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Prevalence of childhood and adolescent overweight and obesity in Asian countries: a systematic review and meta-analysis

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Abstract

Introduction: We conducted a systematic review and meta-analysis to estimate the prevalence of overweight and obesity in children (aged 5–12 years) and adolescents (aged 12–19 years) in Asian countries. Study design: Systematic review and meta-analysis.

Material and methods: We comprehensively searched specialised databases for relevant studies conducted in Asian countries between January 1, 1999, and May 30, 2017. Random effects models (using the DerSimonian-Laird method) and generic inverse variance methods were used for quantitative data synthesis. Sensitivity analysis was conducted using the 'leave-one-out' method. Heterogeneity was quantitatively assessed using the I^2 index. Systematic review registration: CRD42016033061.

Results: Among 22,286 identified citations, 41 studies met the inclusion criteria with $n = 71,998$ and $n = 353,513$ for children and adolescents. The pooled prevalence (overall, boys and girls) was 5.8% ($n = 4175$), 7.0% ($n = 2631$) and 4.8% ($n = 1651$) for obesity in children aged 5–11 years; 8.6% ($n = 30,402$), 10.1% ($n = 17,990$) and 6.2% ($n = 10,874$) for obesity in adolescents age 12–19 years. For overweight in children the values for overall, boys and girls were 11.2% ($n = 7900$), 11.7% ($n = 4280$) and 10.9% ($n = 3698$) respectively; and for overweight in adolescents, 14.6% ($n = 46,886$), 15.9% (27,183), and 13.7% (20,574). These findings were robust in sensitivity analyses. In children and adolescents a higher percentage of boys than girls are obese (children = 7.0 vs. 4.8%, adolescents = 10.1 vs. 6.2%, $p < 0.001$, respectively). Furthermore, in children and adolescents a higher percentage of boys than girls are overweight (children = 11.7 vs. 10.9%, adolescents = 15.9 vs. 13.7%, $p < 0.001$, respectively).

Conclusions: In view of the number of children who are overweight or obese, the associated detrimental effects on health, and the cost to health-care systems, implementation of programmes to monitor and prevent unhealthy weight gain in children and adolescents is needed throughout Asian countries.

Key words: childhood, adolescent, overweight, obesity.

Introduction

The worldwide prevalence of overweight and obesity in children and adolescents has increased in recent decades [1]. An estimated 170 million children under 18 years of age were overweight or obese in 2008, and it has been projected that approximately 30% of all children will be affected by these conditions by 2030 [2, 3]. The prevalence of a body mass index (BMI) at or higher than the 95th percentile among children between the ages of 6 and 11 years in the United States increased from 4.2% in 1963–1965 to 15.3% in 1999–2000, before plateauing during the first decade of the 21st century [4, 5]. The overall prevalence of overweight, including obesity, in school children in European countries was estimated at 20.5%: 15.6% for overweight and 4.9% for obesity. The proportion of overweight and obesity was 24.5% in Eastern Asia countries and 11.9% in the Western Asia regions [6]. The World Health Organization (WHO) has estimated that the majority of overweight or obese children live in developing countries, where the rates are increasing faster than in developed countries [7]. A comparative study across developing countries reported that prevalence rates of obesity in adolescents in Asia are highest [8]. Furthermore, there are large within and between countries variations across Asia: 3.5% in rural Bangladesh to over 65% in the Maldives [9], 30% in Iran and Saudi Arabia and approximately 12.5% for Chinese children [10].

Obesity in early life is a precursor to obesity in adulthood [2], and excess weight in adults is associated with many adverse health outcomes including type 2 diabetes, hypertension, dyslipidaemia, cardiovascular diseases and type of cancers [2]. The current increasing prevalence of childhood overweight and obesity will therefore adversely affect the burden of obesity-related diseases and their consequences on families and health systems in the near future [11]. The etiological factors for childhood obesity include genetic, metabolic, and behavioural components [12]. In spite of the demonstrated genetic influence, a strong obesogenic environment is essential for its phenotypic expression of overweight and obesity [11, 13]. However, environmental modulators of the energy intake and expenditure (the imbalance of which leads to overweight and obesity) vary across regions. Studies in the Middle East have reported that among all of the lifestyle factors, overweight and obesity exhibited significant associations with less frequent vigorous physical activity, consumption of breakfast, vegetables and frequent sugar-sweetened beverage consumption [13]. Although there are some profound differences among Asian countries including socio-economic status, diversity of the cultures, races and genet-

ics, the main contributors to the increasing burden of obesity and overweight among children and adolescents in Asia are very similar [13]. Childhood and adolescence is a short-term, but important, window of opportunity for the prevention management and control of obesity and related health consequences. In this regard, reliable data on the burden are a solid foundation of such prevention efforts. Regarding the size and diversity of the population of Asia and its high number of developing countries, the population of children and adolescents in Asia represents a relatively large proportion of the global population of children and adolescents in developing countries.

We performed a systematic review and meta-analysis to determine the prevalence of childhood and adolescent overweight and obesity in Asian countries, with a view to providing accurate data for monitoring future trends.

Material and methods

Literature search

This systematic review is reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Statement [14]. The study protocol was registered with the International Prospective Register of Systematic Reviews, PROSPERO (registration no: CRD42016033061). We aimed to identify prevalence studies in Asian countries published from Jan 1, 1999, to May 30, 2017. A combination of words from the dictionary Medical Subject Heading Terms (MeSH) descriptors, and Boolean operators were used to search PUBMED, EMBASE, Web of Science, SCOPUS and Gray Literature sources with a range of search terms (Tables I and II). An expert librarian helped in designing the search strategy framework and implementing searches. Websites of relevant agencies such as the International Association for the Study of Obesity (IASO), the International Obesity Task Force, the Global School-based Student Health Survey and World Health Organization (WHO) were browsed. Additionally, we performed a manual search for other articles and references of published articles, and sent email requests to corresponding authors for additional data where relevant. To further minimize the effect of any publication bias, a snowball method, characterized by manual checking of references from retrieved articles, was applied. We also searched grey literature databases including the Virtual Library for Public Health and the System for Information on Grey Literature.

To be included in this systematic review, primary studies had to meet these criteria: 1) population-based cross-sectional or cohort studies reporting the prevalence of overweight and obesity

Table I. Full search terms and strategy used for systematically reviewing the articles indexed in PubMed and Scopus

No.	Concept	Search terms
1	Childhood and adolescence	Child [Text Word] OR Child [MeSH terms] Children [Text Word] OR childhood [Text Word] OR adolescent [MeSH terms] OR adolescent [Text Word] OR adolescent* [Text Word] OR pediatric [Text Word] OR teens [Text Word] OR teen [Text Word] OR Teenage* [Text Word] OR Youth* [Text Word] OR Infan*[Text Word]
2	Obesity and overweight	"Obesity" [MeSH Terms] OR "Obesity" [All Fields] OR "Obese" [MeSH Terms] OR "Obese" [All Fields] OR "Overweight" [MeSH Terms] OR "Overweight" [All Fields] OR "body-mass index " [MeSH Terms] OR "body-mass index " [All Fields] OR "BMI" [All Fields] OR "Weight" [MeSH Terms] OR "Weight" [All Fields]
3	Prevalence	"Epidemiology" [Subheading] OR "Prevalence" [All Fields] OR "epidemiology" [All Fields] OR "prevalence" [MeSH Terms] OR "Proportion " [All Fields] OR "Survey" [All Fields]
4	Asian countries	"Asia" [MeSH Terms] OR (Afghanistan [Text Word]) OR Bahrain [Text Word] OR Bangladesh [Text Word] OR Bhutan [Text Word] OR Brunei [Text Word] OR Cambodia [Text Word] OR China [Text Word] OR Hong Kong [Text Word] OR India [Text Word] OR Indonesia [Text Word] OR Iran [Text Word] OR Iraq [Text Word] OR Israel [Text Word] OR Japan [Text Word] OR Jordan [Text Word] OR Kazakhstan [Text Word] OR Kuwait [Text Word] OR Kyrgyzstan [Text Word] OR Laos [Text Word] OR Lebanon [Text Word] OR Malaysia [Text Word] OR Maldives [Text Word] OR Mongolia [Text Word] OR Myanmar [Text Word] OR Nepal [Text Word] OR North Korea [Text Word] OR Oman [Text Word] OR Pakistan [Text Word] OR Philippines [Text Word] OR Qatar [Text Word] OR Saudi Arabia [Text Word] OR Singapore [Text Word] OR South Korea [Text Word] OR Sri Lanka [Text Word] OR Syria [Text Word] OR Taiwan [Text Word] OR Tajikistan [Text Word] OR Thailand [Text Word] OR Timor-Leste [Text Word] OR Turkmenistan [Text Word] OR United Arab Emirates [Text Word] OR Uzbekistan [Text Word] OR Vietnam [Text Word] OR Yemen [Text Word]
5	Combination	1 AND 2 AND 3 AND 4

Table II. Full search terms and strategy used for systematically reviewing the articles published in EMBASE, Web of Science and Open Grey

No.	Concept	Search terms
1	Childhood and adolescence	Child or youth or childhood or adolescent
2	Obesity and overweight	Obesity or overweight
3	Prevalence	Prevalence OR epidemiology
4	Asian countries	"Asia" OR Afghanistan OR Bahrain OR Bangladesh OR Bhutan OR Brunei OR Cambodia OR China OR Hong Kong OR India OR Indonesia OR Iran OR Iraq OR Israel OR Japan OR Jordan OR Kazakhstan OR Kuwait OR Kyrgyzstan OR Laos OR Lebanon OR Malaysia OR Maldives OR Mongolia OR Myanmar OR Nepal OR North Korea OR Oman OR Pakistan OR Philippines OR Qatar OR Saudi Arabia OR Singapore OR South Korea OR Sri Lanka OR Syria OR Taiwan OR Tajikistan OR Thailand OR Timor-Leste OR Turkmenistan OR United Arab Emirates OR Uzbekistan OR Vietnam OR Yemen
5	Combination	1 AND 2 AND 3 AND 4

in children and adolescents, 2) studies conducted in Asians after 1999 and published between January 1999 and May 30, 2017, 3) age of the participants ranging between 5 and 19 years, with 5–11 years defining children and 12–19 years defining adolescents, 4) original studies containing a minimum of information necessary to calculate pooled analysis of prevalence (number of subjects, sample size), 5) articles with at least the abstract in English language, 6) obesity and overweight defined using directly measured anthropometries and not based on self-report, 7) participants re-

siding in Asian countries, irrespective of ethnic, socioeconomic, and educational backgrounds. Studies were excluded if: 1) they were done in clinical settings and/or in participants with special medical conditions, 2) they were conducted in Asians living outside Asia, 3) they were based on self-reported weight or height, 4) were narrative reviews, commentaries, opinion pieces, methodological, editorials, letters or any other publications lacking primary data and/or explicit method descriptions, 5) they did not report the prevalence of obesity or overweight separately for children and

adolescents. When authors presented the results of the same study in more than one paper, the most recent and most comprehensive paper was included.

Selecting studies for inclusion

We started with the removal of duplicates; next, two reviewers excluded some papers based on titles and abstracts only. Then eligibility was further assessed via the full text (Figure 1). Disagreements between reviewers were resolved by consensus.

Assessment of the methodological quality of included studies

We assessed the methodological quality of included studies in terms of internal validity, external validity, response rate, and generalizability of

study results. We used the ten-item rating system developed by Hoy *et al.* [15] and modified by Werfalli *et al.* [16] (Table III) to assess sampling, the sampling frame and size, outcome measures, outcome assessment, response rate, and statistical reporting [15]. Each item was assigned a score of 1 (yes) or 0 (no), and scores were summed across items to generate an overall quality score that ranged from 0 to 10. Each study was rated as having a low, moderate, or high risk of bias depending on the number of questions answered as “yes (low risk)”: studies at low risk of bias had scores higher than 8, moderate a score of 6–8, and high a score of 5 or lower [15]. Risk of selection and attrition biases were assessed according to the Cochrane guidelines, in Review Manager version 5.2. Two reviewers (MM and PR) independently assessed study quality, with disagreements being resolved by consensus.

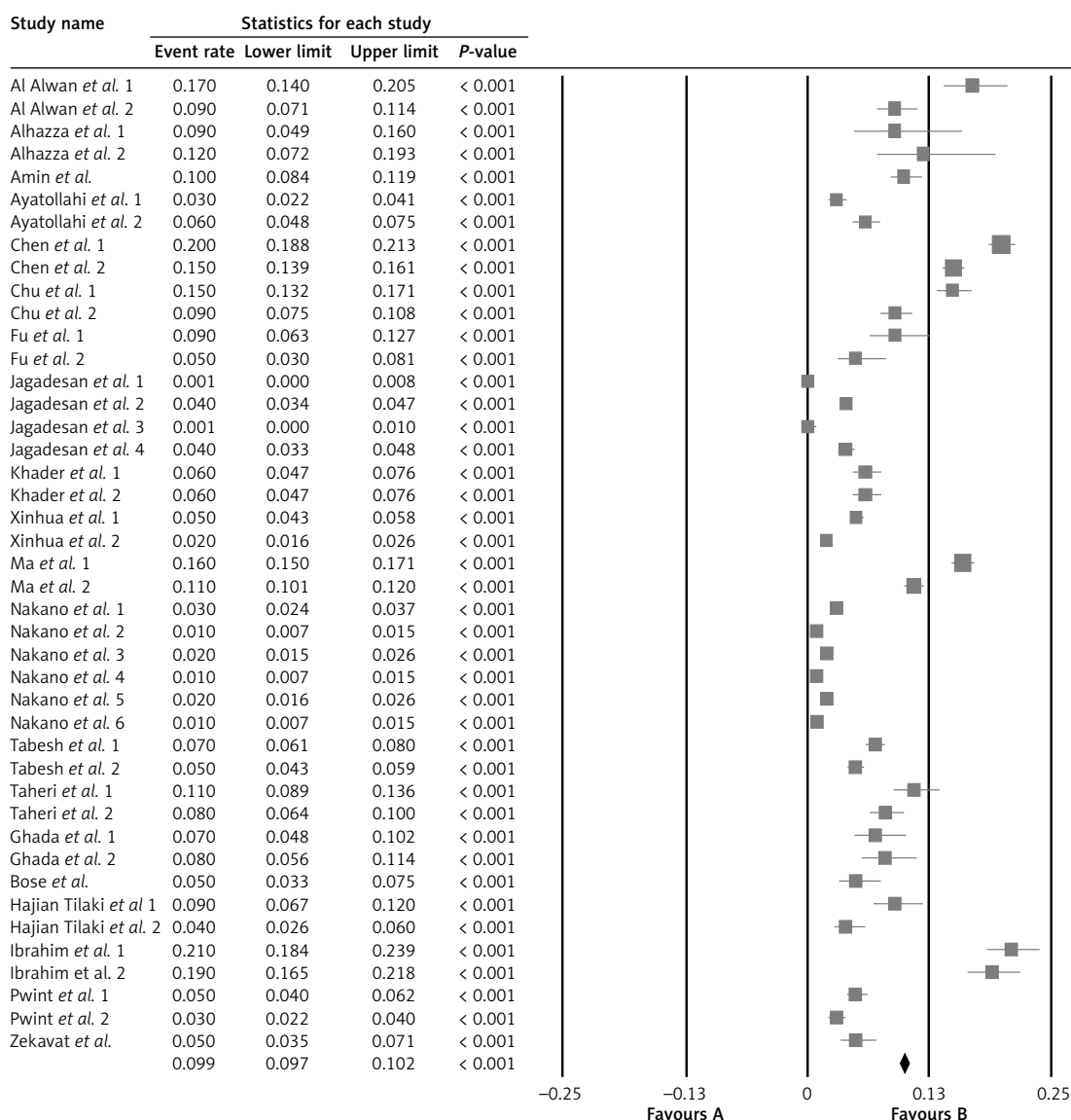


Figure 1. Overall prevalence of obesity in children

Table III. Quality assessment criteria for prevalence studies

Items	Quality score
External validity	
1. Was the study's target population a close representation of the national population in relation to relevant variables?	(1 point)
2. Was the sampling frame a true or close representation of the target population?	(1 point)
3. Was some form of random selection used to select the sample, OR was a census undertaken?	(1 point)
4. Was the likelihood of non-response bias minimal?	(1 point)
Total (4 points)	
Internal validity	
1. Were data collected directly from the participants (as opposed to a proxy)?	(1 point)
2. Was an acceptable case definition used in the study?	(1 point)
3. Was the study instrument that measured the parameter of interest shown to have validity and reliability?	(1 point)
4. Was the same mode of data collection used for all participants? (1 point)	(1 point)
5. Was the length of the shortest prevalence period for the parameter of interest appropriate?	(1 point)
6. Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	(1 point)
Total (6 points)	

Data extraction and management

Two reviewers extracted data onto a purpose-designed data extraction form and independently summarized what they considered to be the most important results from each study. These summaries were compared and disagreements resolved by discussion and consultation with a third reviewer. Any further calculations on study data considered necessary were conducted by the first reviewer and checked by the second reviewer. Study characteristics including prevalence of obesity and/or overweight, country

where the study was conducted, year of publication, study population, age range, sex (boys, girls, or combined), response rate, study design, criteria for sample selection and sample size, diagnostic criteria, results and notes/comments are presented in Table IV. When a study did not present the mean age of the subjects in each age group we assumed the mid-point of the age interval. When an age group also included subjects older than 19 years (e.g. age group 17–22 years), we computed the mid-point and excluded the data if the mid-point year was higher than 19 years old. Data

Table IV. International overweight and obesity classification methods for children and adolescents

Classification	Indicator	Risk of overweight	Overweight*	Obesity	Age range [years]
WHO 2007(23)	BMI/age	–	> 1 SD and ≤ 2 SD	> 2 SD	5–19
IOTF 2000 (97)	BMI/age	–	Age-specific [†] and sex-specific [†] BMI cut-off points for overweight and obesity that track with BMI values of 25 at 18 years of age	Age-specific [†] and sex-specific [†] BMI cut-off points for overweight and obesity that track with BMI values of 30 at 18 years of age	2–18
CDC 2000 (98)	BMI/age	–	≥ p85 < p95	≥ p95	2–19
NCHS/WHO	BMI/age	–	≥ p85 < p95	≥ p95	10–19
1979 (99)	W/H	–	2 SD	–	< 10

W/H – weight-for-height, SD – standard deviation, IOTF – International Obesity Task Force, CDC – Centers for Disease Control and Prevention, NCHS – National Center for Health Statistics, p85 – 85th percentile, p95 – 95th percentile. *In children younger than 5 years, overweight is currently defined as risk of overweight, and obesity as overweight, according to the WHO 2006 norms and for CDC 2000 reference since 2007. †For children younger than 2 years, the indicator is weight-for-length, referred to here and in the text as weight-for-height.

for age ranges that covered more than one age group were not extracted.

Diagnosis of obesity and overweight in included studies

In the case of diagnosis of obesity in school-age children and adolescents (5–19 years) the International Obesity Task Force (IOTF) [17] and the WHO 2007 methods [18] were used. Different classification methods used different cut-off points and reference populations. For school-age children and adolescents (5–19 years), the two most widely used classification methods were the IOTF [17] and the WHO 2007 methods [18], both using BMI. WHO criteria were used for overweight and obesity in adults [18].

Data synthesis and analysis

Data extraction and synthesis was based on Cochrane Handbook recommendations [19]. We used a random-effects meta-analysis model to aggregate prevalence estimates across studies while accounting for the between-study variability [20]. Heterogeneity between studies was assessed with Cochran's χ^2 test based on a 10% level of significance cut-off (due to the low power of the test) and the I^2 statistic where values of 25%, 50% and 75% reflect low, medium and high heterogeneity,

respectively [14]. We explored sources of heterogeneity by comparing obesity and overweight prevalence between subgroups defined by several study level characteristics. In order to evaluate the influence of each study on the overall effect size, sensitivity analysis was conducted using the leave-one-out method, i.e. removing one study each time and repeating the analysis [21–23]. Potential publication bias was explored using visual inspection of Begg's funnel plot asymmetry, Begg's rank correlation and Egger's weighted regression tests. Duval and Tweedie 'trim and fill' and 'fail-safe N' methods were used to adjust the analysis for the effects of publication bias [24]. Meta-analysis was conducted using Comprehensive Meta-Analysis (CMA) V3 software (Biostat, NJ) [25].

Results

Summary of searches and study selection process

The searches identified 22,286 citations. After screening of titles and abstracts, and removal of duplicates, 12,635 studies were selected for further scrutiny, of which 210 were selected for full-text review. Of these, 47 studies ($n = 71,998$ and 353,513 for children and adolescents, respectively) met the inclusion criteria and were included in this systematic review (Figure 2).

Methodological quality of included studies

From all the studies, 30 of them were considered as having a "low risk of bias" while the rest of them had a "moderate risk of bias". Six surveys did not report how subjects were selected; 26 studies mentioned random selection as a selection technique while 12 surveys reported a non-random sampling method. Nineteen studies stated the response rates, which ranged from 71.1% to 100% (median: 85.5%).

Characteristics of included studies

The characteristics of the included studies are summarized in Table V. Of the 44 countries of the Asian continent, 15 were represented in this systematic review: five studies from India [26–30], eight from Iran [31–38], seven from Saudi Arabia [13, 39–43], three from Kuwait [44–46], four from Taiwan [47–50], four from China [51–54], two from the United Arab Emirates [55, 56], four from Jordan [57–60], two from Bahrain [61, 62], two from Japan [63, 64] and one from Singapore [65], Thailand [66], Malaysia [67], Israel [68], Pakistan [69] and Turkey [70]. Two studies conducted in Israel and Thailand [66, 68] had national coverage while the remainder were subnational. Different diagnosis criteria for obesity and overweight were

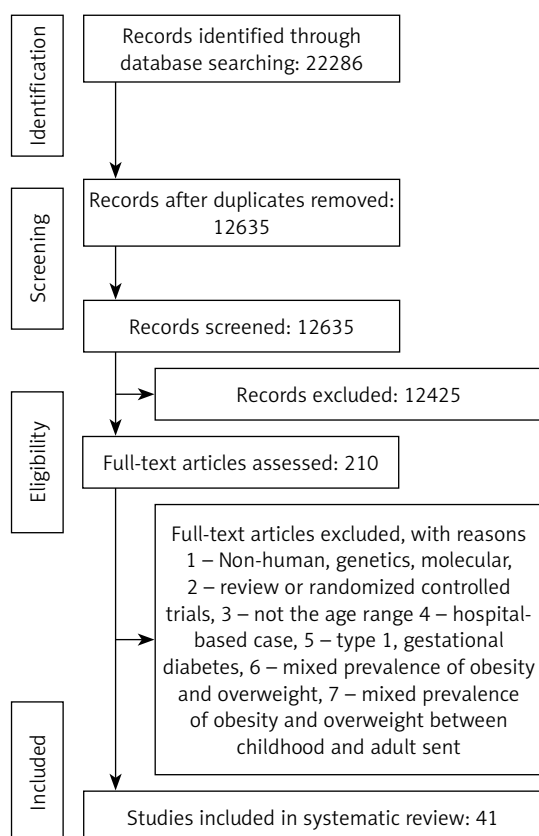


Figure 2. PRISMA Flow chart for the studies selection

Table V. National prevalence of overweight and obesity in children and adolescents from cross-sectional surveys in Asian countries

First author surname, date of publication	Sample design	Date of fieldwork	Sample size (% male)	Age range	Classification method	Urban or rural	Prevalence of overweight	Prevalence of obesity	Combined prevalence of overweight and obesity	Response rate
Baker, 2010 [3]	Cluster random	May 2007.	1355 (44.4%)	13 to 16 years	Based on CDC	Both (urban 29.2% and rural 70.8%)	15.7%	8.7%	24.4%	98.9%
Aggarwal, 2008 [10]	Random	Not known	1000 (50%)	12 to 18 years	WHO	Urban	15% (male) 10.2% (female)	3.4% (male) 3.4% (female)	18.4% 13.6%	Not known
Ahmed, 2013 [12]	Random	January 2008 to June 2009	501 (50.8%)	6 to 10 years	Based on WHO	Urban	8%	12%	20%	99.4%
Akbulut, 2013 [13]	Random	Not known	1348 (50.4%)	10 to 14 years	Based on Cole <i>et al.</i>	Urban	57%	15%	72%	79% to 90%
Al Alwan, 2013 [14]	Multistage cluster random	January to June 2006	1212 (42.2%)	6 to 16 years	Based on WHO	Urban	21.1%	12.7%	33.8%	97.5%
AlHazza, 2014 [24]	A random multistage stratified cluster-sampling	2009–2010	2908 (48.1%)	14 to 19 years	Based on IOTF	Urban	40.3%	38.1%	78.4%	Not known
AlHazza, 2007 [25]	Random	April to May 2006	224 (48.6%)	4 to 6 years	Based on CDC	Urban	20.6%	10.8%	31.4%	75%
Huda, 2003 [26]	Not known	October 1998 to April 1999	898 (females)	11–18 years	Based on NHANES	Urban	14%	9%	23%	Not known
Al Isa, 2004 [27]	Multistage stratified random	October 1999 to April 2000	14659 (49.1%)	10 to 14 years	Based on NCHS	Urban	61.8%	27.8%	89.6%	Not known
Al Sendi, 2003 [30]	Multistage stratified random	September to November 2000	506 (49.2%)	12 to 17 years	Based on WHO, Must <i>et al.</i> and Cole <i>et al.</i>	Urban	11.9% (WHO), 32% (Must <i>et al.</i>), and 39.8% (Cole <i>et al.</i>)	56.7% (WHO), 36.7% (Must <i>et al.</i>), and 32.8% (Cole <i>et al.</i>)	68.6% (WHO), 68.7% (Must <i>et al.</i>), and 72.6% (Cole <i>et al.</i>)	93.7%
Amin, 2008 [31]	Multistage stratified random	Not known	1139 (100%)	10 to 14 years	Based on Cole <i>et al.</i>	Urban/rural	14.2%	9.7%	23.9%	88.8%
Ayatollahi, 2006 [32]	Random	2002–2003	2397 (52.8%)	6.5 to 11.5 years	Based on CDC	Urban	10.6%	9.4%	20%	91.5%

Table V. Cont.

First author surname, date of publication	Sample design	Date of fieldwork	Sample size (% male)	Age range	Classification method	Urban or rural	Prevalence of overweight	Prevalence of obesity	Combined prevalence of overweight and obesity	Response rate
Dayan, 2005 [37]	Not known	Not known	76 732 (57.8%)	17 years	Not known	Urban	23.8%	7.4%	31.2%	Not known
Chen, 2008 [52]	Random	Not known	883 (51%)	12 to 16 years	Not known	Urban and rural	38.4%	12.3%	50.7%	Not known
Chen, 2012 [53]	Random	2007 and 2010	5091 (53.6%) 2839	≤ 9 to ≥ 13 years	Based on WHO	Urban	32.5% (2007) 32% (2010)	18.3% (2007) 15.9% (2010)	50.8 (2007) 47.9 (2010)	86.5% 75.5%
Chu, 2007 [62]	Stratified, multistaged, and clustered	2001	2405 (53.6%)	6 to 13 years	Based on Nutrition and Health Survey in Taiwan (WHO)	Urban	15.5% (male) 14.4% (female)	14.7% (male) 9.1% (female)	30.2% (male) 23.5% (female)	Not known
El Bayoumy, 2009 [80]	Random	January to July 2006	5402 (49.18%)	10 to 14 years	Based on NCHS	Urban	30.7%	14.6%	45.3%	Not known
Fu, 2003 [85]	Random	Not known	623 (51.5%)	6 to 11 years	Based on IOTF and PWH	Urban	Not known	6.9% (IOTF) and (PWH) 16.4%	Not known	Not known
Hamaideh, 2010 [99]	Cluster random	Not known	824 (51.4%)	14 to 17 years	Based on IOTF	Urban and rural	19.1%	6.3%	25.4%	84%
Jagadesan, 2014 [114]	Not known	Not known	18 955 (56.2%)	6 to 17 years	Based on IOTF and Khadilkar's criteria	Urban	13.5% (IOTF) and 19.9% (Khadilkar's criteria)	3.4% (IOTF) and 9.4% (Khadilkar's criteria)	Not known	95.3%
Khader, 2009 [126]	Cluster random	March to May 2006	2131 (49.3%)	6 to 12 years	Based on Cole <i>et al.</i>	Urban and rural	19.4%	5.6%	25%	94.2%
Xinhua, 2010 [135]	Cluster	March to June 2005	6288 (52.5%)	6 to 9 years	Based on IOTF	Urban	10.1%	3.5%	13.6%	100%
Liou, 2010 [136]	Three-stage stratified cluster	2006 and 2007	8640 (51.7%)	13 to 16 years	Based on IOTF	Urban	16.1%	7.2%	23.3%	86.3
Ma, 2011 [138]	Random	2008 to 2009	8 653 (51.9%)	2 to 7 years	Based on WHO, IOTF and CDC	Urban	10.9% (WHO), 10.9% (IOTF) and 11.2% (CDC)	13.8% (WHO), 6.08% (IOTF) and 11.7% (CDC)	24.7% (WHO), 17.7% (IOTF) and 22.9% (CDC)	89.4%

Table V. Cont.

First author surname, date of publication	Sample design	Date of fieldwork	Sample size (% male)	Age range	Classification method	Urban or rural	Prevalence of overweight	Prevalence of obesity	Combined prevalence of overweight and obesity	Response rate
Maddiah, 2010 [139]	Random	October 2006 to March 2007	2577 (female)	12 to 17 years	Based on IOTF	Urban	18.6%	5.9%	24.5%	98.7%
Nakano, 2010 [150]	Not known	2001 to 2007	16245 (51.8%)	6 to 14 years	Based on IOTF	Urban	30% – 14%	6% – 11%	36% – 25%	71.1%
Ramachandran, 2002 [159]	Not known	Not known	4700 (50.7%)	13 to 18 years	Not known	Urban	33.6%	6.5%	40.1%	Not known
Sun, 2009 [168]	Not known	June to July 2010	5753 (49.4%)	12 to 13 years	Based on IOTF	Urban	16.4%	Not known	Not known	91.6%
Tabesh, 2014 [169]	Random	2012–2013	5811 (49.9%)	7 to 11 years	Based on WHO	Urban	21.4%	5.5%	26.8%	Not known
Taheri, 2013 [170]	Cluster	November to February 2012	1541 (44.7%)	6 to 11 years	Based on CDC	Urban	9.6%	9.2%	18.8%	93.5%
Zaal, 2011 [181]	Random	Not known	661 (49%)	12 to 17 years	Based on WHO	Urban	15.7%	21.3%	37%	Not known
Bose, 2007 [195]	Cross-sectional	January to March 2002	431	6 to 9 years	Not known	Not known	17.63%	5.10%	Not known	Not known
Gopalakrishnan, 2012 [199]	Cross-sectional	Not known	290 (45.2%)	19 to 25 years	Not known	Not known	Male; 13.7% Female; 15.7% Total; 14.8%	Male; 9.2%; Female 1.2%; Total 5.2%	Not known	Not known
Ibrahim, 2007 [201]	Random	From March 2006 to September 2006	1695 (49.6%)	3 to 6 years	Based on data provided at the website of Jordanian Ministry of Education for the academic year 2005/2006	Urban and semi-urban	Male; 3.8% Female; 7.2%	Male 20.8%; Female 19.1%	Not known	Not known

Table V. Cont.

First author surname, date of publication	Sample design	Date of fieldwork	Sample size (% male)	Age range	Classification method	Urban or rural	Prevalence of overweight	Prevalence of obesity	Combined prevalence of overweight and obesity	Response rate
Maddah, 2006 [206]	Cross-sectional	December 2004 and April 2005	1054	14 to 17 years	Based on IOTF	Urban	21.9%	5.3%	Not known	Not known
Montazerifar, 2009 [209]	Cross-sectional	2005–2006	752	14 to 18 years	Based on IOTF, NHANES I and CDC	Urban	8.6% (CDC) 8.8% (IOTF) 8.4% (NHANES I)	1.5% (CDC) 1.5% (IOTF) 1.5% (NHANES I)	Not known	Not known
Pwint, 2013 [213]	Cross-sectional	May 2006 to November 2008	3009 (52.2%)	6 to 72 months	Based on IOTF, CDC and NHGP	Urban	8.1% (CDC) 7.6% (IOTF) 7.5% (NHGP)	7.1% (CDC) 3.9% (IOTF) 5.3% (NHGP)	Not known	72.3%
Ghada, 2009	Random	2009	698 (50.0%)	4 to 6 years (male) 2 to 4 years (female)	WHO	Both	8.4% (male) 12.3% (female)	7.2% (male) 8.4% (female)	15.6% (male) 20.7% (female)	Not known
Zekavat, 2014	Random	2009	1158 (50.6%)	7 to 13 years	CDC	Urban	9.9% (male) 10.0% (female)	5.1% (male) 4.9% (female)	15% (male) 14.9% (female)	Not known
Cao, 2012	Sampling	2012	88974 (49.6%)	12 to 17 years	Chinese index	Urban	14.6% (male) 8.6% (female)	7% (male) 2.9% (female)	21.6% (male) 11.5% (female)	Not known
Al-Almaie, 2005	Random	2001	1766 (38.2%)	14 to 18 years	IOTF	Urban	10.2% (male) 17.2% (female)	19.3% (male) 11.8% (female)	29.5% (male) 29% (female)	Not known
Hajian Tilaki, 2008	Population-based cross-sectional	2006	1000 (45.0%)	7 to 12 years	CDC	Urban	12.5% (male) 12.2% (female)	8.8% (male) 3.8% (female)	21.3% (male) 16% (female)	
Al-Rukban, 2003	Cross-sectional study	2001–2002	894 (100%)	12 to 20 years	WHO	Urban	13.8%	20.5%	34.3%	
Goyal, 2010	Random		11328 (50%)	12 to 18 years	WHO	Urban and Rural	14.3% (male) 9.2% (female)	2.9% (male) 1.5% (female)	17.2% (male) 10.7% (female)	

Table V. Cont.

First author surname, date of publication	Sample design	Date of fieldwork	Sample size (% male)	Age range	Classification method	Urban or rural	Prevalence of overweight	Prevalence of obesity	Combined prevalence of overweight and obesity	Response rate
Alenazi, 2015	Cross-sectional study	2012	523 (100%)	15.5 to 17.5 years	CDC	Urban	17.2%	30.4%	47.6%	
Allafi, 2013	Cross-sectional study	2009	906 (51.0%)	14 to 19 years	IOTF-WHO	Urban	25.1% (male) 25.3% (female)	25.5% (male) 21.3% (female)	50.6% (male) 46.6% (female)	
Seubsman, 2010	A National Cohort Study	2005	29065 (34%)	15 to 25 years	WHO	Urban		10.4% (male) 5.9% (female)		

applied across studies including the CDC criteria in 7 studies [31, 33, 35, 37, 38, 41, 57], IOTF criteria in 11 studies [29, 42, 45, 50, 52, 58, 63–65, 71, 72], NCHC criteria in 2 studies [44, 46], WHO criteria in 16 studies [28, 32, 36, 39, 42, 49, 54, 56, 59, 62, 66–69, 73, 74], NHANES criteria in 1 study [55], Cole criteria in 6 studies [27, 30, 43, 53, 60, 75] and the Chinese index in 1 study [51], Table IV. These studies were published between 1994 and 2015. Participants in two studies were only female, while the proportion of men in other studies ranged from 34% [66] to 100% [43]. Participants' age ranged from 2 years [54] to 25 years [67].

Prevalence by age, sex, region, and type of residence

Overall prevalence of obesity

The overall prevalence of obesity was 5.8% ($n = 4175$) (95% CI: 4.6–7.3; 43 studies, heterogeneity $p = 0.214$; $I^2 = 6.3\%$) in children (Figure 1) and 8.6% ($n = 30,402$) (95% CI: 7.2–10.2; 47 studies, heterogeneity $p = 0.318$; $I^2 = 4.1\%$) in adolescents (Figure 3). The prevalence of obesity in children by diagnostic criteria was 6.7% (95% CI: 6.1–7.5; 7 studies, heterogeneity $p = 0.091$; $I^2 = 4.2\%$) for CDC, 3.1% (95% CI: 2.8–3.3; 14 studies, heterogeneity $p = 0.122$; $I^2 = 6.9\%$) for IOTF, 12.1% (95% CI: 11.0–12.9; 14 studies, heterogeneity $p = 0.213$; $I^2 = 1.3\%$) for WHO and 12.8% (95% CI: 12.3–13.4; 8 studies, heterogeneity $p = 0.203$; $I^2 = 4.6\%$) for Cole criteria; $p < 0.001$ for the difference in the prevalence of obesity across criteria in children.

The prevalence of obesity in adolescents by diagnostic criteria was 15.3% (95% CI: 13.7–17.1; 4 studies, heterogeneity $p = 0.412$; $I^2 = 6.3\%$) for CDC, 8.9% (95% CI: 8.4–9.3; 10 studies, heterogeneity $p = 0.124$; $I^2 = 2.1\%$) for IOTF, 14.1% (95% CI: 13.7–14.6; 4 studies, heterogeneity $p = 0.532$; $I^2 = 9.6\%$) for NCHC, 8.8% (95% CI: 8.7–8.9; 23 studies, heterogeneity $p = 0.421$; $I^2 = 8.3\%$) for WHO, 9.0% (95% CI: 7.3–11.1; 1 study, heterogeneity $p = 0.100$; $I^2 = 0.0\%$) for NHANES, 4.4% (95% CI: 3.9–5.0; 3 studies, heterogeneity $p = 0.632$; $I^2 = 1.2\%$) for Cole and 5.4% (95% CI: 5.2–5.6; 2 studies, heterogeneity $p = 0.100$; $I^2 = 0.0\%$) for the Chinese index; $p < 0.001$ for the difference in the prevalence of obesity across criteria in adolescents.

Overall prevalence of overweight

The overall prevalence of overweight was 11.2% ($n = 7902$) (95% CI: 9.3–13.4; 39 studies, heterogeneity $p = 0.183$; $I^2 = 6.4\%$) in children (Figure 4) and 14.6% ($n = 46,886$) (95% CI: 12.5–17.1; 51 studies, heterogeneity $p = 0.128$; $I^2 = 9.7\%$) in adolescents (Figure 5). The prevalence of overweight in children by diagnostic criteria was 8.8%

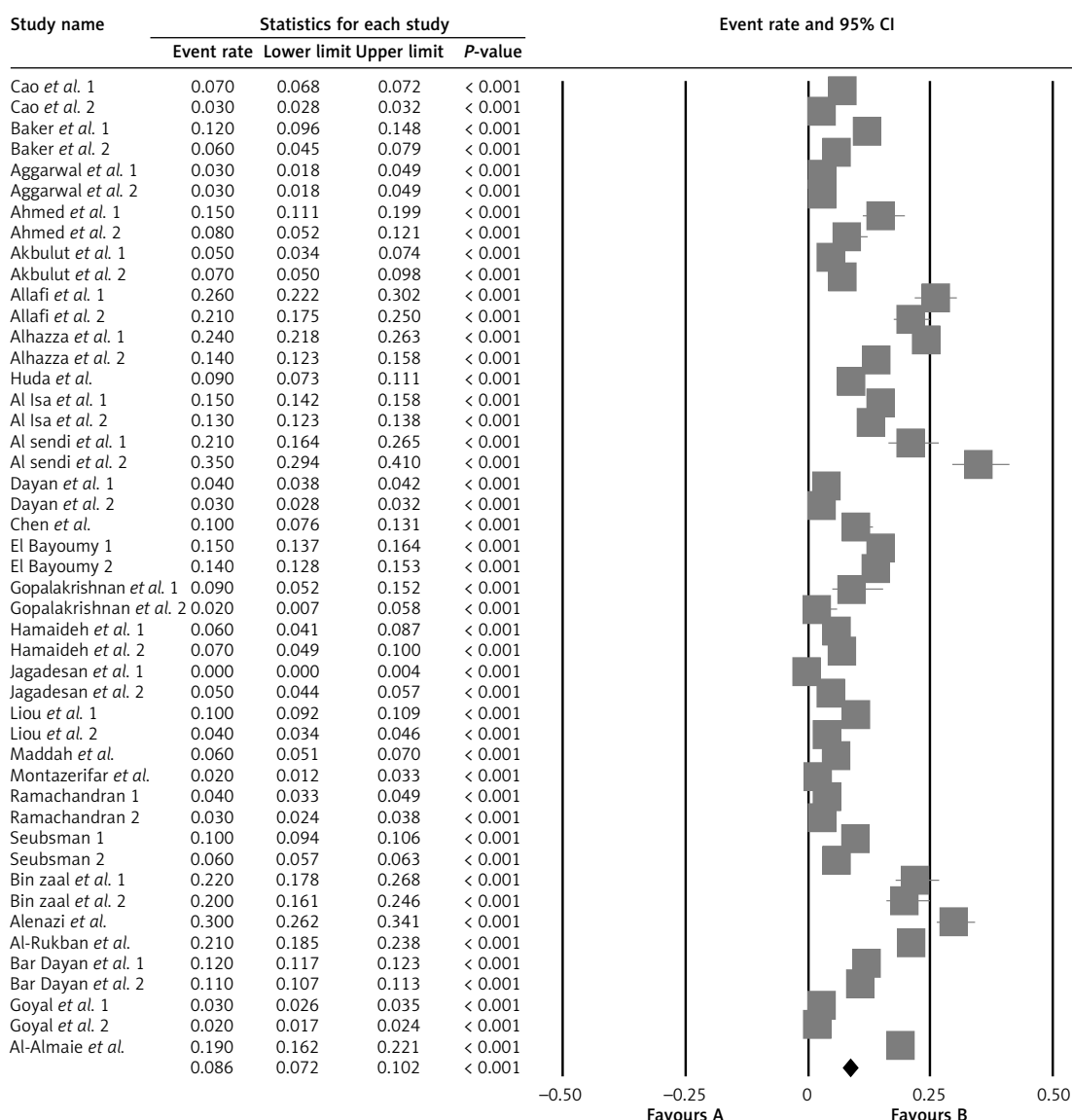


Figure 3. Overall prevalence of obesity in adolescents

(95% CI: 8.1–9.6; 7 studies, heterogeneity $p = 0.421$; $I^2 = 4.6\%$) for CDC, 10.8% (95% CI: 10.5–11.2; 12 studies, heterogeneity $p = 0.692$; $I^2 = 4.1\%$) for IOTF, 15.5% (95% CI: 15.0–16.0; 12 studies, heterogeneity $p = 0.158$; $I^2 = 3.1\%$) for WHO and 23.7% (95% CI: 23.0–24.3; 8 studies, heterogeneity $p = 0.782$; $I^2 = 9.6\%$) for Cole criteria; $p < 0.001$ for the difference in the prevalence of obesity across criteria in children.

The prevalence of overweight in adolescents by diagnostic criteria was 14.6% (95% CI: 13.3–16.0; 4 studies, heterogeneity $p = 0.084$; $I^2 = 6.5\%$) for CDC, 17.0% (95% CI: 16.5–17.4; 14 studies, heterogeneity $p = 0.142$; $I^2 = 4.2\%$) for IOTF, 30.9% (95% CI: 30.2–31.5; 4 studies, heterogeneity $p = 0.823$; $I^2 = 4.2\%$) for NCHC, 9.8% (95% CI: 9.7–10.0; 22 studies, heterogeneity $p = 0.961$; $I^2 = 2.8\%$) for WHO and 17.4% (95% CI: 16.4–18.4; 4 studies, heterogeneity $p = 0.635$; $I^2 = 1.4\%$) for Cole criteria;

$p < 0.001$ for the difference in the prevalence of obesity across criteria in adolescents.

Prevalence of obesity and overweight by sex

The overall prevalence of obesity in children by gender was 7.0% ($n = 2631$) (95% CI: 5.0–9.6; 21 studies, heterogeneity $p = 0.262$; $I^2 = 6.9\%$) in boys and 4.8% ($n = 1561$) (95% CI: 3.4–6.8; 21 studies, heterogeneity $p = 0.102$; $I^2 = 2.1\%$) in girls; $p < 0.001$ for the difference by gender. The overall prevalence of obesity in adolescents by gender was 10.1% ($n = 17,989$) (95% CI: 8.0–12.6; 24 studies, heterogeneity $p = 0.832$; $I^2 = 1.4\%$) in boys and 6.2% ($n = 10,872$) (95% CI: 4.6–8.2; 25 studies, heterogeneity $p = 0.209$; $I^2 = 9.2\%$) in girls; $p < 0.001$ for the difference by gender.

The overall prevalence of overweight in children by gender was 11.7% ($n = 4296$) (95% CI:

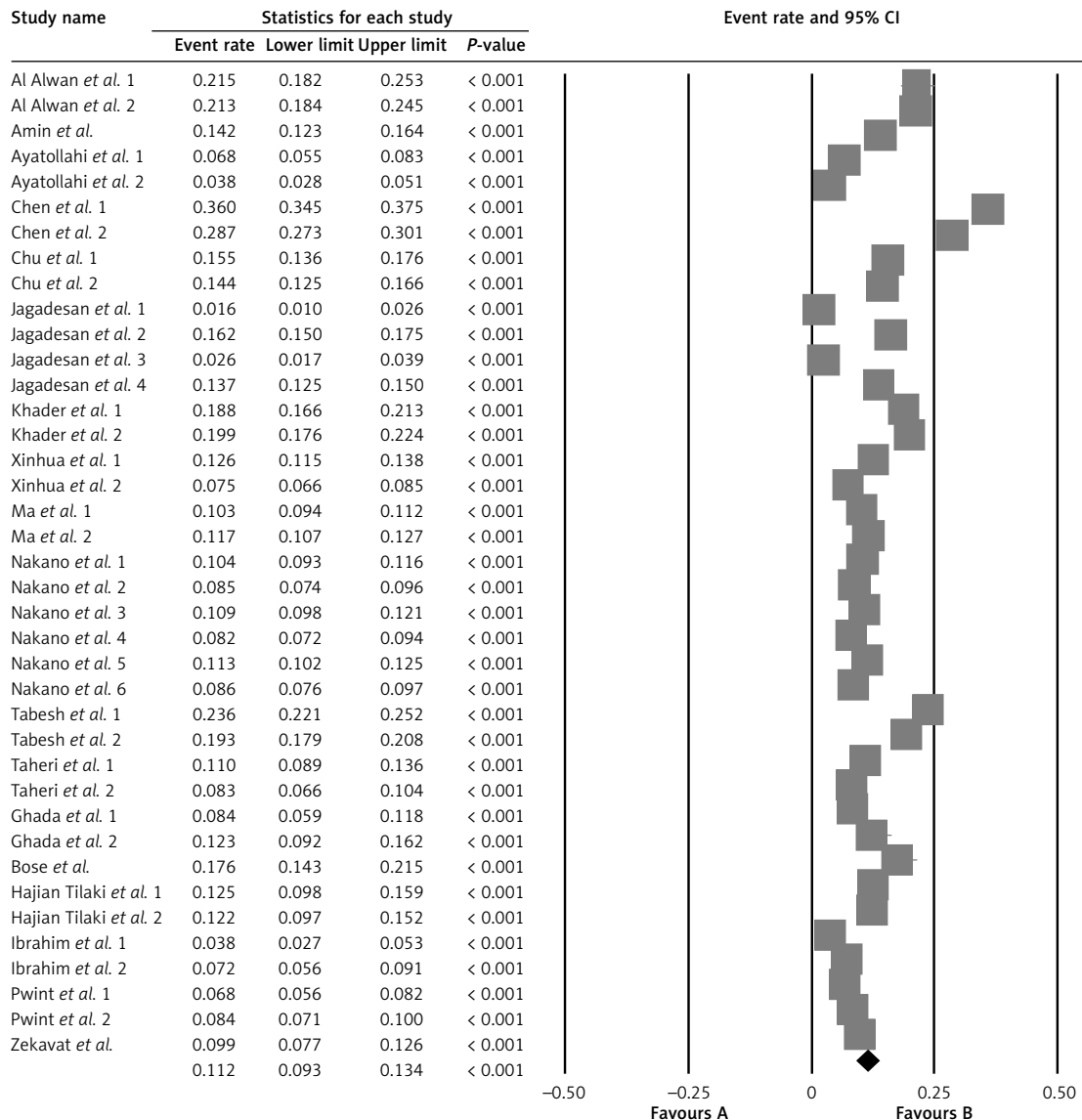


Figure 4. Overall prevalence of overweight in children

8.8–15.3; 19 studies, heterogeneity $p = 0.965$; $I^2 = 7.1\%$) in boys and 10.9% ($n = 3694$) (95% CI: 8.4–14.1; 19 studies, heterogeneity $p = 0.101$; $I^2 = 3.4\%$) in girls; $p < 0.001$ for the difference by gender. The overall prevalence of overweight in adolescents by gender was 15.9% ($n = 27,183$) (95% CI: 12.8–19.7; 24 studies, heterogeneity $p = 0.321$; $I^2 = 8.9\%$) in boys and 13.7% ($n = 20,574$) (95% CI: 10.6–17.6; 26 studies, heterogeneity $p = 0.215$; $I^2 = 3.3\%$) in girls; $p < 0.001$ for the difference by gender.

Prevalence of obesity and overweight by region

Childhood obesity prevalence in urban boys and girls was 6.6% (95% CI: 4.3–9.9; heterogeneity $p = 0.425$; $I^2 = 6.2\%$) and 4.6% (95% CI: 3.1–6.7; heterogeneity $p = 0.329$; $I^2 = 8.3\%$), and for over-

weight it was 12.6% (95% CI: 8.9–17.6; heterogeneity $p = 0.211$; $I^2 = 2.1\%$) and 10.8% (95% CI: 7.8–14.8; heterogeneity $p = 0.159$; $I^2 = 1.4\%$) respectively.

The prevalence of obesity in urban adolescent boys and girls was 10.3% (95% CI: 7.7–13.7; heterogeneity $p = 0.825$; $I^2 = 2.1\%$) and 6.6% (95% CI: 4.8–9.0; heterogeneity $p = 0.742$; $I^2 = 6.3\%$) and for overweight it was 17.1% (95% CI: 14.3–20.1; heterogeneity $p = 0.269$; $I^2 = 1.3\%$) and 14.8% (95% CI: 11.7–18.6; heterogeneity $p = 0.867$; $I^2 = 8.6\%$) respectively.

Sensitivity analysis

In leave-one-out sensitivity analyses, the pooled effect estimates remained similar across all studies and within specific subgroups (Table VI). This stability confirmed that the significant difference

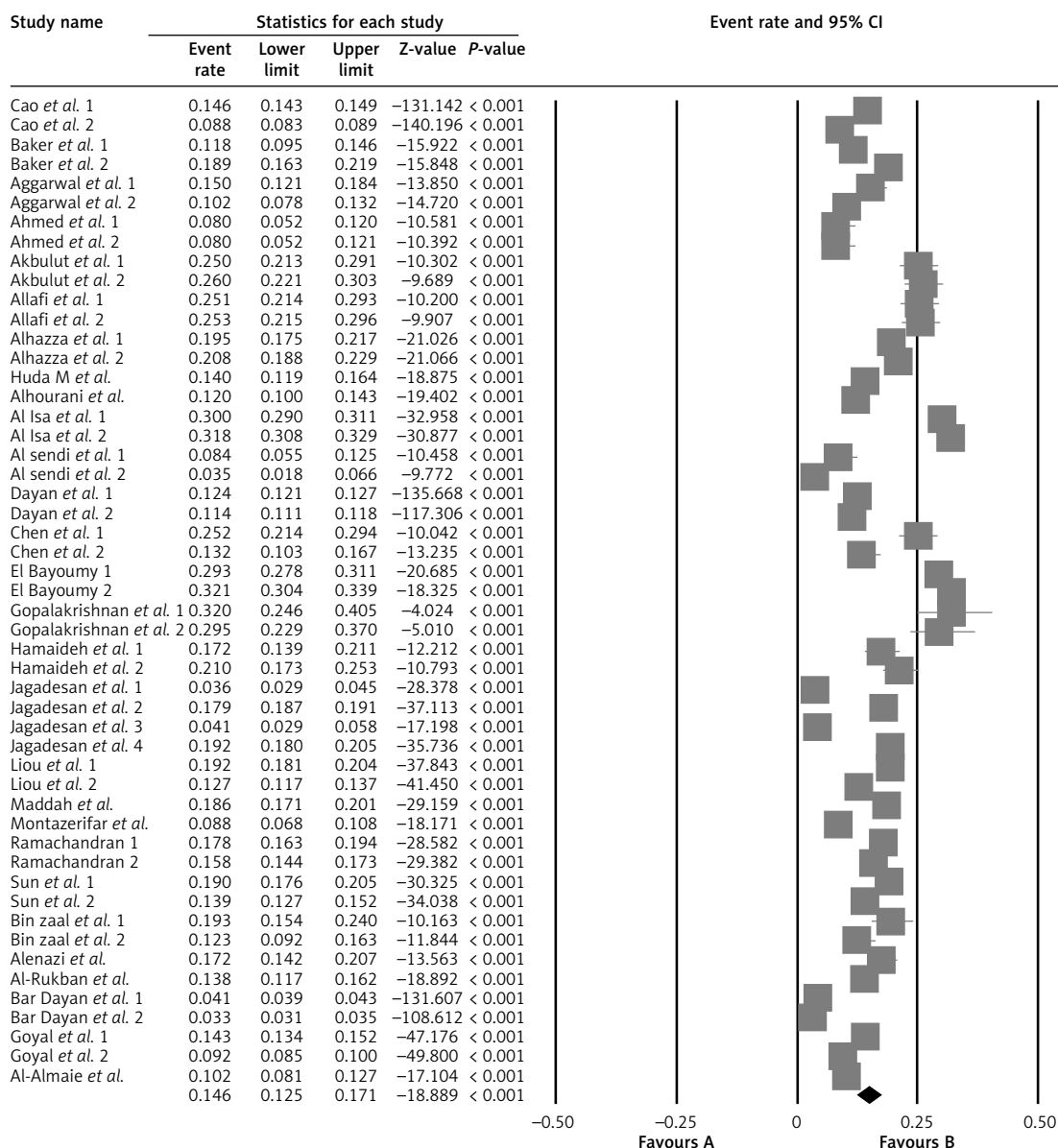


Figure 5. Overall prevalence of overweight in adolescents

between the studied groups is the overall effect from all included studies.

Publication bias

Visual inspection of funnel plot symmetry suggested no potential publication bias for the overall prevalence of obesity in children and adolescents (Figures 6 and 7). The presence of publication bias was also not suggested by Begg's rank correlation test (Kendall's τ with continuity correction = -0.17, $z = 1.61$, $p = 0.107$ in children and -0.13, $z = 1.30$, $p = 0.192$ in adolescents). After adjustment of effect sizes for potential publication bias using the 'trim and fill' correction, no potentially missing studies were imputed in the funnel plot (Figures 8 and 9). The 'fail-safe N' test showed that 7525 studies (in children) and 8070 studies

(in adolescents) would be needed to bring the result to a non-significant ($p > 0.05$) value.

Discussion

This study has systematically evaluated the scientific literature to provide robust estimates for obesity and overweight prevalence by age group, sex and setting in children and adolescents in Asian countries. The overall prevalence of obesity was 5.8% in Asian children and 8.6% in adolescents. Equivalents for overweight were 11.2% in children and 14.6% in adolescents. The overall prevalence by gender was 7.0% and 4.8% in boys and girls for obesity in children, and 11.7% and 10.9% in boys and girls respectively for overweight in children. Furthermore, according to our findings, childhood obesity prevalence in urban boys

Table VI. Sensitivity analysis across all studies

Variables	Result of the leave-one-out sensitivity analyses
Total obesity in children	5.8% (95% CI: 4.6–7.3)
Total obesity in adolescents	8.6% (95% CI: 7.2–10.2)
Obesity in children:	
CDC	6.7% (95% CI: 6.1–7.5)
WHO	3.1% (95% CI: 2.8–3.3)
Cole	12.8% (95% CI: 12.3–13.4)
Obesity in adolescents:	
CDC	15.3% (95% CI: 13.7–17.1)
IOTF	8.9% (95% CI: 8.4–9.3)
NCHC	14.1% (95% CI: 13.7–14.6)
WHO	8.8% (95% CI: 8.7–8.9)
NHANES	9.0% (95% CI: 7.3–11.1)
Cole	4.4% (95% CI: 3.9–5.0)
Chinese index	5.4% (95% CI: 5.2–5.6)
Total overweight in children	11.2% (95% CI: 9.3–13.4)
Total overweight in adolescents	14.6% (95% CI: 12.5–17.1)
Overweight in children:	
CDC	10.8% (95% CI: 10.5–11.2)
WHO	15.5% (95% CI: 15.0–16.0)
Cole	23.7% (95% CI: 23.0–24.3)
Overweight in adolescents:	
CDC	14.6% (95% CI: 13.3–16.0)
IOTF	17.0% (95% CI: 16.5–17.4)
NCHC	30.9% (95% CI: 30.2–31.5)
WHO	9.8% (95% CI: 9.7–10.0)
Cole	17.4% (95% CI: 16.4–18.4)

and girls was 6.6% and 4.6% and for overweight it was 12.6 and 10.8% respectively, and the prevalence of obesity in urban adolescent boys and girls was 10.3% and 6.6%, while for overweight it was 17.1% and 14.8% respectively.

In line with our findings, some systematic reviews have reported on growing prevalence of obesity and overweight among children and adolescents. The Global Burden of Disease Study estimated that the prevalence of obesity/overweight in children and adolescents in developing countries was 12.9% for boys and 13.4% for girls in 2013 [76]. A meta-analysis concluded that the prevalence of obesity in children and adolescents aged 2 to 19 years in the United States in 2011–2014 was 17.0%, while the prevalence of

extreme obesity was 5.8% [77]. The combined prevalence of overweight and obesity in European children below the age of 10 ranged from > 40% in southern Europe to < 10% in northern Europe [78]. These findings confirm the high prevalence of overweight and obesity in children and adolescents worldwide. In another study in which worldwide trends in mean BMI in children and adolescents were estimated, they reported that the rising trends in children's and adolescents' BMI have plateaued in many high-income countries, albeit at high levels, but have accelerated in parts of Asia [79].

Different definitions have been used for childhood and adolescent obesity; thus, it is difficult to make meaningful comparisons across countries

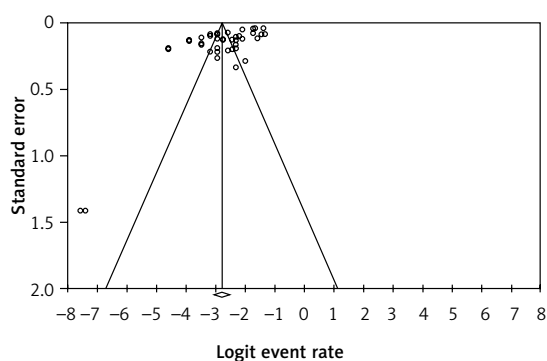


Figure 6. Funnel plots for publication bias for the overall prevalence of obesity in children. Open circles represent observed published studies; open diamond represents observed effect size

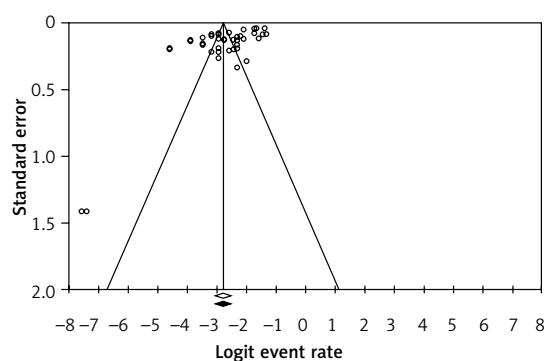


Figure 7. Funnel plots for publication bias for the overall prevalence of obesity in adolescents. Open circles represent observed published studies; open diamond represents observed effect size

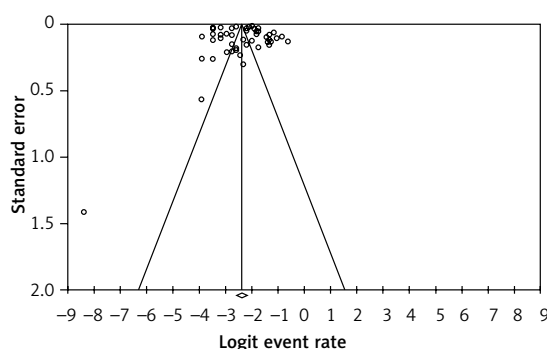


Figure 8. Trim and fill method to impute potentially missing studies (prevalence of obesity in children). No potentially missing study was imputed in the funnel plot. Open circles represent observed published studies; open diamond represents observed effect size; closed diamond represents imputed effect size

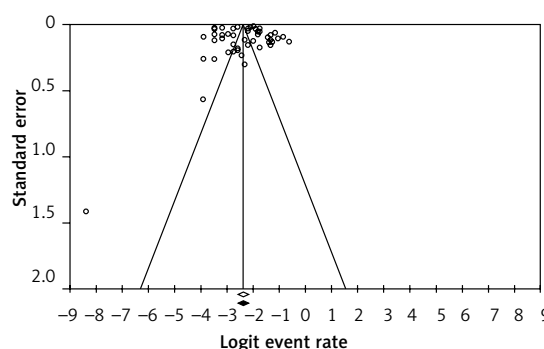


Figure 9. Trim and fill method to impute potentially missing studies (prevalence of obesity in adolescents). No potentially missing study was imputed in the funnel plot. Open circles represent observed published studies; open diamond represents observed effect size; closed diamond represents imputed effect size

and studies. According to the cut-off point references when used to compare the obesity status in this meta-analysis, we found that compared with the CDC criteria, the IOTF, WHO and Cole definitions tend to underestimate the prevalence of obesity and overestimate the prevalence of overweight among Asian children and adolescents.

The WHO reported that childhood overweight and obesity could be the results of the changing life style including consuming high energy-dense diets that are high in fat content and carbohydrate but low in vitamins and minerals, and doing less physical activity because of the sedentary lifestyles [80]. Asian investigations have reported epidemiologic transition along with a notable nutrition transition in the Asian child and adolescent population, and suggested that urbanization in most parts of Asia is associated with increased sedentary behaviour and lack of physical activity [28, 81], due to a lack of play areas, both in the community and in schools, as well as increasing time spent watching television and playing computer games [82, 83]. Additionally, due to more recent widespread availability of fast food shops in Asian countries, increasing consumption of junk foods has also contribut-

ed to dietary changes [83]. Furthermore, it has been reported that socioeconomic status (SES) influences the prevalence of childhood overweight and obesity [84]. National studies have confirmed a diet with higher energy-dense, animal-based foods in childhood with a high SES, and desire in city children to have a lower intake of fruit and vegetables [85]. It has been reported that urban families spend more time watching television, have less sleep and digital playing. Moreover, compared to rural area, subjects in urban areas have easier access to cars, which could be a contributing factor [86].

In our study the prevalence of obesity and overweight differed by sex. We found that girls had a lower prevalence of obesity than boys, and this ratio in adolescents was higher in boys compared to girls. It could be due to differences in body fat composition or physical activity, or the fact that girls care more about their appearance and pay higher attention to their body image than boys [87]. Boys and girls differ in several factors such as body composition, hormone biology and susceptibility to certain social, patterns of weight gain, ethnic, genetic, and environmental factors, which can explain gender differences [88].

The alarmingly high rate of overweight/obesity in Asian children and adolescents warrants immediate intervention: raising awareness among children, adolescents and their families about the health consequences of obesity and its related diseases including diabetes and cardiovascular diseases, teaching community members to encourage lifestyle changes including in diet and physical activity, national and international monitoring programmes in order to decrease the rate of overweight and obesity in the community in order to avoid an obesity epidemic in the future generation.

The comparisons of overweight and obesity prevalence need to be interpreted with caution due to the differences in survey sampling methods, sample sizes, age range of subjects, quality of data in terms of height and weight measurement. Moreover, like most meta-analyses, we pooled together studies conducted under different circumstances in different parts of Asian countries among different population groups. In addition, a specific limitation of our meta-analysis is related to the difficulty of combining studies that used four different diagnostic criteria to assess overweight/obesity. This is directly related to the lack of consensus about the diagnostic criteria for overweight/obesity. In order to evaluate the sources of bias in the review, we performed subgroup analyses. Important strengths of the present study include the use of meta-analytic techniques to derive the pooled estimates, and the application of sensitivity analyses to confirm the robustness of our findings.

In conclusion, from our findings it was revealed that in regard of the number of children who are overweight or obese, relevant health authorities should review the obesity preventive strategies and, using public health interventions, reduce the rate of obesity throughout Asian countries.

Acknowledgments

The study protocol was registered with the International Prospective Register of Systematic Reviews, PROSPERO (registration no: CRD42016033061).

Conflict of interest

The authors declare no conflict of interest.

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