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Obesity and oral health in Mexican children and adolescents: systematic review and meta-analysis.

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Special Article

Obesity and oral health in Mexican children and adolescents: systematic review and meta-analysis

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Context: *A relationship between obesity and poor oral health has been reported.* ***Objective:*** *To investigate the association between overweight/obesity and oral health in Mexican children and adolescents.* ***Data Sources:*** *A literature search was conducted of 13 databases and 1 search engine for articles published from 1995 onward.* ***Data Analysis:*** *A total of 18 publications were included. Evidence was inconclusive and varied according to sociodemographic factors or outcome measuring tools. The Decayed, Missing, and Filled Teeth and Filled Teeth Surfaces indices and the decayed extracted filled teeth index outcomes were included in a random effects model meta-analysis. Pooled estimates showed no statistically significant oral health differences (measured via the decayed extracted filled teeth or the Decayed, Missing, and Filled Teeth Surfaces indexes) among body mass index (BMI) categories. However, pooled estimates of 6 studies showed that children with higher BMI had worse oral health in permanent teeth (measured via the Decayed Missing Filled Teeth Index) than children with lower BMI (overall mean difference, –0.42; 95%CI, –0.74, –0.11).* ***Conclusion:*** *Whether there is an association between poor oral health and high BMI is inconclusive; however, both co-exist among Mexican children. Therefore, health promotion and prevention efforts should address common risk factors and broader risk social determinants shared between noncommunicable diseases.*

BACKGROUND

Oral health is an integral component of overall health and well-being, enabling vital daily functions.[1,2] Dental caries (also known as tooth decay) is among the most prevalent oral chronic diseases affecting children and adolescents worldwide.[3–6] Dental caries negatively affects children's quality of life[7] because of discomfort, pain, infection, or altered sleeping habits.[1] Dental caries also might alter children's normal growth and development

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and may increase the risk of hospitalization.[5] It has been suggested that oral health outcomes might vary according to income, ethnicity, or other sociodemographic factors.[6] Dental caries continues to be a public health problem, even with technological advancements and a better understanding of the carious process.[1,8]

Several studies have examined the relationship between overweight or obesity with children's oral health, especially dental caries. Obesity and dental caries are 2 conditions that share several predisposing factors, such as unhealthy lifestyles, a diet high in sugar, sociodemographic characteristics, and other environmental factors.[5–9] One of the most frequently studied factors is diet, mainly high consumption of sugar. Consuming high amounts of sugar might lead to both high body mass index (BMI) and a high prevalence of caries.[3–8] Consequently, many researchers have hypothesized that excess weight might be linked with children's dental caries. However, recent evidence suggests that any association between obesity and dental caries might vary according to different factors, including the country of the studied cohort'. The finding has been reported of significantly more caries among children with overweight or obesity (in both primary and permanent teeth) in high-income countries, but not those in low- and middle-income countries.[9]

Several individual studies and systematic reviews have recently evaluated the association between overweight or obesity and oral health outcomes (eg, caries).[5,8–10] However, the results and methodologies are mixed and provided uncertain and inconclusive evidence. Furthermore, most of the published systematic reviews include only English-language publications, excluding valuable evidence from non–English-speaking or low- and middle-income countries, such as Mexico.

To our knowledge, no systematic review have been conducted on oral health, dental caries, and obesity in Mexican children and adolescents. Mexico is an upper-middle–income Latin -American country experiencing a double burden of malnutrition (ie, the coexistence of overweight and obesity alongside stunning and wasting) in the past few decades.[11] The "Childhood and Adolescent Obesity in Mexico: Evidence, Challenges, and Opportunities" (COMO) project intends to synthesize and use data to comprehend the extent, nature, effects, and costs of childhood and adolescent obesity in Mexico.[12] The aim for this systematic review, which is part of the COMO project, is to evaluate the association of oral health outcomes (eg, oral health indexes, caries, dental plaque, gingivitis) with overweight or obesity in Mexican children and adolescents.

METHODS

This project's systematic review has been registered in the International Prospective Register of Systematic Reviews[13] (PROSPERO registration no. CRD42019154132). It has been reported according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[14] The research question and inclusion and exclusion criteria were established following the Population, Exposure, Comparison, Outcomes, Study Design (PECOS) framework. (Table 1)

The databases searched included MEDLINE, EMBASE, the Cochrane Library, Global Health Library, LILACS, CINAHL, CAB abstracts, ERIC, PsycINFO, ScienceDirect, Scopus, AGRICOLA, and SciELO Citation Index. Also, we searched for relevant material in the search engine Google Scholar. When possible, searches were also done in Spanish to capture relevant references. A sensitive search was developed to include index terms, free-text words, abbreviations, and synonyms to combine the key concepts for this review. Terms such as "overweight," "obesity," "body mass index," "bodyweight," "child," "adolescent," "dental caries," and "oral health" were included in the strategy with different term variations or synonyms and Boolean connectors to capture relevant publications. Full reports or conference abstracts were included if these met the inclusion criteria. Reference lists of included papers also were scrutinized for additional publications, and experts in the field were contacted for additional relevant reports. Original searches were conducted in January 2020 and updated in January 2021.

Selection criteria

As noted, the eligibility criteria were based on the PECOS framework (Table 1). The criteria are detailed by category in the following paragraphs.

Population. Studies that included children and adolescents from zero to 18 years old (mean reported age at the start of the study) from any ethnicity or sex living in Mexico were considered. Mexican children living in a different country were excluded from this review to better conceptualize the obesity problem within the country's sociodemographic characteristics and avoid confounding information inherent to migration phenomena. Likewise, studies that analyzed children's severe conditions (eg, HIV, cancer, fibrosis, Down syndrome) or pregnant adolescents were excluded.

Exposure. Included studies had to report baseline participants' BMI. The assessment of childhood and adolescent overweight and obesity differs worldwide and

Table 1 **PECOS criteria for inclusion of studies**

Population	Children and adolescents from zero to 18 years old from any ethnicity or sex living in Mexico
Exposure	Overweight or obesity measured via BMI and categorized with national or international references
Comparator	Studies that compared the prevalence of oral health outcomes across BMI categories
Outcomes	Oral health outcomes measured with indexes such as Decayed, Missing, and Filled Teeth; Decayed, Missing, and Filled (permanent) Teeth Surfaces; Decayed, Extracted, and Filled (primary) Teeth; International Caries Detection and Assessment System
Study design	Observational studies

Abbreviations: BMI, body mass index; PECOS, population, exposure, comparison, outcomes, study design.

relies intensely on the reference data, making BMI comparisons challenging.[5,9,15] For this reason, articles that used references of calculated BMI (ie, weight [in kilograms]/height [in meters] squared) and categorized with national or international references (eg, World Health Organization [WHO], International Obesity Task Force, Centers for Disease Control and Prevention) were considered.

Outcomes. Studies testing the association between overweight and/or obesity with oral health were included. Oral health indexes such as Decayed, Missing, and Filled (permanent) Teeth (DMFT); Decayed, Missing, and Filled (permanent) Teeth Surfaces (DMFS); decayed, extracted, and filled primary teeth (*deft*); and International Caries Detection and Assessment System were included. Also, any other reported oral health outcome (eg, dental plaque index, gingival state) was considered.

Study design. Human observational studies were considered in this review.

Since the early 1990s, there is evidence of a continued increase in the prevalence of childhood and adolescent obesity in Mexico.[11] To focus on contemporary epidemiological and environmental circumstances of childhood and adolescent obesity in Mexico, evidence published from 1995 onward was included in this review. Relevant studies included English, Spanish, or Portuguese publications to capture reports from the most widespread languages spoken in the Americas.

Data selection and extraction

Titles, abstracts, and relevant full texts were screened by 2 reviewers (L.L.-C., M.G.-B.) and all were checked by a third reviewer (M.A.-M). In addition, 2 reviewers (M.A.-M., N.L.G.-F.) extracted data from relevant studies independently. In case of any disagreement, a third author was contacted (Y.Y.G.-G.).

A data extraction form was structured following the PECOS framework. Relevant data from the included studies included population characteristics (ie, target population, mean and range of age, sex distribution, other socioeconomic or demographic characteristics); study design; references linked to the study; setting characteristics (eg, city, Mexican state, recruitment location); exposure (ie, BMI and any other anthropometric or adiposity measurement considered), BMI categorization (ie, number of children who were underweight, of normal weight, overweight, or obese), and references used to categorize BMI (eg, WHO, International Obesity Task Force, Centers for Disease Control and Prevention); outcomes: oral health evaluated through commonly used indexes (eg, DMFT, DMFS, *deft*, International Caries Detection and Assessment System), or any other oral health outcomes (eg, dental plaque, gingival state). It was also recorded if outcomes were measured in primary, permanent, or both types of teeth.

Data synthesis

As reported in previous reviews,[9] BMI classification in children and adolescents may vary according to included participants' age or the references used to categorize BMI. The 4 BMI classifications used across child- and adolescent-targeted studies include "underweight," "normal weight," "at risk of overweight," and "overweight." In contrast, some others categorized BMI as "underweight," "normal weight," "overweight," and "obese." For the synthesis purposes, the categories "at risk of overweight" and "overweight" were unified in this review. The categories "overweight" and "obesity" refer to children and adolescents in the 2 highest BMI categories, respectively, regardless of the anthropometric reference used in the studies. The data obtained from the included studies were synthesized narratively, and key characteristics were tabulated. In addition, textual descriptions of studies and reported statistical analysis were recorded and tabulated. Reported outcomes presented per tool or index used are reported narratively in the Results section.

Statistical analysis

Studies that reported oral health using the DMFT, DMFS, and *deft* indexes were included in a random-effects meta-analysis. The analysis did not combine indexes (ie, DMFT, DMFS, and *deft*), because the numbers of teeth and surfaces with dental caries reveal a different severity of dental caries, which have been reported as not suitable for direct combination.[9]

The included studies reported oral health data using several BMI categories: overweight, obesity, underweight, and normal weight. As a primary analysis, higher BMI categories (overweight and obesity) were pooled and compared with data on lower BMIs (underweight or normal weight). Also, as secondary analysis, meta-analyses of specific BMI categories were conducted, and results are provided in Appendix S1 in the Supporting Information online. The weighted mean difference was used to compare oral health indexes' continuous variables among BMI categories. All results were reported with 95%CIs. Considering that all the included papers were observational studies, we used the DerSimonian and Laird method to construct a random-effects model.[16]. Whenever possible, sensitivity analyses were performed to exclude studies considered having a "low" quality to test the impact of study quality on the heterogeneity and effect size. The analysis was performed with R statistical software using the library *metafor*. The main results are presented in forest plots.

Risk of bias and quality assessment

The JBI (formerly, Joanna Briggs Institute) critical appraisal tool for cross-sectional studies[17] was used to assess the quality of the included studies. This tool assesses the methodological quality of observational studies and determines the extent to which a study has addressed the possibility of bias.[17] The tool evaluates 8 critical items: explicit inclusion and exclusion criteria; details about study participants and the setting; method of measurement of exposure; standard criteria used for measurement of the condition; identification of confounding factors; strategies to deal with confounding factors; outcome measurement validity and reliability; and appropriate statistical analysis. Articles were not included or excluded on the basis of their quality. However, the appreciation of the quality was used to categorize the papers: *high quality* for those papers that reported sufficient detail for the critical items; *unclear quality* was assigned for those papers with ≥ 1 "unclear" appreciation in the items; And *low quality* for those papers that did not report or consider ≥ 1 items of the tool. Two reviewers (M.A.-M., N.L.G.-F.) performed this evaluation independently. If there was any disagreement, a third reviewer was consulted (Y.Y.G.-G.) to reach an agreement.

RESULTS

After searching the literature databases, 7363 references were identified, of which 1432 were retrieved for full-text review. Overall, 886 references were identified by reporting obesity-related data from Mexican children and are included in the COMO database (Figure 1). Of these, 18 publications met the eligibility criteria and were included in this review.[18–35] The overall characteristics of included studies are presented in Table 2.[18–35] All the included studies had a cross-sectional design, except 1,[30] which had a longitudinal design. Studies were conducted in 8 of the 32 states in Mexico (Figure 2).

Most of the studies recruited participants in schools, but 3[22,27,29] recruited participants in clinics. The study samples varied from 40[22] to 6230 participants.[21] The age range of included participants was 2.5[35] to 15 years.[24] All the studies included both girls and boys and targeted a general population (including, but not limited to, children with overweight and obesity), except for 1[22] study that included only children with obesity. Overweight or obesity prevalence varied across studies from 19% to 66% of the included participants. (Table 2)

Various tools were used to measure oral health of participants, and some used >1 tool. The DMFT Index was used in 10 of the 18 studies[18,19,21–23,25,27,31,32,34]; 6 used *deft*[28,30–33,35]; 4 used the DMFS Index[20,22,25,30]; 4 used the Simplified Oral Hygiene Index[19,23,28,34]; 2 used the International Caries Detection and Assessment System[20,29]; 2 used the Significant Caries Index[18,21]; 2 used the Community Periodontal Index[19,24]; 2 used the O'Leary's dental plaque index[25,31]; 1 used the Treatment Needs Index[18]; 1 estimated the loss of periodontal attachment[24]; and 2 evaluated the gingival state[28,32] (Table 2).

Overall, results were poorly reported and varied according to the tool used to measure oral health and how the tool was used. For instance, the DMTF Index was the most used tool to measure oral health among the included studies. However, some studies presented just the summary data for DMFT. In contrast, others reported individual index components (ie, number of decayed or missing teeth because of caries or filled teeth) or in a dichotomized form.

Reported results are presented by age group in Table 3.[18–35] Overall, the results are inconclusive within and across different age groups. Some studies found no association between BMI and oral health indexes or prevalence of caries.[20,25,26,29,35] Some study findings suggested a significant relationship between poorer oral health and overweight or obesity.[18,21,27,33] Others reported worst oral health among underweight or normal-weight children.[19,23,30–32,34] However, some

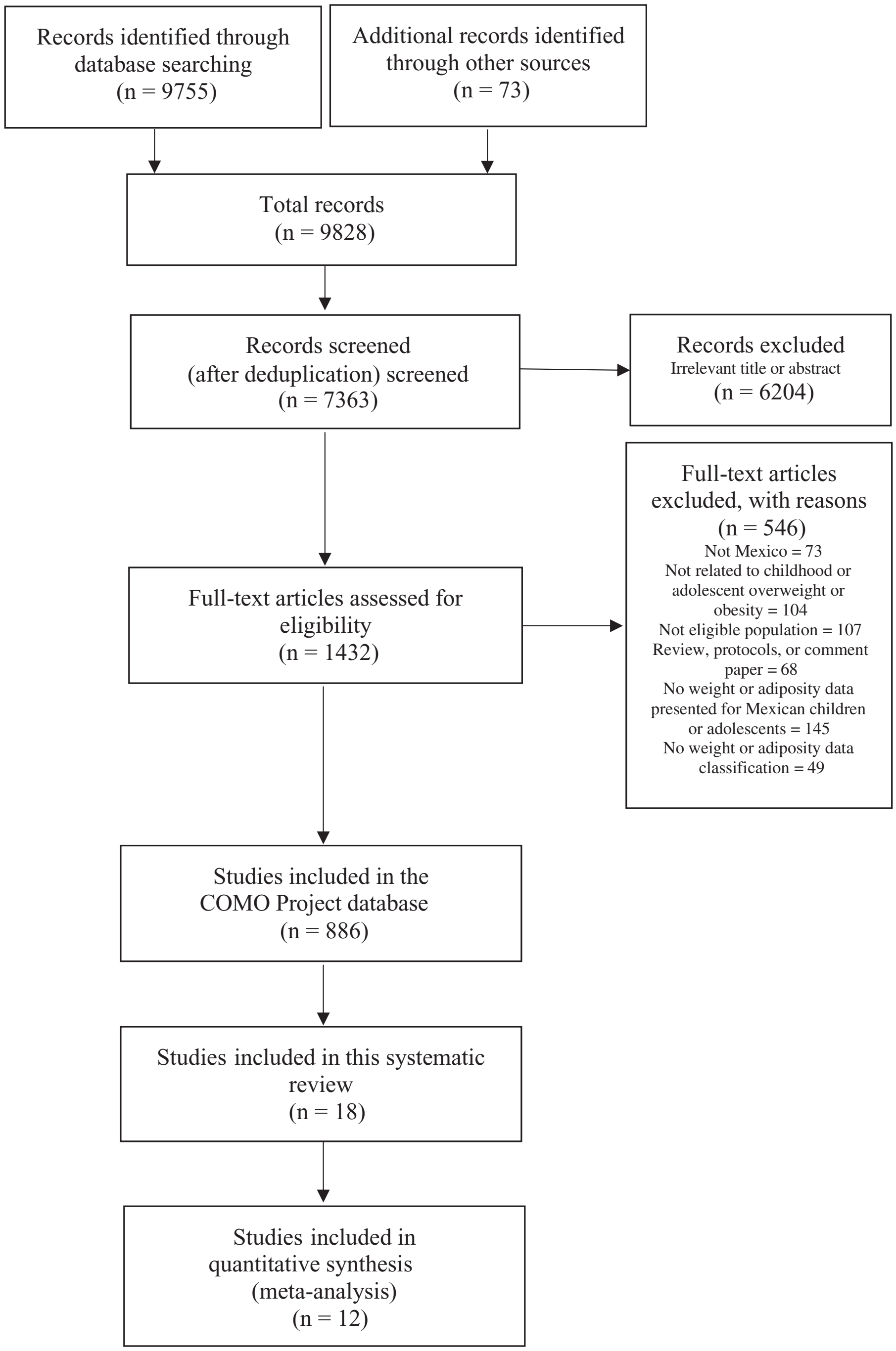

Figure 1 **PRISMA flowchart of the Childhood and Adolescent Obesity in Mexico (COMO): Evidence, Challenges, and Opportunities project.**

results varied with other variables considered in the analysis, such as the setting (ie, rural or urban),[18,26] socioeconomic status,[30] or the sex[25] of included participants, and the tool used to measure outcomes.[21] Also, 1 study reported that oral health was worst among those adolescents with obesity and insulin resistance[27] (Table 3).

For children younger than 5 years, 2 studies reported that visible plaque and higher BMI categories were associated.[25,28] However, for children 6–12 years old, no statistical relationship between this dental plaque and BMI was reported in 1 study.[31] According to another study, adolescents (aged 13–18 years) who had overweight or obesity were more likely to have bleeding on probing (odds ratio [OR], 1.57; $P < 0.01$) and periodontal pockets (OR, 1.78; $P < 0.01$) than those with normal weight. The odds were higher for those with obesity only (OR, 7.07; $P < 0.01$) and (OR, 5.56; $P < 0.01$).[24]

Table 2 **General characteristics of included studies**

Reference	Setting in Mexico	Population	Outcome measurements	Reported outcome
Adriano-Anaya et al 2014[18]; cross-sectional	Milpa Alta Municipality, Mexico City Setting: 19 elementary schools (8 urban, 11 rural)	N = 4734; 46.7% girls Age range, 6–12 y 40.3% OW/OB	Anthropometric variables: BMI was classified according to the Latin-American Diabetes Association[a] 2014. Oral health variables: DMFT; SCI; TNI	Overall, DMFT Index was higher in children with obesity (3.2) and the lowest in children underweight (1.9) ($P < 0.001$). However, these rates also differed according to the setting: higher in rural schools (3.1), lower in urban schools (2.1) ($P < 0.001$). The SCI Index was lower among underweight children (4.6) and higher in children with obesity (5.4) teeth with a history of the disease. However, differences among BMI categories were not statistically significant. Most (94%) of the included population had at least some dental issues that needed treatment, according to the TNI, with no statistical differences($P > 0.05$) among BMI categories.
Aguilera-Galaviz et al 2019[19]; cross-sectional	Zacatecas City, Zacatecas Setting: 3 high schools. No other detail provided.	N = 203; 59.1% girls Mean age, 13.6 (SD 1.0) y 25.1% OW/OB	Anthropometric variables: BMI and height for age, waist/hip index, and body density, according to the Durnin formula. BMI for age classification using the AnthroPLUS (WHO) program[b] Oral health variables: DMFT; OHI-S; CPI	The DMFT Index, according to the BMI, was underweight (3.6), normal weight (3.2), overweight (2.7), and obesity (2.7). However, no statistical analysis using these data was reported in the article. OHI-S and CPI were presented for the overall sample. No data were presented according to any anthropometric variable.
Ashi et al 2019[20]; cross-sectional	City or municipality: NR, Veracruz Setting: schools. No further detail was provided. Study part of a multicenter, multinational study	N = 224; 46.8% girls Age range, 13–15 y 41.5% OW/OB	Anthropometric variables: BMI classified according to WHO[b] BMI-for-age classification, WHO reference[b] Oral health variables: DMFS; ICDAS	The DMFS Index, according to the BMI, was normal weight (1.3), overweight (1.2), and obesity (1.0). There was no statistical difference among BMI categories ($P > 0.05$). No significant correlation was found between BMI and the sweet-taste threshold or preference and dental caries variables ($P > 0.05$). No results were presented for ICDAS.
Caudillo-Joya et al 2014[21]; cross-sectional	Iztapalapa Municipality, Mexico City Setting: 20 elementary schools	N = 6230; 50% girls Age range, 6–12 y 41.1% OW/OB	Anthropometric variables: BMI classified according to the Latin-American Diabetes Association 2014[a] Oral health variables: DMFT; SCI	The DMFT Index, according to the BMI, was underweight (2.4), normal weight (2.9), overweight (3.1), and obesity (3.2). There was a statistical difference among BMI categories ($P < 0.001$). The SCI average of children who were underweight was 4.8, of normal weight was 5.0, and of children with overweight and obesity was 5.1. However, no statistical differences were found between the SCI and the BMI ($P > 0.05$).

(continued)

Table 2 **Continued**

Reference	Setting in Mexico	Population	Outcome measurements	Reported outcome
De la Cruz Cardoso et al 2015[22]; cross-sectional	Mexico City Setting: obesity outpatient clinic of a public hospital	N = 40 Sex distribution: NR Age range, 6–12 y 100% OB	Anthropometric variables: After a physical exploration, all participants were diagnosed as having obesity. The references' cutoff for the diagnosis were not reported. Oral health variables: DMFS; DMFT	The prevalence of caries in primary and permanent dentition was 71% and 22%, respectively. For the total population, the average DMFS Index was 1.4, and the DMFT Index was 0.37.
Garcia-Perez et al 2020[23]; cross-sectional	Mexico City Setting: 2 elementary public schools with a program of school breakfasts	N = 522; 51.7% girls Mean age: 9.5 (SD 1.2) y 37.7% OW/OB	Anthropometric variables: BMI and BMI z-score were classified according to the WHO.[b] BMI-for-age z-score classification: $\leq +1$ SD normal weight; $> +1$ SD to $< +2$ SD overweight; $> +2$ SD obesity Oral health variables: OHI–S; DMFT (dichotomized)	Using a dichotomized DMFT variable, there was a statistical difference among BMI categories, showing that most subjects with obesity presented a lower percentage of caries ($P = 0.041$). Logistic regression, adjusted by age, sex, OHI-S, toothbrushing frequency, and the consumption of sweets, showed that children with obesity were less likely to have dental caries (OR, 0.53; 95%CI, 0.31–0.89; $P = 0.017$) than children without obesity.
Irigoyen-Camacho et al 2013[24]; cross-sectional	Mexico City Setting: 2 private and 2 public high schools in middle-income neighborhoods	N = 257; 46.7% girls Mean age, 15 (SD NR) y 29.9% OW/OB	Anthropometric variables: BMI and BMI z-score were classified according to the IOTF. Bioelectrical impedance was performed on participants. IOTF BMI age- and sex-specific cutoff points (boys and girls, respectively) were: overweight, 23.6 and 24.17; obese, 28.6 and 29.29 Oral health variables: CPI; LOA	In adjusted regression models, adolescents with overweight or obesity were more likely (OR, 1.57; 95%CI, 1.45–1.63; $P < 0.01$) to have bleeding on probing (CPI = 1) and (OR, 1.78; 95%CI, 1.51–2.10; $P < 0.01$) to have periodontal pockets (CPI = 2) than those with normal weight. The odds were higher for those with obesity only (OR, 7.07; 95%CI, 2.74–18.24; $P < 0.01$) and (OR, 5.56; 95%CI, 5.39–5.74; $P < 0.01$), respectively.
Juarez-Lopez et al 2010[25]; cross-sectional	Iztapalapa Municipality, Mexico City Setting: preschool children. No further detail provided.	N = 189; 41.0% girls Mean age, 4.6 (SD 0.7) y 66.6% OW/OB	Anthropometric variables: BMI was classified according to the IOTF. However, the specific cutoff used was not reported. Oral health variables: DMFS; DMFT; O'Leary's Dental Plaque Index	The prevalence of caries was 79% for the obese group, 84% for the overweight group, and 77% for the normal-weight group. No differences were found with statistical significance between the groups, nor was an association found between the prevalence of caries with overweight and obesity (OR, 1.31; 95%CI: 0.62–2.76; $P > 0.05$). However, when analyzed by sex, girls had a higher risk of caries (OR, 4.24; 95%CI, 1.04–17.31; $P < 0.05$) than boys. Children with overweight, but not with obesity, were more likely (OR, 7.83; 95%CI, 1.74–35.21; $P = 0.003$) to have dental plaque ($\geq$ 24%) than were normal-weight children.

(continued)

Table 2 **Continued**

Reference	Setting in Mexico	Population	Outcome measurements	Reported outcome
Lara-Capi et al 2018[26]; cross-sectional	Tepancan and Veracruz City, Veracruz Setting: 1 rural-area school (in Tepancan) and 1 urban area school (in Veracruz City)	N = 464; 43.7% girls Mean age, 13.5 (SD 0.9) y 58.4% OW/OB	Anthropometric variables: BMI classified according to the WHO[b] Oral health variables: ICDAS	No association found between body weight and caries severity in the overall population. However, when overweight and area of residence were combined (urban and rural), a significant association was found ($P > 0.01$). Overweight adolescents with caries in dentine were most frequently found in the rural area. A higher prevalence of caries in enamel and a lower prevalence of caries in dentine ($P < 0.01$) were recorded in adolescents from the urban area, where better oral habits but higher sweets intake ($P = 0.04$) were reported.
Loyola-Rodriguez et al 2011[27]; cross-sectional	San Luis Potosi City, San Luis Potosi Setting: oral medicine clinic of a hospital	N = 100; 58% girls Mean age, 13 (SD 1.1) y 50% OB with insulin resistance	Anthropometric variables: BMI age and sex specific, classified according to the CDC 2000[36]. BMI percentiles classification: ≤85th, normal weight; 85th–<95th, overweight; ≥95th, obesity Oral health variables: DMFT	DMFT Index was 3.02 in adolescents without obesity and 4.78 in adolescents with obesity and insulin resistance ($P < 0.05$). When testing each component separately from the DMF, only the decay component showed a significant statistical difference ($P < 0.05$) among groups. Multivariate analysis showed that DMFT Index (OR, 3.10; 95%CI, 0.20–1.02; $P = 0.042$) and decay (OR, 3.30; 95%CI: 0.19–1.0; $P = 0.011$) were associated with participants with obesity and insulin resistance.
Patiño-Marín et al 2018[28]; cross-sectional	San Luis Potosi City, San Luis Potosi Setting: 40 elementary schools (public and private)	N = 1527; 51% girls Mean age: 4.5 (SD 0.5) y 42% OW/OB	Anthropometric variables: BMI and BMI z-score classified according to the WHO BMI percentiles classification: 5th to < 85th, normal weight; ≤ 85th to < 95th, overweight; ≤ 95th obesity Oral health variables: OHI-S; gingival state; *deft*	The presence of visible plaque and risk of being overweight or overweight were positively associated ($P < 0.0001$), as was the mean score of the presence of gingivitis (OR, 8.28; 95%CI, 3.30–19.8; $P < 0.001$). The absence of visible plaque and being categorized as at risk of overweight or overweight was positively associated with gingivitis (OR, 2.44; 95%CI, 0.68–8.06).
Ramirez-De los Santos et al 2020[29]; cross-sectional	Guadalajara, Jalisco Setting: Pediatric Dentistry specialty clinic, part of a university hospital	N = 80; 38.8% girls Mean age: 5.8 (SD NR) y 46.5% OW/OB	Anthropometric variables: BMI age and sex specific classified according to the CDC 2000 BMI percentiles classification: ≤ 85th, normal weight; 85th to <95th, overweight; ≥ 95th obesity Oral health variables: ICDAS	The percentage of cavitated carious lesions was higher in children with overweight or obesity (94.6%), but this was not statistically significant. Children with cavitated lesions did not have a higher BMI than the infants with carious lesions without cavitation (17.7 ± 0.3 vs 16.9 ± 0.2, respectively; $P = 0.075$).
Sanchez-Perez et al 2010[30]; longitudinal	Mexico City Setting: public elementary school in a middle-income area	N = 110; 50% girls Mean age, 7.1 (SD 0.32) y 29.5% OW/OB	Anthropometric variables: BMI age and sex specific classified according to the CDC 2000 BMI for age sex-specific percentiles classification: < 5th underweight; 5th to < 50th thin; 50th to < 85th normal weight; 85th to < 95th risk of overweight; ≥ 95th overweight Oral health variables: DMFT; *deft*	The *deft* Index mixed-model results showed that children with a high BMI had fewer dental caries ($P < 0.01$). At baseline, children in the overweight group had a *deft* Index of 3.2, whereas in thin children, the *deft* Index was 6.2; at age 9 y, the indices were 2.1 and 5.8, respectively. Again, socioeconomic status was significant in the model: children with fewer economic resources had higher *deft* scores ($P = 0.01$). However, no association was detected between BMI and DMFS Index values ($P > 0.05$).

(continued)

Table 2 **Continued**

Reference	Setting in Mexico	Population	Outcome measurements	Reported outcome
Serrano-Piña et al 2020[31]; cross-sectional	San Mateo Atenco, State of Mexico Setting: Public elementary school	N = 331; 48.3% girls Mean age, 10.2 (SD 1.0) y 58.3% OW/OB	Anthropometric variables: Waist circumference, BMI age and sex specific, classified according to the CDC 2000 BMI for age sex-specific percentiles classification: < 5th, underweight; 5th to < 85th, normal weight; 85th to < 95th, risk of overweight; ≥ 95th overweight Oral health variables: DMFT; *deft* Index; O'Leary's Dental Plaque Index	The total amount of carious lesions was greater in the low- and normal-weight groups (5.27 and 5.26, respectively). Participants with overweight had more carious lesions according to the DMFT Index (1.69) compared with the primary dentition *deft* Index (4.0). However, no statistically significant differences among BMI categories were reported. The O'Leary's dental plaque index was higher in the participants with obesity and underweight (27.97 and 27.15, respectively). However, adjusted logistic regression methods showed no statistical relationship between this variable and BMI.
Silva-Flores et al 2013[32]; cross-sectional	Victoria City, Tamaulipas Setting: 3 public elementary schools and 1 private school	N = 402; 51.7% girls Mean age: 9.5 (SD 1.5) y 36.2% OW/OB	Anthropometric variables: BMI is used to classify nutritional status; however, the reference was not provided. Oral health variables: DMFT; *deft*; gingival state	The *deft* Index means differed significantly between children with underweight and overweight ($P = 0.011$), and the same was observed between normal-weight schoolchildren with overweight ($P = 0.003$). An adjusted, multiple linear regression analysis showed that the *deft* Index changed, on average, −0.653 ($P = 0.016$) for each change in the weight condition, with certain age and sex adjustments.
Vazquez-Nava 2010 et al[33]; cross-sectional	Tampico, Madero and Altamira, Tampico Setting: public nursery schools	N = 1160; 50.1% girls Mean age: 4.5 (SD 0.5) y 46.6% OW/OB	Anthropometric variables: BMI classified according to the CDC 2005 BMI for age sex-specific percentiles classification: < 5th, underweight; 5th to < 85th, normal weight; 85th to < 95th, risk of overweight; ≥ 95th, overweight Oral health variables: *deft*	A higher percentage of caries prevalence was reported in children at risk for overweight (26.1%) than those who were not (16.6%). Using adjusted regressions models, the risk of dental caries for children who were at risk for overweight was 1.94 (95%CI, 1.30–2.89; $P < 0.001$) and 1.95 (95%CI, 1.42–2.64; $P < 0.001$), compared with those with a normal weight.
Zelocuatecatl-Aguilar et al 2005[34]; cross-sectional	Mexico City Setting: public secondary school.	N = 587; 52.3% girls Mean age: 15.8 (SD 0.9) y 43.1% OW/OB	Anthropometric variables: BMI classified according to the CDC 2000 BMI percentile cutoff points used: < 5th, underweight; 5th to < 85th, normal weight; 85th to < 95th, overweight; ≥ 95th, obesity Oral health variables: OHI–S; DMFT	DMFT Index was presented per component and not as a complete index. For example, 90.56% of children with overweight people had dental caries. However, 27.35% had their teeth filled or well rehabilitated compared with the rest of the schoolchildren. According to the OHI-S Index, more children with overweight (32.1%) got oral hygiene. In contrast, concerning "good and excellent" oral hygiene, the highest percentage was obtained by children at risk of being overweight (63.3% and 8.8%, respectively). Differences between OHI-S and BMI were statistically significant.

(continued)

Table 2 **Continued**

Reference	Setting in Mexico	Population	Outcome measurements	Reported outcome
Zúñiga-Manríquez et al 2013[35]; cross-sectional	Pachuca, Hidalgo Setting: public nursery schools	N = 152; 48.7% girls Mean age: 2.5 (SD 0.8) y 19.1% OW	Anthropometric variables: Weight and height were categorized according to a national reference, "Federico Gómez." Nutritional status was estimated by dividing weight by the reference weight and multiplying by 100. The results were classified as follows: 0 = underweight; 1 = normal weight; 2 = overweight Oral health variables: *deft*; SCI	The *deft* Index and SCI values did not differ according to nutritional status ($P > 0.05$). The caries experience between girls and boys was similar ($P > 0.05$), as were the different levels of nutrition between girls and boys.

Abbreviations: BMI, body mass index; CDC, Centers for Disease Control and Prevention; CPI, Community Periodontal Index; *deft*, decayed, extracted, and filled teeth; DMF, Decayed, Missing, and Filled; DMFS, Decayed, Missing, and Filled Surfaces; DMFT, Decayed, Missing, and Filled Teeth; ICDAS, International Caries Detection and Assessment System; IOTF, International Obesity Task Force; LOA, loss of periodontal attachment; NR, not reported; OHI-S, Simplified Oral Hygiene Index; OB, prevalence of obesity; OR, odds ratio; OW, prevalence of overweight; SCI, Significant Caries Index; SD, Dtandard Deviation, TNI, Treatment Needs Index; WHO, World Health Organization. It was unclear from the text if Adriano-Anaya et al 2014 and Caudillo-Joya et al 2014 were part of the same study, hence these were presented separately.

[a]BMI percentiles classification: < 10th, underweight; < 10th–85th, normal weight; ≥ 85th, overweight; ≥ 95th, obesity; ≥ 97th, severe obesity.

[b]Thinness: < −2 SD; overweight: > +1 SD; obesity: > +2 SD.

Only 3 studies[23,26,33] considered other habits or lifestyles factors to analyze BMI and its relationship with oral health outcomes. The authors of these 3 studies concurred that sugar consumption, bottle feeding, and tooth-brushing frequency were strongly associated with caries ($P < 0.05$).

Quality of the included studies

Overall, 10 of the 18 included studies were of high quality,[23–30,33,34] 4 were of unclear quality,[18,21,31,32] and another 4 were of low quality.[19,20,22,35] The population inclusion and exclusion criteria were not reported clearly in 2 studies.[18,21] All the studies measured oral health outcomes validly and reliably. All but 2[32,35] recorded weight and nutritional status validly and reliably. In 4 studies,[19,20,22,35] confounding factors were not identified or the authors did not state their strategies to deal with confounding factors. In almost all the studies, statistical analysis was appropriate (Table 4).[18–35]

Meta-analyses

BMI and oral health (using deft *Index in primary teeth).* Among the 18 included studies, 5[28,31–33,35] studies that assessed oral health with the *deft* index for primary teeth provided sufficient data to be included in the analysis. Overall, no significant differences in the mean *deft* index were found among children with lower or higher BMIs (overall mean difference [MD], 0.13; 95%CI, –0.49, 0.75). Sensitivity analyses were performed with the only low-quality study removed,[35] and the result remained insignificant (overall MD, −0.12; 95%CI, –0.59, 0.83) (Figure 3[29,32–34]).

BMI and oral health (using the DMFS Index in permanent teeth). Among the 18 included studies, only 2[20,25] studies that assessed oral health with the DMFS Index provided relevant data to the analysis. One[20] was considered to have a low quality, and the other[25] was of high quality. When pooling the means and SD estimates for the DMFS Index, no significant differences were found among children with lower BMIs vs children with higher BMIs (overall MD, 0.21; 95%CI, −0.20, 0.62).

BMI and oral health (using the DMFT Index in permanent teeth). Among the 18 included studies, 7[18,19,21,25,27,31,32] assessed oral health with the DMFT Index in permanent teeth and provided relevant data to the analysis. When pooling the means and SD estimates for the DMFT Index, no significant differences were found among children with different BMIs (overall MD, −0.28; 95%CI, −0.63, 0.07). However, when

Figure 2 **Map of the Mexican 8 states from which evidence was reported.**

Table 3 **Oral Health outcomes per age group**

Age group, y	Reported outcomes
≤5[26,29,34,37]	Oral health indexes and caries: 1 study[34] reported a higher percentage of caries in children at risk for overweight than those who were not. The risk of dental caries for children who were at risk for overweight was 1.94 (95%CI, 1.30–2.89; $P < 0.001$) and for overweight was 1.95 (95%CI: 1.42–2.64; $P < 0.001$), compared with those of normal weight. However, 2 other studies found no association between BMI and the prevalence of caries.[26,37] In 1 of these, significant results were found when data were analyzed by sex; girls had a higher risk of caries (OR, 4.24; 95% CI, 1.04–17.31; $P < 0.05$) than did boys.[26] Dental plaque: the presence of visible plaque and overweight were positively associated. [26,29] Gingivitis: the absence of visible plaque and being categorized as at risk of overweight or being overweight was positively associated with gingivitis.[29]
6–12[19,22–24,30–33]	Oral health indexes and caries: 2 studies reported the worst oral health indexes in children with higher BMIs.[19,22] One study reported no statistical differences among BMIs and association and oral health outcomes.[30] But 4 studies reported that participants with obesity had a lower percentage of caries.[24,31–33] However, the associations also varied according to the setting,[19] SES,[31] or tool used to evaluate oral health.[22] Dental plaque: no statistical relationship between this dental plaque and BMI was reported in 1 study.[32]
13–18[0,21,25,28,35,38]	Oral health indexes and caries: 3 studies reported the worst oral health in underweight or normal-weight participants compared with other BMI categories.[20,21,35] One study reported that such differences were not statistically significant.[21] One study reported worse oral health indexes in adolescents with obesity and insulin resistance ($P < 0.05$) than adolescents without obesity.[28] Differences between OHI-S and BMI were statistically significant.[35] And 1 study reported no association between body weight and caries severity in the overall population.[27] However, when overweight and area of residence (urban and rural) were combined, there was an association with caries severity ($P > 0.01$): overweight adolescents with caries in dentine were most frequently found in the rural area.[27] A higher prevalence of caries in enamel and a lower prevalence of caries in dentine ($P < 0.01$) were recorded in adolescents from the urban area, where better oral habits but greater sweets intake ($P = 0.04$) were reported.[27] Bleeding on probing and periodontal pockets: in adjusted regression models, adolescents who had overweight or obesity were more likely to have bleeding on probing (OR, 1.57; 95%CI, 1.45–1.63; $P < 0.01$; CPI = 1) and to have periodontal pockets (OR, 1.78; 95%CI,1.51–2.10; $P < 0.01$; CPI = 2) than those with normal weight. The odds were higher for those with obesity only (OR, 7.07 [95%CI, 2.74–18.24], $P < 0.01$; and OR, 5.56 [95%CI, 5.39–5.74], $P < 0.01$).[25]

Abbreviations: BMI, body mass index; CPI, Community Periodontal Index; OHI-S, Simplified Oral Hygiene Index; OR, odds ratio; SES, socioeconomic status.

conducting the sensitivity analyses by removing the low-quality study,[19] there were statistically significant lower DMFT Index values among children with lower BMIs than among children with higher BMI (overall MD, −0.42; 95%CI, −0.74, −0.11) (Figure 4).[18,21,25,27,31,32] Nevertheless, the underweight group had significantly lower DMFT Index values than did other BMI groups (Appendix S1 in the Supporting Information online).

DISCUSSION

For this systematic review, we aimed to investigate oral health outcomes in overweight or obesity in Mexican

Table 4 **Overall quality appraisal of included studies**

Reference	Clearly defined inclusion criteria	Study participants and setting described in detail	Exposure measured in a valid and reliable way	Objective standard measurements of the condition	Confounding factors identified	Strategies to deal with confounding factors stated	Outcomes measured in a valid and reliable way	Appropriate statistical analysis used	Overall quality appraisal
Adriano-Anaya et al 2014[18]	?	✓	✓	✓	✓	✓	✓	✓	Unclear
Aguilera-Galaviz et al 2019[19]	✓	✓	✓	✓	✓	×	✓	?	Low
Ashi et al 2019[20]	✓	×	✓	✓	×	×	✓	✓	Low
Caudillo-Joya et al 2014[21]	?	✓	✓	✓	✓	✓	✓	✓	Unclear
De la Cruz Cardoso et al 2015[22]	✓	?	✓	?	×	×	✓	?	Low
Garcia-Perez et al 2020[23]	✓	✓	✓	✓	✓	✓	✓	✓	High
Irigoyen-Camacho et al 2013[24]	✓	✓	✓	✓	✓	✓	✓	✓	High
Juarez-Lopez et al 2010[25]	✓	✓	✓	✓	✓	✓	✓	✓	High
Lara-Capi et al 2018[26]	✓	✓	✓	✓	✓	✓	✓	✓	High
Loyola-Rodriguez et al 2011[27]	✓	✓	✓	✓	✓	✓	✓	✓	High
Patiño-Marín et al 2018[28]	✓	✓	✓	✓	✓	✓	✓	✓	High
Ramirez-De los Santos et al 2020[29]	✓	✓	✓	✓	✓	✓	✓	✓	High
Sanchez-Perez et al 2010[30]	✓	✓	✓	✓	✓	✓	✓	✓	High
Serrano-Piña et al 2020[31]	✓	✓	✓	?	✓	✓	✓	✓	Unclear
Silva-Flores et al 2013[32]	✓	✓	?	?	✓	✓	✓	✓	Unclear
Vázquez-Nava et al 2010[33]	✓	✓	✓	✓	✓	✓	✓	✓	High
Zelocuatecatl-Aguilar et al 2005[34]	✓	✓	✓	✓	✓	✓	✓	✓	High
Zúñiga-Manríquez et al 2013[35]	✓	✓	?	✓	×	?	✓	✓	Low

Symbols: ✓, yes; ×, no;?, unclear.

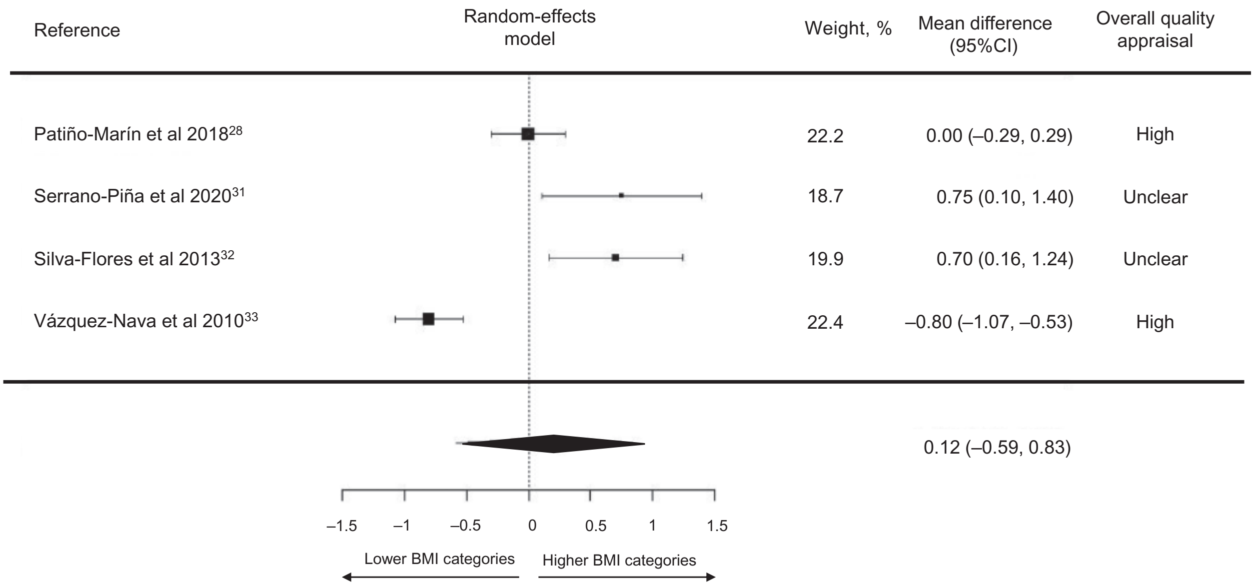

Figure 3 **Decayed extracted filled teeth index in primary teeth (*deft*) difference between children with lower or higher BMIs** (lower BMI categories, n = 1904; higher BMI categories, n = 1516; $I^2 = 92.37\%$). BMI, body mass index.

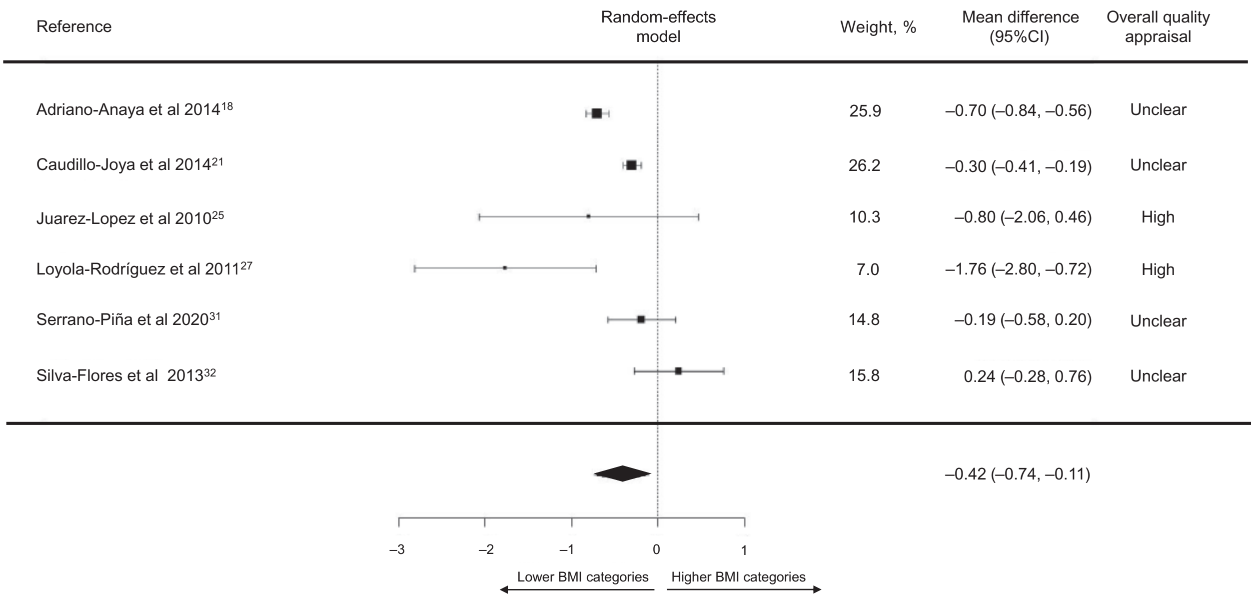

Figure 4 **Decayed Missing Filled Teeth Index in permanent teeth (DMFT) difference between children with lower or higher BMIs** (lower BMI categories, n = 6999; higher BMI categories, n = 4986; $I^2 = 85.92\%$). BMI, body mass index.

children and adolescents. Overall, the evidence was inconclusive and varied depending on the study's methods, appraised quality, the population included, sociodemographic factors considered, tools used to measure outcomes, and how such tools were used. According to pooled estimates, no differences in oral health (measured with the *deft* or DMTS indexes) were found between children with lower or higher BMIs. However, the pooled estimates of 6 of the 18 studies of high or unclear quality showed that children with higher BMIs (overweight or obesity) have worse oral health (measured with the DMTF Index) than children with lower BMIs (normal weight or underweight).

Some of the results of this review are in line with those presented in a recent meta-analysis by Chen et al.[9] For instance, no significant differences were found among BMI categories and oral health outcomes in primary teeth (*deft* Index). Nevertheless, for permanent teeth (DMFT Index), childhood overweight and obesity were related to poorer oral health and caries. However, Chen et al[9] suggested that this association was only found in high-income countries and did not include Mexican population data.

Some have suggested that nutrients such as vitamin A, vitamin D, calcium, or phosphate play crucial roles in teeth morphology, chemical composition, and eruption patterns.[37–40] Reduced consumption of these nutrients may affect the susceptibility of teeth to dental caries.[41] Although some micronutrient deficiencies might be produced, in part, by behaviors (eg, decreased outdoor activities because of social distress, which results in vitamin D deficiency), diet plays a crucial role in vitamin and mineral deficiencies. It is estimated that vitamin D deficiency affects 26% of preschoolers and approximately 37% of school-age children in Mexico.[42] Some suggest vitamin D intake is low among Mexican children, and this vitamin deficiency is also associated with overweight in school-age children.[42] Moreover, as shown in Figure 2, evidence for these observations comes from different areas of Mexico. The definition and composition of the diet consumed in Mexico can vary according to the geographical region.[43] Most of the country consumes maize and cereals as a base, but consumption of fish, vegetables, and fruits depends on the area.[43]

Some speculative biological and biomolecular causal pathways between BMI and oral health have been defined.[44] Some biomolecular theories suggest that because of the infection caused by dental caries, chronic inflammation can be present, affecting not only oral health but also could be linked to other health issues such as anemia, which could affect weight-related outcomes.[44] Physiological theories include a compromised ability to bite or chew foods in the presence of worst oral health or caries, which could lead to an altered BMI, because teeth with more severe lesions may have a higher impact while chewing and could affect the nutritional intake of some children.[44] Likewise, eating difficulties are more commonly reported in children with dental caries.[45,46]

The relation of body composition and oral health outcomes among children and adolescent is complex and multifactorial. Such a relationship may be bidirectional, because both might be perceived as exposure or outcome. It has been described that although overweight and obesity shared some causal factors with poor oral health outcomes (eg, high-sugar diets), there seem to be more factors influencing this association. Other studies have suggested that genetic or biological factors,[47] sedentary behaviors,[48] socioeconomic status,[49,50] lower parental education levels,[47] and food insecurity[51] might determine the development of both conditions (ie, obesity and poor oral health) in children.

Some methodological issues have also been highlighted when studying the relationship between obesity and oral health in children. For instance, age and sex might influence the results.[47,52,53] Because caries indexes represent a cumulative disease status, older groups may demonstrate a greater disease experience. This might be influenced by the differences in diet among age groups, the prevalence of dental caries over time, and the exfoliation of primary teeth.[54] The evidence in Mexico was inconclusive within and across different age groups (ie, ≤5 years, 6–12 years, and 13–18 years).

Some of the included studies reported relevant data from subanalyses. For instance, 1 study[25] found no association between BMI and the prevalence of caries. However, when analyzing per sex, girls had a higher risk of caries than did boys. Two other studies,[18,26] suggested that residence area (urban or rural) was associated with caries severity. In 1 study,[30] children with fewer economic resources had the worst oral health indexes. One reported the worst oral health outcomes in those adolescents with obesity and insulin resistance.[27] Likewise, only 3[23,26,33] of the 18 studies considered other lifestyles behaviors in the analysis. The authors of the 3 studies agree that caries prevalence was strongly associated with dietary (high-sugar consumption and bottle feeding) and hygiene (tooth brushing) factors. However, few included studies clarified if they adjusted their analysis to relevant confounders or considered other lifestyles in the analysis.

Furthermore, different obesity diagnosis standards were used among included studies, with some not reporting the standards used to classify participants' BMI. Some studies reported using international references (eg, WHO or International Obesity Taskforce), whereas others used references relevant to Latin America or the Mexican region. Although some studies used similar references, the cutoffs differed among some studies, as shown in Table 2. This is a major limitation, considering that the BMI classification and diagnosis of overweight or obesity could differ among references and alter the correlation with dental health. A systematic review and meta-analysis by Hayden et al[55] showed a significant association between obesity and dental caries when the BMI for age and sex percentile (using Centers for Disease Control and Prevention standards) were reported and no significant associations when z-scores (WHO standards) were reported. Nevertheless, in the analysis, those children and adolescents in the 2 highest BMI categories were considered, regardless of the anthropometric reference, similar to previous meta-analyses.[9]

Some other limitations of the present review include heterogeneity among included observational studies. For instance, a variety of tools were used to measure oral health (eg, *deft*, DMTS, DMTF indices), sample sizes (range, 40–6230 participants), and the quality appraisal across studies (only 55.5% were high quality). In addition, studies reported different age groups, data were presented for both girls and boys (only 1 study provided data per sex), and obesity was diagnosed with a mix of national and international BMI classification references, as we discussed previously. Consequently, insufficient studies were available to conduct a subgroup analysis. Also, the retrieved evidence was from 8 of 32 states in Mexico, so the results did not present a nationwide picture. This is relevant, considering that some lifestyles (eg, diet) might vary depending on the geographic region and setting (urban vs rural).

This work's strengths include an exhaustive search for evidence across 13 databases and 1 search engine performed in 2 languages, which helped us capture relevant publications. As part of the COMO project, an extensive search for gray literature was conducted, but no relevant information about oral health among Mexican children was identified.[12] This is important because recent meta-analyses and reviews have not considered data from Mexican children or adolescents.[5,8,9,56]

Mexico had led the implementation of different nationwide strategies to tackle obesity among the general population, which might also affect oral health outcomes. For instance, Mexico recently introduced a 1 peso/L excise tax on sugar-sweetened beverages.[57,58] More recently, implementing a front-of-pack labelling system has been achieved.[59] Still, effective and targeted efforts to identify vulnerable populations are needed in Mexico. In addition, different organizations, including WHO and the British Society of Paediatric Dentistry, are calling for more coordinated efforts to tackle both oral health issues (eg, caries) and obesity.[60,61] Although whether an association exists between BMI and oral health among Mexican children and adolescents remains inconclusive, health professionals involved in young people's care should consider individual, family, and environmental factors that might affect dental health and unfavorable BMI, because these are likely to have shared trails, such as diets with a high sugar content. More evidence is available on interventions to prevent[62] or treat[63] obesity among Mexican children and adolescents. However, understanding how development, dental caries, and nutritional status are linked could inform broader risk factor–based preventive strategies. Doing so could facilitate collaborative and multidisciplinary approaches among public health, nutrition, clinic, and dental specialists involved in children's and adolescents' care.

CONCLUSION

Although whether there is an association between oral health and high BMI in Mexican children and adolescents remains inconclusive, both conditions (ie, poor oral health and high BMI) coexist in this population. Therefore, health promotion and prevention efforts should address common risk factors and social determinants of broader risk shared with a number of other noncommunicable diseases.

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Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

Appendix S1 **Meta-analyses of specific body mass index (BMI) categories**

Figure S1 **DMFT between obesity and normal weight**

Figure S2 **DMFT between obesity and overweight**

Figure S3 **DMFT between obesity and underweight**

Figure S4 **DMFT between overweight and obesity and underweight**

Figure S5 **DMFT between overweight and obesity and normal weight**

Author contributions

M.A.-M. and C.F.M.-G. conceptualized and led the COMO project. All authors contributed significantly to the data collection, interpretation, and analysis; participated in the critical writing and revision of the article; and read and approved the versions submitted to the journal.

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Declaration of interest

MA-M, NLGF, DR, LL-C, MG-B, CFMG have no conflict of interest to declare. Y.Y.G.-G. received funding from Bonafont to present data at a congress in 2016 and funding from Abbott to write 2 book chapters in 2020. The other authors have nothing to declare.

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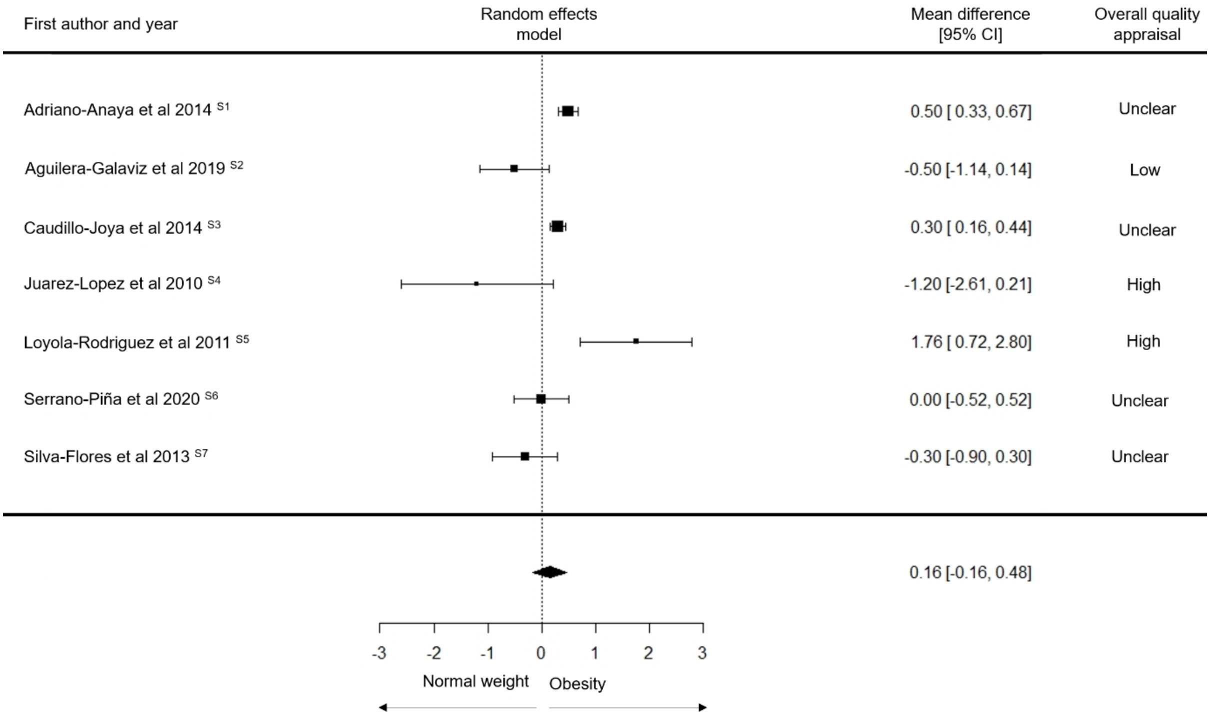
Appendix S1. Meta-analysis per different BMI categories.

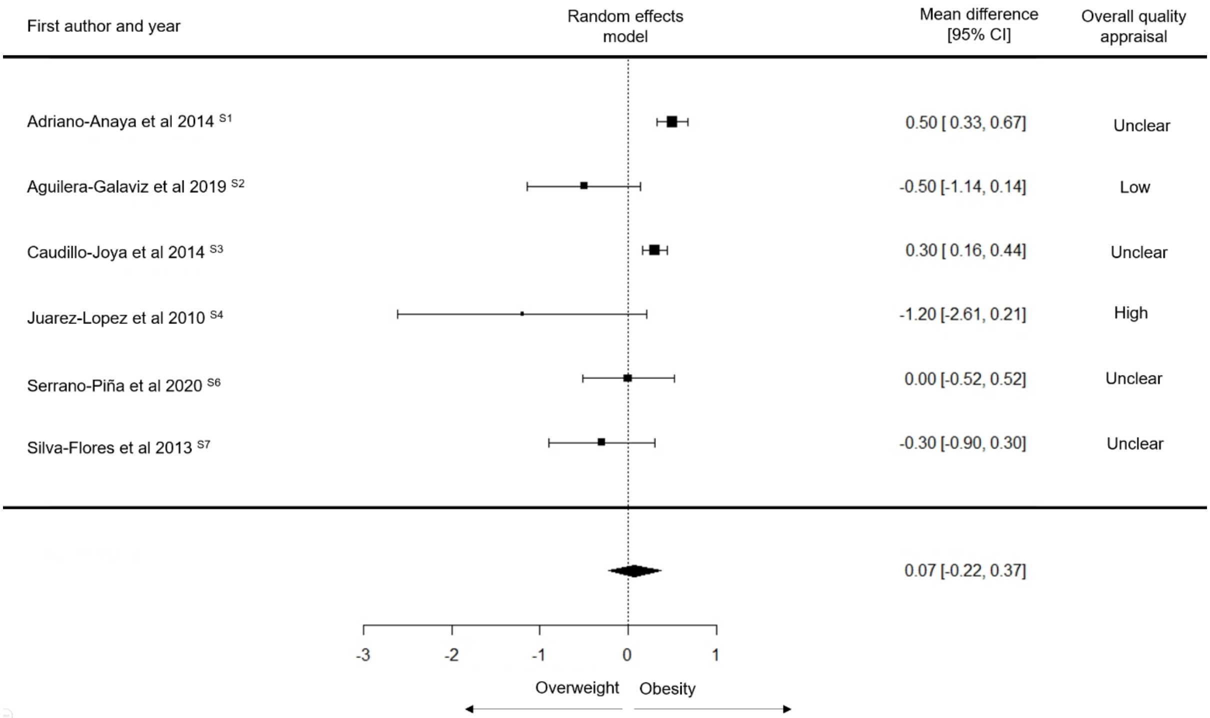
Supplementary Figure 1. DMFT between obesity vs normal weight



Results Summary:
Random-Effects Model (k = 7; tau^2 estimator: DL)
logLik deviance AIC BIC AICc
-8.0895 22.5836 20.1791 20.0709 23.1791
tau^2 (estimated amount of total heterogeneity): 0.1037 (SE = 0.1196); tau (square root of estimated tau^2 value): 0.3220; I^2 (total heterogeneity / total variability): 78.36%; H^2 (total variability / sampling variability): 4.62;
Test for Heterogeneity:
Q(df = 6) = 27.7229, p-val = 0.0001
Model Results:
estimate se zval pval ci.lb ci.ub
0.1573 0.1625 0.9684 0.3329 -0.1611 0.4758

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Supplementary Figure 2. DMFT between obesity vs overweight



Results Summary:

Random-Effects Model (k = 6; tau^2 estimator: DL)

logLik	deviance	AIC	BIC	AICc
-4.1560	15.2957	12.3119	11.8955	16.3119

tau^2 (estimated amount of total heterogeneity): 0.0754 (SE = 0.0915); tau (square root of estimated tau^2 value): 0.2746; I^2 (total heterogeneity / total variability): 75.51%; H^2 (total variability / sampling variability): 4.08

Test for Heterogeneity:

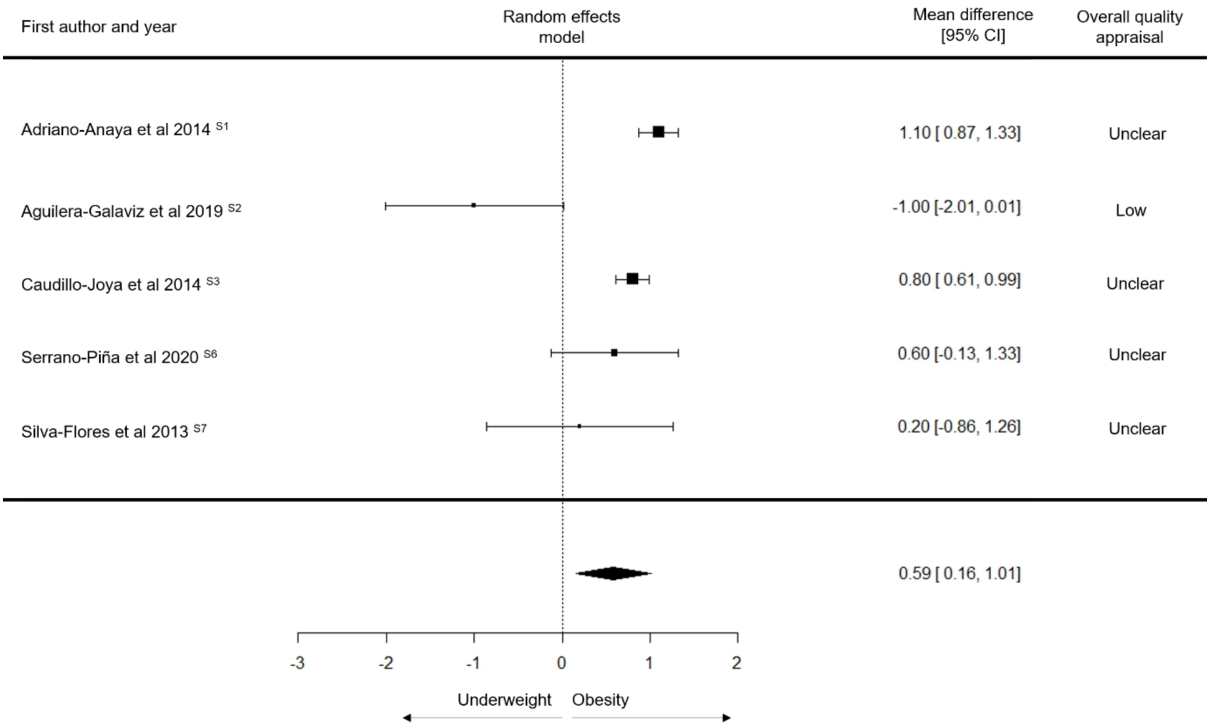
Q(df = 5) = 20.4144, p-val = 0.0010

Model Results:

estimate	se	zval	pval	ci.lb	ci.ub
0.0722	0.1502	0.4807	0.6307	-0.2221	0.3665

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Supplementary Figure 3. DMFT between obesity vs underweight



Random-Effects Model (k = 5; tau^2 estimator: DL)

```
  logLik deviance       AIC       BIC      AICc
 -5.4635   15.2914   14.9269   14.1458   20.9269
```

tau^2 (estimated amount of total heterogeneity): 0.1428 (SE = 0.1825); tau (square root of estimated tau^2 value):   0.3779; I^2 (total heterogeneity / total variability): 79.70%; H^2 (total variability / sampling variability): 4.93;

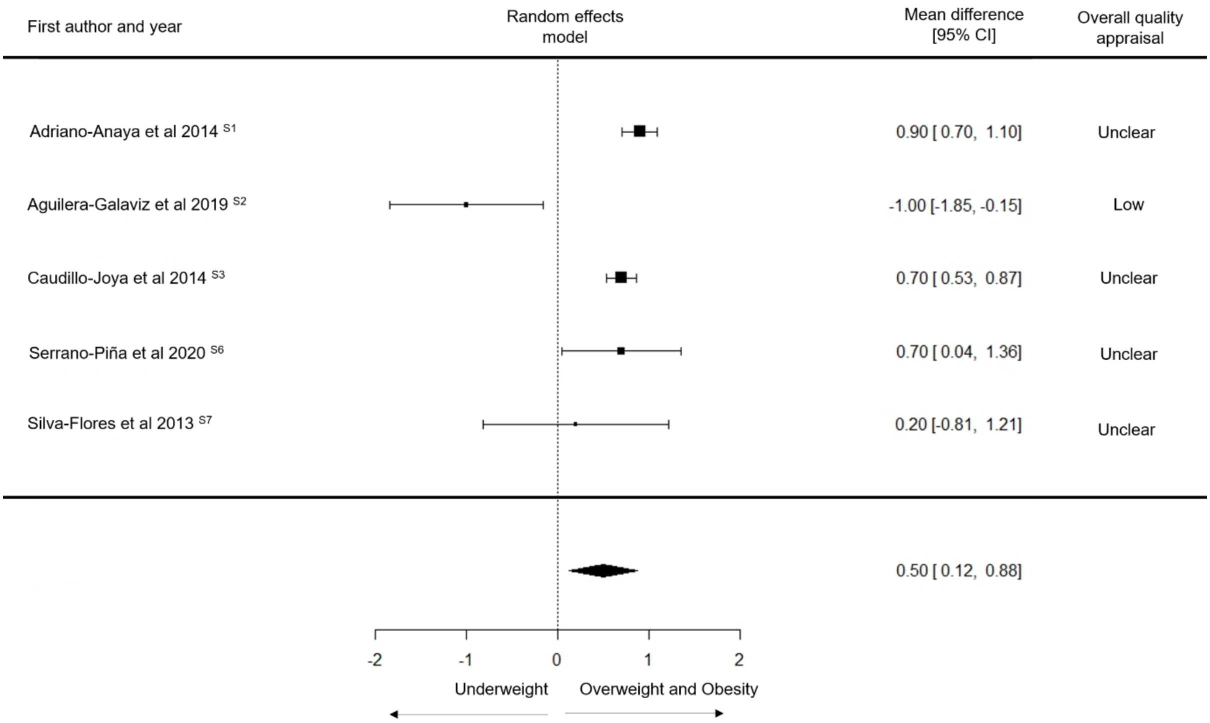
Test for Heterogeneity:

Q(df = 4) = 19.7025, p-val = 0.0006

Model Results:

```
estimate      se    zval    pval   ci.lb   ci.ub
  0.5854  0.2166  2.7023  0.0069  0.1608  1.0100  **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Supplementary Figure 4. DMFT between overweight and obesity vs underweight



Random-Effects Model (k = 5; tau^2 estimator: DL)

logLik	deviance	AIC	BIC	AICc
-5.4343	16.3938	14.8687	14.0875	20.8687

tau^2 (estimated amount of total heterogeneity): 0.1138 (SE = 0.1459); tau (square root of estimated tau^2 value): 0.3373; I^2 (total heterogeneity / total variability): 80.15%; H^2 (total variability / sampling variability): 5.04;

Test for Heterogeneity:

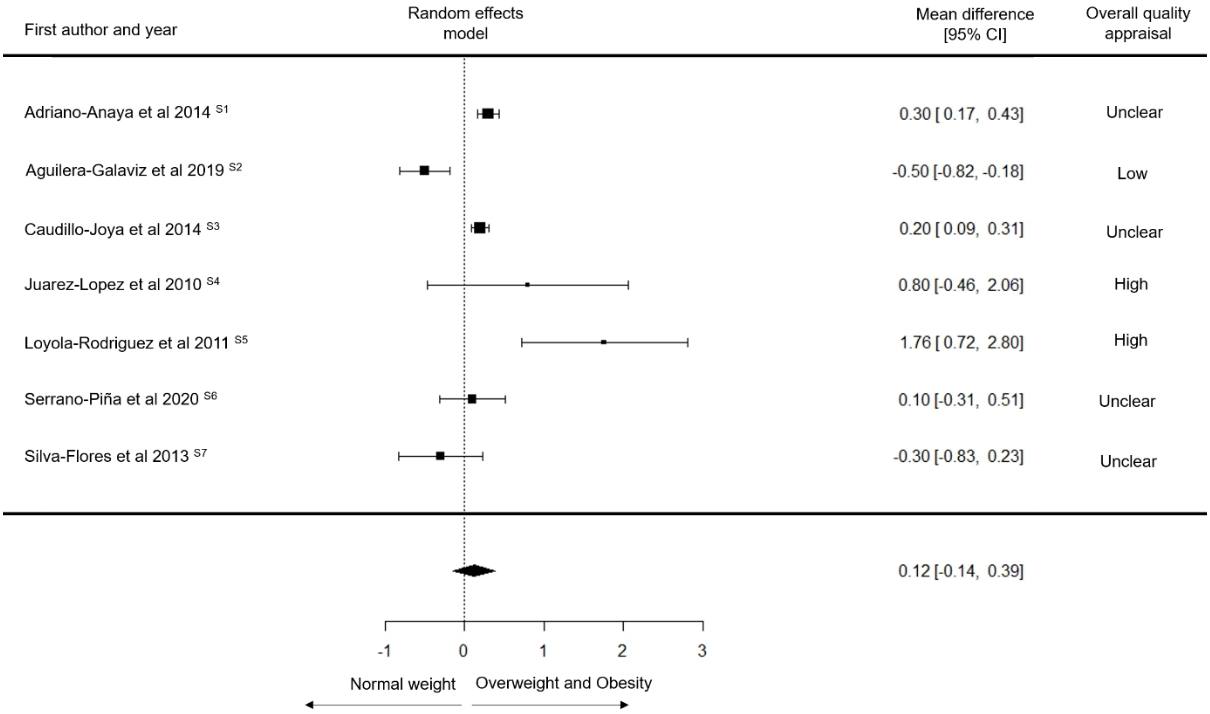
Q(df = 4) = 20.1545, p-val = 0.0005

Model Results:

estimate	se	zval	pval	ci.lb	ci.ub	
0.4995	0.1934	2.5824	0.0098	0.1204	0.8787	**

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Supplementary Figure 5. DMFT between overweight and obesity vs normal weight



Random-Effects Model (k = 7; tau^2 estimator: DL)

logLik	deviance	AIC	BIC	AICc
-6.8083	23.3552	17.6166	17.5084	20.6166

tau^2 (estimated amount of total heterogeneity): 0.0758 (SE = 0.0831); tau (square root of estimated tau^2 value): 0.2754; I^2 (total heterogeneity / total variability): 82.21%; H^2 (total variability / sampling variability): 5.62

Test for Heterogeneity:

Q(df = 6) = 33.7333, p-val < .0001

Model Results:

estimate	se	zval	pval	ci.lb	ci.ub
0.1225	0.1352	0.9061	0.3649	-0.1425	0.3875

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Supplementary References:

S1. Adriano Anaya MD, Caudillo Joya T, Juárez López ML, Caudillo Adriano PA. Obesidad y caries dental problemas de salud publica en una población escolar. International Journal of Odontostomatology. 2014;8(3):475-80.

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PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3-4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5, Table 1
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4-5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	3-4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	4
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5 & Figure 1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5-6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6-7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	6-7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	8
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	8 & Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	8-9 & Table 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	10 & Table 3
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Table 1
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	10-12 Figs. 3-6
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	NA
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	11 & Appendix 1
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	11
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	11
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	16-17
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097.