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Review

Gender Difference and Changes in the Prevalence of Obesity Over Time in Children Under 12 Years Old: A Meta-analysis

Chen X et al. Obesity and Gender in Children

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What is already known on this topic?
Childhood obesity is a global epidemic with an alarming increase. A comprehensive approach including diet, exercise, behavior modification, and psychological support is vital in combating obesity in children and adolescents. There is ongoing debate surrounding the relationship between obesity and gender among children, particularly across various regions.

What this study adds?
There is no difference in obesity rates among children under the age of 12 based on gender or time trends. Comprehensive interventions are necessary in order to control obesity among children.

Abstract
Objective: Evaluating changes over time in the odds of obesity according to sex.
Methods: PubMed, Embase, Cochrane Library, and China National Knowledge Database were searched for relevant studies. Full-text studies evaluating the influence of sex on obesity were analyzed. We used R 3.4.3 to assess the impact of results in the selected studies, calculated pooled prevalence and odds ratio (OR) with their respective 95% confidence intervals (CIs). $P<0.10$ and $I^2>50\%$ indicated high heterogeneity, and the random-effects model was used, otherwise, the fixed-effects model was used.
Results: The included studies reported the prevalence of obesity in children covering 1987-2017 intervals. The pooled prevalence of obesity in boy and girl groups were 0.13 (95% CI: 0.08, 0.20) and 0.10 (95% CI: 0.07, 0.13). In the analysis of the boy group, the pooled OR in earlier time (1987-2013) vs. recent time (2011-2017) was 0.98 (95% CI: 0.76, 1.26). The estimated OR for girls in earlier vs. recent time was 1.01 (95% CI: 0.80, 1.28). In the analysis of studies with follow-up period ≥ 10 years, the pooled OR for obesity in earlier vs. recent time period was 0.99 (95% CI: 0.76, 1.30). For those with follow-up period < 10 years, the pooled OR in earlier vs. recent time period was 0.94 (95% CI: 0.57, 1.54).
Conclusions: Comprehensive measurements are required to control obesity among children albeit with nonsignificant gender difference and time trend for obesity rates in children.
Keywords: Children, obesity, trend, gender, meta-analysis

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Introduction
Childhood obesity has become a global epidemic. The World Health Organization (WHO) estimated that, in 2000, the global overweight rate for children aged 5-17 years was 10%, and the obesity rate was 2%–3%[1, 2]. In 2016, the worldwide prevalence of obesity was 5.6% in girls and 7.8% in boys aged 5-19 years, with prevalence >20% in many regions [3]. Another study estimated the prevalence of childhood obesity in 2013 at 23% in developed countries and 13% in developing countries [4]. Developed countries report higher prevalence rates compared to developing ones, where obesity is less common among children and adolescents.[5-7]. The occurrence of childhood obesity is the result of a combination of genetic, environmental, and other factors and is caused by the long-term imbalance of energy intake and energy consumption[8]. A high-energy-density diet, low physical activity, sedentary lifestyle, and unhealthy eating behaviors are generally considered to be important risk factors for the development of obesity. Comprehensive dietary interventions, exercise, behavior, and psychology at different times and different levels are necessary to develop an effective strategy for curbing the spread of obesity among children and adolescents[9].
Some studies found sex-related differences in obesity. In many Western countries, the obesity rate is higher in girls than in boys, and in Asian countries, the trend is opposite[10, 11]. Among children aged 6-18 years in Taiwan and China, during 1991-2003, the overweight rate of boys increased from 5.7% to 14.2%, and the obesity rate increased from 7.9% to 17.4%. At the same time, the overweight rate of girls increased from 11.1% to 13.4%, and the obesity rate increased from 3.1% to 11.11%[12]. Recent trends indicated a rise in obesity rates among both boys and girls, with boys experiencing a higher incidence. Over time, the disparity in obesity rates between genders has widened, particularly in urban areas where boys are more affected than girls. This urban predominance in boys significantly influences the global increase in childhood obesity and overweight cases. [13]. A meta-analysis showed that childhood obesity increases the prevalence of prediabetes and non-alcoholic fatty liver disease [14].
Considerable debate continues on the trend of obesity among children. Ogden et al. stated that the prevalence of obesity in children aged 2-5 years increased until 2003-2004 and then decreased, while Skinner et al. found no evidence of a decline in obesity prevalence at any age [15, 16]. From 1999 to 2016, in Europe, the prevalence of childhood obesity increased in the Mediterranean region, decreased in the Iberic region, and remained stable in Atlantic or Central Europe [17]. In addition, whether biological sex has an impact on eventual differences is unknown. The present study aimed to evaluate changes over time in the odds of obesity according to sex and follow-up. The results provided a trend of obesity over time according to sex and follow-up period.
Materials and Methods
This article is a meta-analysis. The data comes from published articles and does not require ethical approval and written informed consent.

Literature search and study selection

This study was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guideline[18]. Databases, such as PubMed, Embase, Cochrane Library, and China National Knowledge Database (CNKI), were searched for studies published up to March 13, 2024 on a comparison between boys and girls in terms of obesity. The following keywords were used for the search: (1) obesity or overweight; and (2) child* or adolescent*. All these words were combined with the Boolean operators "AND" and "OR" in the strategy: (obesity OR obese OR overweight) AND (child* OR children*). No restrictions were imposed on the language of publication in document retrieval. The reference lists of the retrieved studies were further screened to find other relevant studies that were not identified by the retrieval strategy to maximize the specificity and sensitivity of retrieval. The definition of obesity was based on WHO's, i.e., body mass index (BMI) >30 kg/m^2 (http://www.emro.who.int/health-topics/obesity/). Meanwhile, the included samples were children under 12 years old.

After the primary selection, the full text of the potentially relevant studies was reviewed to ensure that they met the following inclusion criteria:

(1) Comparison between boys and girls, i.e., separate effect estimates for boys and girls;

(2) Children with obesity;

(3) Containing prevalence of obesity in different gender groups, and/or in recent and earlier time periods, "earlier time period" is referred to as the prevalence rates in the first time period reported, and "recent time period" is referred to as the prevalence rates in the latest time period reported;

(4) Available in full text;

(5) In the case of overlapping samples from the same organization, only the most recent ones were selected.

The exclusion criteria were as follows:

(1) Studies on health problems other than obesity;

(2) Studies that only included adults;

(3) Studies lacking available data;

(4) Other study types such as reviews, letters or case reports, and in vitro or in vivo studies.

Database search and study identification were performed by two independent authors, discrepancies were resolved through discussion.

Data extraction and quality assessment

Two commentators independently screened the full text of the manuscript and extracted the following data from each eligible study: first author's name, patient's age and sex, country of origin, year of publication, sample size, and duration of each study. Two authors assessed related studies independently, complying with inclusion and exclusion criteria. In case of disagreement between two evaluators, a third evaluator was consulted to resolve the issue. The Newcastle–Ottawa Scale (NOS) table was used to evaluate the methodological quality of the study.

Statistical analysis

R (Version 3.4.3; Comprehensive R Archive Network), package meta was used for data analysis. Pooled prevalence with 95% confidence interval (CI) was calculated. Pooled estimate of odds ratio (OR) was used to compare change in prevalence rates from the earliest time periods to the most recent time periods in included studies. Heterogeneity was evaluated by I^2 statistics, a quantitative measure of inconsistency in studies; 25%–50% of the studies with I^2 were considered to have low heterogeneity, 50%–75% of the studies with I^2 were considered to have medium heterogeneity, and 75% of the studies with I^2 >75% were considered to have high heterogeneity [19]. If I^2 >50%, the potential sources of heterogeneity were examined by sensitivity analysis, which omitted one study in each round and investigated the impact of a single study on portfolio estimation [19]. In addition, when heterogeneity was observed, the random-effects model was used, and when it did not exist, the fixed-effects model was used [19]. Egger's test along with funnel plot were adopted to detect the publication bias. A P value < 0.05 was considered to be statistically significant.

Results

Search process

Since the number of selected results from several databases was huge, the electronic search ended with 4113 most relevant studies. After careful reading, 175 studies reached the preliminary standard. After further screening, 165 studies were excluded because of improper research type (n=74), insufficient data (n=71), and study type (n=20). Finally, eight studies were included for analysis. Figure 1 shows the flowchart of identification, inclusion, and exclusion of the studies, reflecting the search process and the reason for exclusion.

Characteristics of included studies

Table 1 summarizes the types of studies reported and the total number of patients associated with each group. It includes the author, year of publication, country, age, sex, group, sample size, and recruitment time. Ten studies[16, 20-28] published from 2017 to 2024, with a sample size between 221 and 55,260, were included in the analysis.

Results of quality assessment

The NOS table (Table S1) was used to evaluate the risk of study quality of the ten included trials. On a maximum of nine points (indicating the highest quality), six studies scored 8 points, and four scored 9 points.

Prevalence of obesity in different gender groups

The included studies reported the prevalence of obesity in children covering 1987-2017 intervals. The overall prevalence in both genders was 0.11 (95% CI: 0.08, 0.15). The pooled prevalence in boy and girl groups were 0.131 (95% CI: 0.08, 0.20) and 0.10 (95% CI: 0.07, 0.13) (p = 0.37) (Figure 2).

Time Trends in the Prevalence of Severe Obesity

Six studies revealed time trends of obesity over a period of time. Results showed pooled OR of 1.00 (95% CI: 1.53, 1.90) for obesity in the earlier time period, 1987–2013 than during the recent time period 2011–2017. In the analysis regarding boys, the pooled OR in earlier vs. recent time was 0.98 (95% CI: 0.76, 1.26). The estimated OR for girls in earlier vs. recent time was 1.01 (95% CI: 0.80, 1.28) (Figure 3). In the analysis of data limited to follow-up period ≥ 10 years, the pooled OR for obesity in earlier vs. recent time period was 0.99 (95% CI: 0.76, 1.30). For studies with follow-up period < 10 years, the pooled OR in earlier vs. recent time period was 0.94 (95% CI: 0.57, 1.54) (Figure 4).

Sensitivity analysis and publication bias

Results of sensitivity analysis revealed the robust of the meta-analysis. Specifically, the Egger's test results for the overall prevalence of obesity indicated an intercept of 0.2885, with a t-value of 1.14 and a p-value of 0.27. In the analysis of time trends in different gender groups, the intercept was found to be -0.9874, with a t-value of 0.79 and a p-value of 0.4540. Finally, for the time trend analysis in different follow-up periods, the intercept was 0.3660, with a t-value of -1.75 and a p-value of 0.1550. As shown in Figure 5, the symmetric funnel plot suggested a lack of publication bias in this meta-analysis.

Discussion

In our meta-analysis, we systematically reviewed and included a total of 10 studies to assess the prevalence and temporal trends of obesity among boys and girls. Our analysis reveals that the pooled prevalence of obesity in boys was 0.13 (95% CI: 0.08, 0.20), and in girls, it was slightly lower at 0.10 (95% CI: 0.07, 0.13). These findings suggest that while obesity is a significant concern in both genders, the prevalence rates are relatively similar.

Obesity has become a global public health concern. With the improvement in living conditions, abundant food is available for children, their growth and development levels have significantly improved, and the prevalence of malnutrition has declined significantly[29]. The incidence of children being overweight and obese has increased rapidly in recent years. According to recent data released by the WHO, the number of overweight children aged less than 5 years has reached about 22,000,000[30].

In the United States of America, two national health surveys conducted in the 1960s and four national health and nutrition surveys conducted during 1971–2000 provided information on childhood obesity. Childhood obesity has almost doubled, and the obesity rate has almost quadrupled, and this upward trend continues. According to the International Working Group on Obesity standard, the overweight and obesity rate of children and adolescents aged 6–18 years in the United States of America increased from 15.4% during 1971–1974 to 25.6% during 1988–1994[30]. The overweight rate of Canadian children also increased from 11% for boys and 13% for girls in 1981 to 33% (boys) and 27% (girls), respectively, in 1996. Xiao et al. stated that in China, the mean values of BMI *z*-scores decreased from 2006 to 2014 among Chinese children aged 3–6 years due to the significant increase in height *z*-scores. The prevalence of obesity increased from 2006 to 2010 and then remained stable until 2014 among children aged 5–6 years[13]. On the other hand, Sagbo et al. suggested that the relative fatness of children with morbid obesity, as measured by the BMI *z*-score, has remained stable[29]. The proportion of obese and morbidly obese children also plateaued between 2007 and 2014.

To assess the presence of publication bias in our study, we employed Egger's regression test and funnel plot. Egger's test, a statistical method designed to detect funnel plot asymmetry, yielded p-values greater than 0.05 across all analyses, which indicated that there is no significant evidence of publication bias within our dataset. The funnel plots demonstrated a symmetric distribution of studies around the combined effect size. This symmetry in the plots further supports the conclusion drawn from Egger's test, suggesting an absence of noticeable publication bias in our meta-analysis. Results of this meta-analysis showed overall prevalence in both genders was 0.10, the pooled prevalence of obesity in boys was greater than that in girls, nevertheless, there was no statistically significant difference of prevalence in the two groups.

Nonsignificant differences in earlier period between recent period. In China, Xiao et al. showed that the prevalence of obesity was higher in boys than in girls[13]. The reason for the inconsistent results compared to previous study may be the varying definitions of obesity, time periods, ethnicity of children and study designs in studies included. The current study only included studies with children under 12 years old. However, targeted preventive measures should be implemented, such as more exercise and proper food intake for children.

Study Limitations

This study had some limitations that must be considered when analyzing the implications of the results. Firstly, only eight articles could be included as per the pre-defined eligibility criteria, probably biasing the results. Secondly, the subgroup comparison in different countries was not considered because too few studies were available from different countries or even continents, which needs further evaluation. Thirdly, the details about different races were not included, and the comparison about different races should be included in future studies. Indeed, the difference in the childhood obesity rate among races has been reported. The data from 1999 to 2000 showed that the obesity rate of black and Hispanic children was almost twice that of white and non-Hispanic children. Especially for black people, the obesity rate of children has increased rapidly in recent decades[31]. Again, the small number of studies precluded such an analysis. Fourthly, since the included articles were published from 2017 to 2019, they did not cover the relevant articles in history, which could be conducted in the next step. Finally, there is a lack of PROSPERO registration, no meta-regression could be performed, and the heterogeneity was significant, and more well-designed studies including meta-analysis are needed in the future.

Conclusion

In conclusion, there is no gender and time period difference for obesity rate in children under 12 years old. Comprehensive measures are required to control childhood obesity regardless of the nonsignificant results.

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Table 1. Characteristics of studies included in the meta-analysis

Study	Year	Language	Type	Country	Age range (mean)	Groups	*n*	Years of onset
Keß (Kess et al. 2017)	2017	English	Cross-sectional study	Germany	8.2 ± 5.3	Boys	28,691	2005–2010
						Girls	26,569	
Chen (Chen et al. 2019)	2019	English	Cross-sectional study	China	4.9 ± 2.5	Boys	2,542	2011–2017
						Girls	2,071	
de Ruiter (de Ruiter et al. 2017)	2017	English	Cross-sectional study	Spain	8.5 ± 4.5	Boys	3,908	1987–2011
						Girls	3,376	
Skinner (Skinner et al. 2018)	2018	English	Cross-sectional study	America	6.5 ± 5.5	Boys	1,962	2015–2016
						Girls	1,872	
Celmeli (Celmeli et al. 2019)	2019	English	Case-control study	Turkey	7.4 ± 6.6	Boys	308	2003–2015
						Girls	249	
Ogden (Ogden et al. 2018)	2018	English	Cross-sectional study	America	8.6 ± 7.5	Boys	2,584	2013–2016
						Girls	2,540	
Vanhelst (Vanhelst et al. 2017)	2017	English	Case-control study	France	8.4 ± 6.5	Boys	173	2009–2013
						Girls	200	
Zhang (Zhang et al. 2018)	2018	English	Cross-sectional study	China	10.5 ± 7.5	Boys	1,297	2011–2015
						Girls	1,245	
Decyk (Decyk et al. 2020)	2020	English	Cross-sectional study	Poland	9.1 ± 1.8	Boys	181	2017-2018
						Girls	269	
Mai (Mai et al. 2024)	2024	English	Cross-sectional study	Australia	10.6 ± 0.5	Boys	101	2020
						Girls	120	

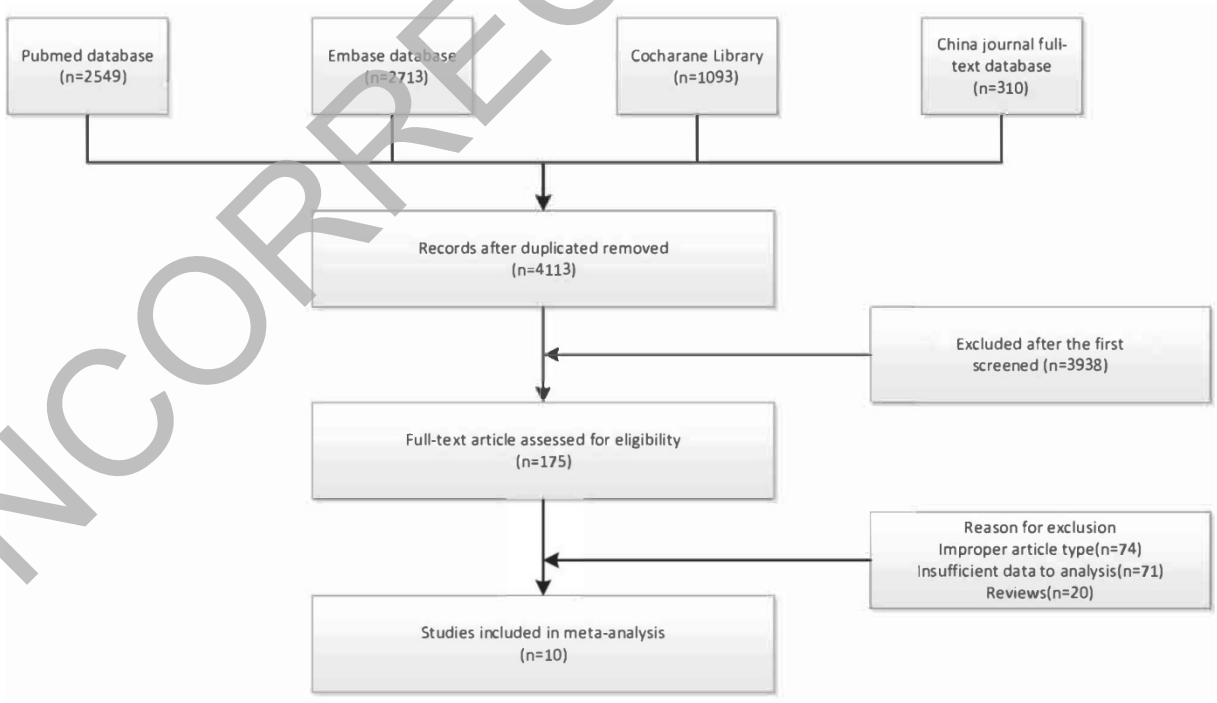

Figure 1. Flow diagram of the study selection.

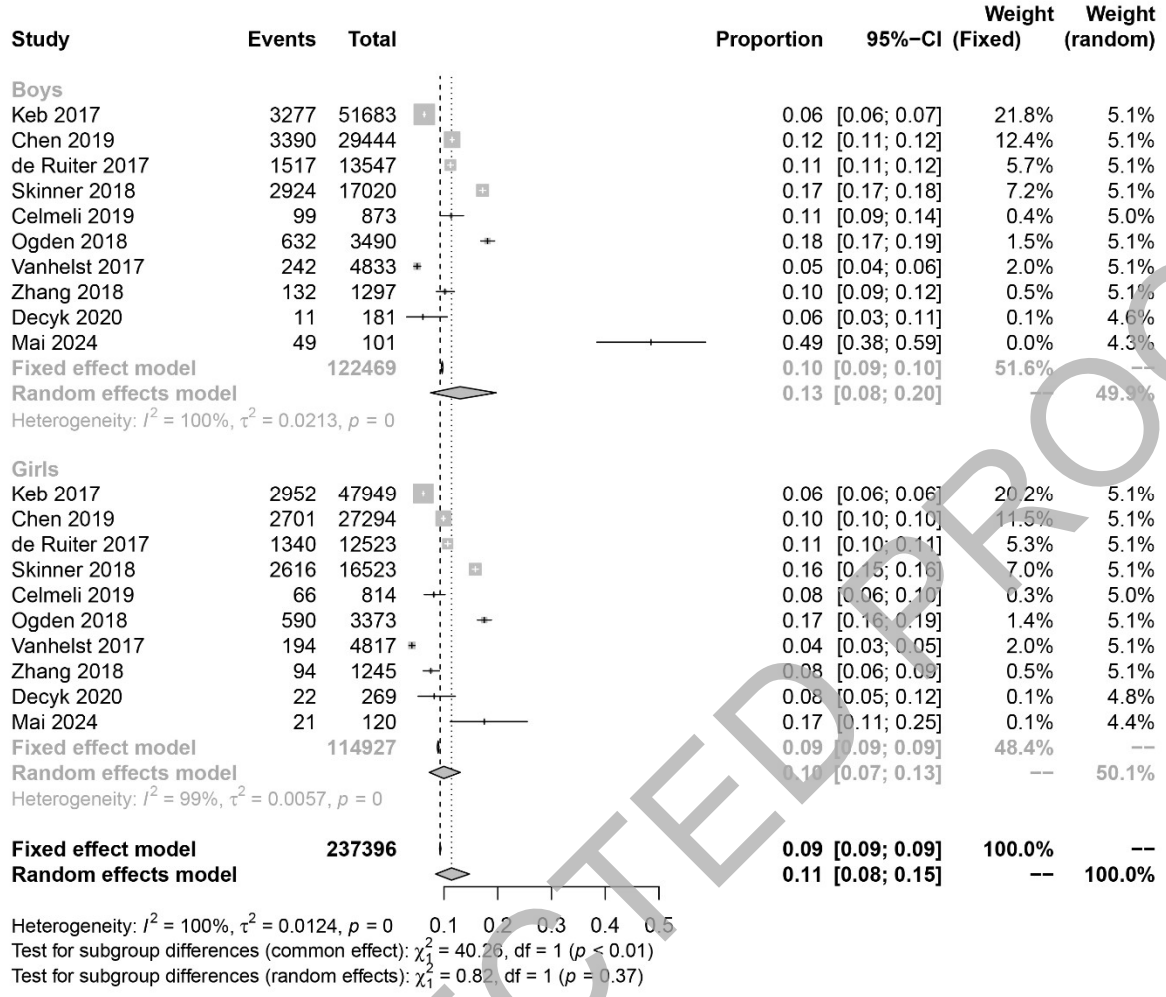

Figure 2. Forest plots of obesity rates in boys and girls.

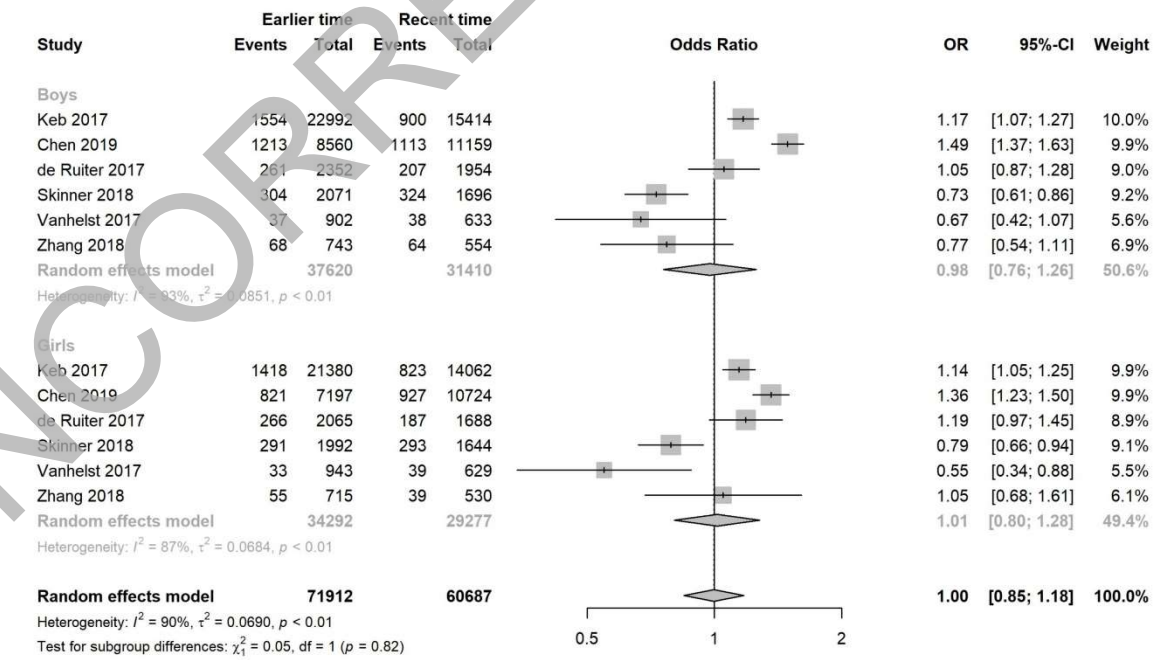

Figure 3. Time trend of obesity rates in boys and girls.

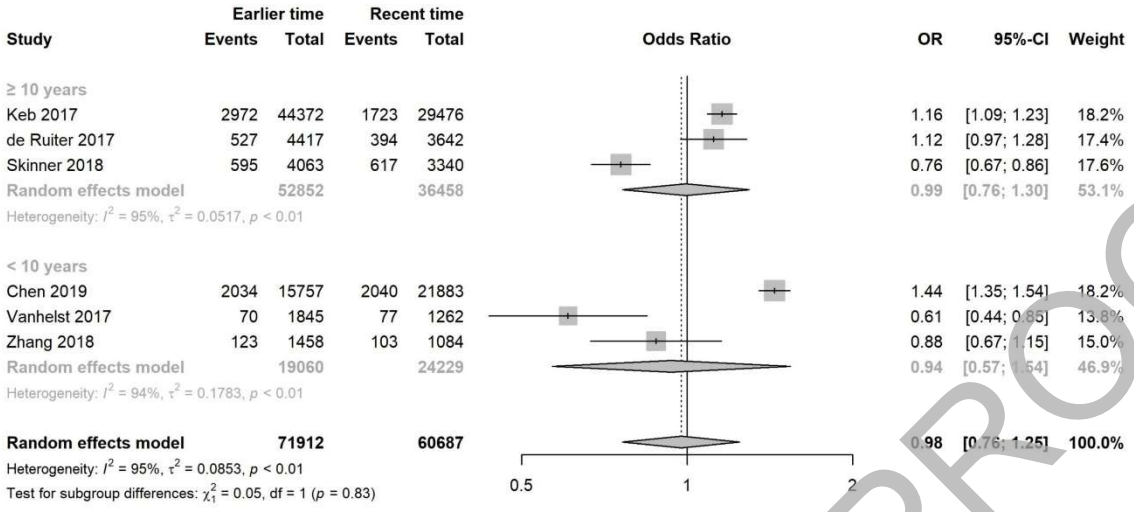

Figure 4. Time trend of obesity rates in different follow-up periods.

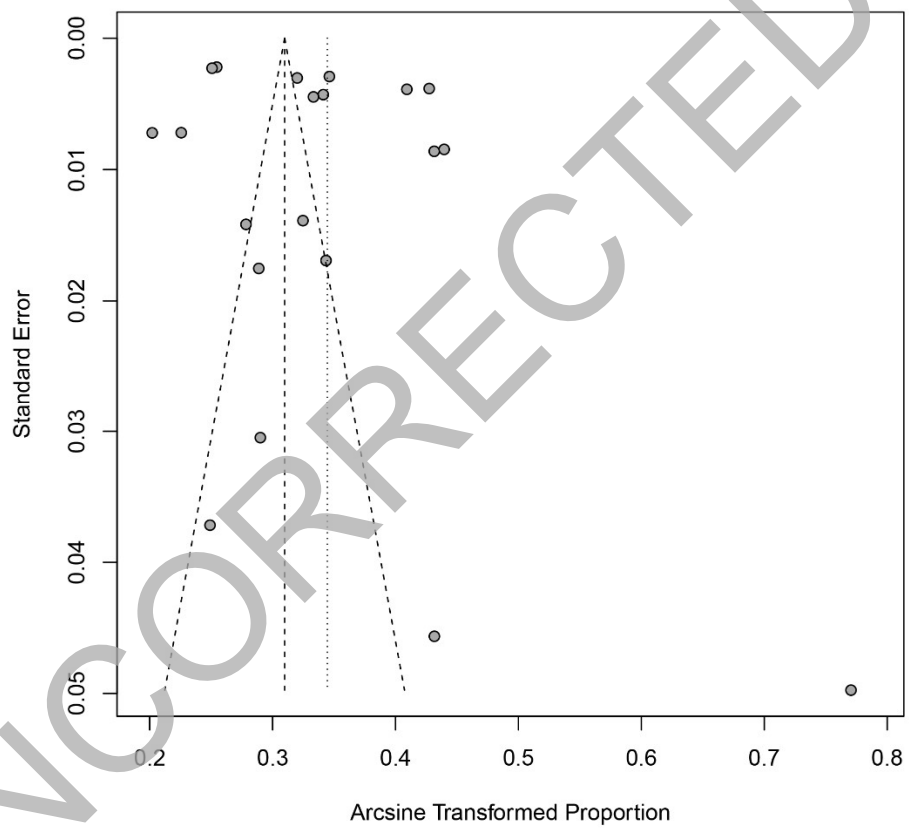

Figure 5. Funnel plot for publication bias.

Table S1. Quality assessment by the Newcastle–Ottawa Scale

Study	Definition adequate	Representativeness of the cases	Selection of controls	Definition of controls	Comparability of cases and controls on the basis of the design or analysis	Ascertainment of exposure	The same method of ascertainment for cases and controls	Nonresponse rate	Total quality scores
Keß, 2017	☆	☆	☆	☆	☆	☆	☆	☆	8
Chen, 2019	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Ruiter, 2017	☆	☆	☆	☆	☆	☆☆	☆	☆	9
Skinner, 2018	☆	☆	☆	☆	☆	☆	☆	☆	8
Gamze, 2019	☆	☆	☆	☆	☆	☆	☆	☆	8
Ogden, 2018	☆	☆	☆	☆	☆	☆☆	☆	☆	9
Vanhelst, 2017	☆	☆	☆	☆	☆	☆	☆	☆	8
Zhang, 2018	☆	☆	☆	☆	☆☆	☆	☆	☆	9
Decyk 2020	☆	☆	☆	☆	☆	☆	☆	☆	8
Mai 2024	☆	☆	☆	☆	☆	☆	☆	☆	8