prevalence of the metabolic syndrome and abnormal lipid levels among Korean adolescents,” Journal of Paediatrics and Child Health, vol. 49, no. 7, pp. 582–587, 2013.

[95] J. Lee and H. Park, “Relation between sleep duration, overweight, and metabolic syndrome in Korean adolescents,” Nutrition, Metabolism, and Cardiovascular Diseases, vol. 24, no. 1, pp. 65–71, 2014.

[96] J. M. Miller, M. B. Kaylor, M. Johannsson, C. Bay, and J. R. Churilla, “Prevalence of metabolic syndrome and individual criterion in US adolescents: 2001-2010 National Health and
Nutrition Examination Survey,” *Metabolic Syndrome and Related Disorders*, vol. 12, no. 10, pp. 527–532, 2014.

[97] A. Monzani, A. Rapa, N. Fuiano et al., “Metabolic syndrome is strictly associated with parental obesity beginning from childhood,” *Clinical Endocrinology*, vol. 81, no. 1, pp. 45–51, 2014.

[98] R. Galera-Martínez, E. García-Garcia, M. Vázquez-López et al., “Prevalence of metabolic syndrome among adolescents in a city in the Mediterranean area: comparison of two definitions,” *Nutrición Hospitalaria*, vol. 32, no. 2, pp. 627–633, 2015.

[99] E. González-Jiménez, M. A. Montero-Alonso, J. Schmidt-RioValle, C. J. García-García, and C. Padez, “Metabolic syndrome in Spanish adolescents and its association with birth weight, breastfeeding duration, maternal smoking, and maternal obesity: a cross-sectional study,” *European Journal of Nutrition*, vol. 54, no. 4, pp. 589–597, 2015.

[100] J. W. Kim, S. H. Park, Y. Kim, M. Im, and H. S. Han, “The cutoff values of indirect indices for measuring insulin resistance for metabolic syndrome in Korean children and adolescents,” *Annals of Pediatric Endocrinology & Metabolism*, vol. 21, no. 3, pp. 143–148, 2016.

[101] S. Kim and W.-Y. So, “Prevalence of metabolic syndrome among Korean adolescents according to the National Cholesterol Education Program, Adult Treatment Panel III and International Diabetes Federation,” *Nutrients*, vol. 8, no. 10, p. 588, 2016.

[102] A. M. Lee, M. J. Gurka, and M. D. DeBoer, “Trends in metabolic syndrome severity and lifestyle factors among adolescents,” *Pediatrics*, vol. 137, no. 3, article e20153177, 2016.

[103] M. Mac Pherson, M. de Groh, L. Loukine, D. Prud’homme, and D. Louis, “Prevalence of metabolic syndrome and its risk factors in Canadian children and adolescents: Canadian Health Measures Survey Cycle 1 (2007-2009) and Cycle 2 (2009-2011),” *Health Promotion and Chronic Disease Prevention in Canada*, vol. 36, no. 2, pp. 32–40, 2016.

[104] J. Cho, H. Hong, S. Park, S. Kim, and H. Kang, “Insulin resistance and its association with metabolic syndrome in Korean children,” *Bio Med Research International*, vol. 2017, article 8728017, 7 pages, 2017.

[105] D. H. Choi, Y. H. Hur, J. H. Kang et al., “Usefulness of the waist circumference-to-height ratio in screening for obesity and metabolic syndrome among Korean children and adolescents: Korea National Health and Nutrition Examination Survey, 2010–2014,” *Nutrients*, vol. 9, no. 3, p. 256, 2017.

[106] Y. S. Kim, J. H. Hwang, and M. R. Song, “The association between vitamin D deficiency and metabolic syndrome in Korean children,” *Journal of Pediatric Nursing*, vol. 38, pp. c7–e11, 2018.

[107] D. R. Stevens, A. M. Malek, C. Laggis, and K. J. Hunt, “In utero exposure to tobacco smoke, subsequent cardiometabolic risks, and metabolic syndrome among U.S. adolescents,” *Annals of Epidemiology*, vol. 28, no. 9, pp. 619–624.e1, 2018.

[108] F. Bacoopoulu, V. Ethymiou, G. Palaiologos et al., “Telemedicine screening adolescent metabolic syndrome in Greek schools,” *European Journal of Clinical Investigation*, vol. 49, no. 4, article e13075, 2019.

[109] M. D. DeBoer, S. L. Filipp, and M. J. Gurka, “Geographical variation in the prevalence of obesity and metabolic syndrome among US adolescents,” *Pediatric Obesity*, vol. 14, no. 4, article e12483, 2019.

[110] G. K. Elitok, N. S. Duru, M. Elevli, Z. A. Saglam, and K. Karsidag, “Prevalence of metabolic syndrome in middle school children and evaluation of components of metabolic syndrome,” *Sis University Journal of Health Sciences*, vol. 53, no. 4, pp. 403–408, 2019.

[111] S. M. Shah, F. Aziz, F. Al Meskari, J. Al Kaabi, U. I. Khan, and L. M. Maack, “Metabolic syndrome among children aged 6 to 11 years, Al Ain, United Arab Emirates: role of obesity,” *Pediatric Diabetes*, vol. 21, no. 5, pp. 735–742, 2020.

[112] D. Haroun, R. Mecih, R. Sahuri et al., “Metabolic syndrome among adolescents in Dubai, United Arab Emirates, is attributable to the high prevalence of low HDL levels: a cross-sectional study,” *BMC Public Health*, vol. 18, no. 1, p. 1284, 2018.

[113] M. Yoshinaga, S. Tanaka, A. Shimago et al., “Metabolic syndrome in overweight and obese Japanese children,” *Obesity Research*, vol. 13, no. 7, pp. 1135–1140, 2005.

[114] M. E. Atabek, O. Pirgon, and S. Kurtoglu, “Prevalence of metabolic syndrome in obese Turkish children and adolescents,” *Diabetes Research and Clinical Practice*, vol. 72, no. 3, pp. 315–321, 2006.

[115] G. Bueno, O. Bueno, L. Moreno et al., "Diversity of metabolic syndrome risk factors in obese children and adolescents," *Journal of Physiology and Biochemistry*, vol. 62, no. 2, pp. 125–133, 2006.

[116] C. Druet, M. Dabbas, V. Baltakse et al., "Insulin resistance and the metabolic syndrome in obese French children," *Clinical Endocrinology*, vol. 64, no. 6, pp. 672–678, 2006.

[117] C. Invitti, C. Maffioli, L. Gilardini et al., “Metabolic syndrome in obese Caucasian children: prevalence using WHO-derived criteria and association with nontraditional cardiovascular risk factors,” *International Journal of Obesity*, vol. 30, no. 4, pp. 627–633, 2006.

[118] M. López-Capapé, M. Alonso, C. Mustieles, J. Corbatón, and R. Barrio, “Frequency of the metabolic syndrome in obese Spanish pediatric population,” *European Journal of Endocrinology*, vol. 155, no. 2, pp. 313–319, 2006.

[119] S. Bokor, M. L. Frelut, A. Vania et al., "Prevalence of metabolic syndrome in European obese children," *International Journal of Pediatric Obesity*, vol. 3, Suppl 2, pp. 3–8, 2008.

[120] V. Calcaterra, C. Klersy, T. Muratori et al., "Prevalence of metabolic syndrome (MS) in children and adolescents with varying degrees of obesity," *Clinical Endocrinology*, vol. 68, no. 6, pp. 868–872, 2008.

[121] F. M. Cizmecioğlu, S. Hatun, and S. Kalaça, “Metabolic syndrome in obese Turkish children and adolescents: comparison of two diagnostic models,” *The Turkish Journal of Pediatrics*, vol. 50, no. 4, pp. 359–365, 2008.

[122] Y. Sen, N. Kandemir, A. Alikastifoglu, N. Gonç, and A. Ozon, "Prevalence and risk factors of metabolic syndrome in obese children and adolescents: the role of the severity of obesity," *European Journal of Pediatrics*, vol. 167, no. 10, pp. 1183–1189, 2008.

[123] D. Taha, "The prevalence of metabolic syndrome and cardiovascular risk factors in a group of obese Saudi children and adolescents: a hospital-based study," *Annals of Saudi Medicine*, vol. 29, no. 5, pp. 357–360, 2009.

[124] E. P. Wickham, M. Stern, R. K. Evans et al., "Prevalence of the metabolic syndrome among obese adolescents enrolled in a multidisciplinary weight management program: clinical
correlates and response to treatment,” *Metabolic Syndrome and Related Disorders*, vol. 7, no. 3, pp. 179–186, 2009.

[125] P. Bustos, K. Saez, A. Gleisner, N. Ulloa, C. Calvo, and S. Asenjo, “Metabolic syndrome in obese adolescents,” *Pediatric Diabetes*, vol. 11, no. 1, pp. 55–60, 2010.

[126] C. Druet, K. Ong, and C. Levy Marchal, “Metabolic syndrome in children: comparison of the International Diabetes Federation 2007 consensus with an adapted National Cholesterol Education Program definition in 300 overweight and obese French children,” *Hormone Research in Pediatrics*, vol. 73, no. 3, pp. 181–186, 2010.

[127] V. Eapen, A. Mabrouk, and S. Yousef, “Metabolic syndrome among the young obese in the United Arab Emirates,” *Journal of Tropical Pediatrics*, vol. 56, no. 5, pp. 325–328, 2010.

[128] C. L. Lafortuna, F. Adorni, F. Agostì et al., “Prevalence of the metabolic syndrome among extremely obese adolescents in Italy and Germany,” *Diabetes Research and Clinical Practice*, vol. 88, no. 1, pp. 14–21, 2010.

[129] Ö. Sangun, B. Dündar, M. Kösker, O. Pırgon, and N. Dündar, “Prevalence of metabolic syndrome in obese children and adolescents using different criteria and evaluation of risk factors,” *Journal of Clinical Research in Pediatric Endocrinology*, vol. 3, no. 2, pp. 70–76, 2011.

[130] M. G. G. de Armas, S. M. Megías, M. M. Viveros, P. I. Bolaños, and B. V. Piñero, “Prevalencia de síndrome metabólico en una población de niños y adolescentes con obesidad,” *Endocrinología y Nutrición (English Edition)*, vol. 59, no. 3, pp. 155–159, 2012.

[131] D. Pastucha, R. Filipčíková, D. Horáková et al., “The incidence of metabolic syndrome in obese Czech children: the importance of early detection of insulin resistance using homeostatic indexes HOMA-IR and QUICKI,” *Physiological Research*, vol. 62, no. 3, pp. 277–283, 2013.

[132] N. Santoro, A. Amato, A. Grandone et al., “Predicting metabolic syndrome in obese children and adolescents: look, measure and ask,” *Obesity Facts*, vol. 6, no. 1, pp. 48–56, 2013.

[133] J. Suazo, M. I. Hodgson, A. M. Obregón et al., “Prevalence of metabolic syndrome in obese Chilean children and association with gene variants of the leptin-melanocortin system,” *Journal of Pediatric Endocrinology & Metabolism*, vol. 26, no. 11-12, pp. 1131–1139, 2013.

[134] M. Šimunović, J. Božić, L. Milić, I. Unić, and V. Škribić, “The prevalence of metabolic syndrome and cardiovascular risk factors in obese children and adolescents in Dalmatia: a hospital based study,” *International Journal of Endocrinology*, vol. 2016, Article ID 1823561, 7 pages, 2016.

[135] K. Szabelska-Zakrzewska, A. Durko, A. Socha-Banasiak et al., “Metabolic syndrome in overweight or obese children and adolescents based on own material abstract key words,” *Developmental Period Medicine*, vol. 22, no. 4, pp. 351–357, 2018.

[136] L. Davidsson, E. Alkhabbaz, V. Vijayan, A. Alhubail, A. Shaltout, and H. Alkandari, “Intermediate hyperglycemia, insulin resistance and metabolic syndrome among obese Arab children (12–17 years old) in Kuwait,” *Primary Care Diabetes*, vol. 15, 2020.

[137] R. Kelishadi, S. Hovsepian, S. Djalalinia, F. Jamshidi, and M. Qorbani, “A systematic review on the prevalence of metabolic syndrome in Iranian children and adolescents,” *Journal of Research in Medical Sciences: The Official Journal of Isfahan University of Medical Sciences*, vol. 21, no. 1, p. 90, 2016.

[138] A. M. Tailor, P. H. Peeters, T. Norat, P. Vineis, and D. Romaguera, “An update on the prevalence of the metabolic syndrome in children and adolescents,” *International Journal of Pediatric Obesity*, vol. 5, no. 3, pp. 202–213, 2010.

[139] P. Ye, Y. Yan, W. Ding et al., “Prevalence of metabolic syndrome in Chinese children and adolescents: a meta-analysis,” *Zhonghua liuxingbingxue zazhi*, vol. 36, no. 8, pp. 884–888, 2015.

[140] C. Reisinger, B. N. Kneh-Chungag, P. M. Fredriksen, and N. Goswami, “The prevalence of pediatric metabolic syndrome—a critical look on the discrepancies between definitions and its clinical importance,” *International Journal of Obesity*, vol. 45, no. 1, pp. 12–24, 2021.

[141] C. Graf and N. Ferrari, “Metabolic syndrome in children and adolescents,” *Vesical Medicine*, vol. 32, no. 5, pp. 357–362, 2016.

[142] A. T. Titmuß and S. Srinivasan, “Metabolic syndrome in children and adolescents: old concepts in a young population,” *Journal of Paediatrics and Child Health*, vol. 52, no. 10, pp. 928–934, 2016.

[143] Z. W. Bitew, A. Alemu, E. G. Ayele, Z. Tenaw, A. Alebel, and T. Worku, “Metabolic syndrome among children and adolescents in low and middle income countries: a systematic review and meta-analysis,” *Diabetologia & Metabolic Syndrome*, vol. 12, no. 1, pp. 1–23, 2020.

[144] Z. Akbarzadeh, M. Nourian, S. Hovsepian, and R. Kelishadi, “ Dietary patterns and metabolic syndrome in children and adolescents: a systematic review,” *Journal of Pediatrics Review*, vol. 6, no. 2, 2017.

[145] Y. Tian, L. Su, J. Wang, X. Duan, and X. Jiang, “Fruit and vegetable consumption and risk of the metabolic syndrome: a meta-analysis,” *Public Health Nutrition*, vol. 21, no. 4, pp. 756–765, 2018.

[146] S. N. Bleich, D. Cutler, C. Murray, and A. Adams, “Why is the developed world obese?,” *Annual Review of Public Health*, vol. 29, no. 1, pp. 273–295, 2008.

[147] V. H. Wang, J. Min, H. Xue et al., “What factors may contribute to sex differences in childhood obesity prevalence in China?”, *Public Health Nutrition*, vol. 21, no. 11, pp. 2056–2064, 2018.

[148] Z. Semnani-Azad, T. A. Khan, S. B. Mejia et al., “Association of major food sources of fructose-containing sugars with incident metabolic syndrome: a systematic review and meta-analysis,” *JAMA Network Open*, vol. 3, no. 7, pp. e209993–e209993, 2020.

[149] E. Nehrus and M. Mitsnefes, “Childhood obesity and the metabolic syndrome,” *Pediatric Clinics*, vol. 66, no. 1, pp. 31–43, 2019.

[150] J. Kim, I. Lee, and S. Lim, “Overweight or obesity in children aged 0 to 6 and the risk of adult metabolic syndrome: a systematic review and meta-analysis,” *Journal of Clinical Nursing*, vol. 26, no. 23-24, pp. 3869–3880, 2017.