SYSTEMATIC REVIEW AND META-ANALYSIS

Early Childhood Caries and Weight Status: A Systematic Review and Meta-Analysis

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Abstract: ***Purpose:*** *The purposes of this study were to: (1) examine the association between body weight status and caries experience; and (2) determine if overweight or underweight children are at greater risk of developing early childhood caries.* ***Methods:*** *A search of studies in PubMed, Cochrane Library, and Google Scholar databases that tested the association of body weight with dental caries index in preschool children was conducted in April 2018. Studies' characteristics were extracted for the qualitative review, and means and standard deviations of decayed, missing, and filled teeth/surfaces (dmft/dmfs) index by body mass index standardized categories were retrieved for quantitative syntheses. Random effects meta-analyses were conducted by calculating the mean difference and the associated 95 percent confidence intervals.* ***Results:*** *A total of 293 studies were identified through the databases' search. Thirty-two qualified for qualitative review and 12 of them reported data to conduct a meta-analysis. The meta-analysis showed that overweight/obese children are at a statistically significant greater risk of having early childhood caries (P<0.01).* ***Conclusions:*** *The results of the included studies were inconsistent; however, the meta-analysis suggested that overweight/obese children are at greater risk of having early childhood caries.* *(Pediatr Dent 2019;41(4):261-70.E24-E25) Received December 9, 2018 / Last Revision April 30, 2019 / Accepted May 7, 2019*

KEYWORDS: EARLY CHILDHOOD CARIES, BODY MASS INDEX, OVERWEIGHT, UNDERWEIGHT, OBESITY

Dental caries is the most prevalent chronic health problem in children around the world.[1] Caries has been associated with frequent consumption of fermentable carbohydrates, and especially sugars that are popular in children.[2] Early childhood caries (**ECC**) is defined as "the presence of one or more decayed (cavitated or noncavitated), missing, or filled tooth surface in any primary tooth in a child 71 months of age or younger."[3] ECC is a public health concern because of both the short- and long-term effects it has on the quality of life of preschool children. More specifically, severe ECC has been found to affect a child's ability to eat, speak, grow, and socialize and cause varying degrees of pain.[4] In addition, it has been related with increased utilization of the emergency room, need for dental treatment under general anesthesia, frequent time of missing school, and increased cost of dental treatment.[3]

Higher carbohydrate intake has also been shown to increase the risk for obesity.[5] The Center of Disease Control and Prevention estimated that the prevalence of obesity was 18.5 percent, affecting approximately 13.7 million children and adolescents.[6] Studies show that, since the 1970s, the prevalence of obesity in children between the ages of two and five years old has more than doubled,[7] and approximately 10 percent of these children were at or above the 95th percentile for body mass index (**BMI**).[8] There are many different risk factors for the increasing prevalence of obesity, including genetics, physical activity, socioeconomic status (**SES**), and individual behavior.[9]

The strong association of dental caries and obesity with diet and sociopsychological factors suggests that a relationship may exist between the two diseases. However, current literature is inconclusive as to whether dental caries is associated with increased risk of being either overweight or underweight. Some studies suggest obese/overweight children are at greater risk of having high caries than normal weight children.[10-16] This finding is based on the fact that frequent intake of sugar-sweetened drinks and sugary foods, and frequent snacking between meals, can be risk factors both for dental caries and obesity.[17] By contrast, some other studies have shown that there may be a relationship between high caries and being underweight.[18-24] It is thought that caries may precede low weight in these situations, because of the pain these children experience as a result of severe decay, leading them to eat less food and, as a result, weigh less.[25,26] A systematic review and meta-analysis was recently conducted that aimed to investigate the association of dental caries and body mass weight in children and adolescents.[27] However, this systematic review reported results for children of all ages and not specifically in preschool years that are affected by ECC. Also, many dental caries studies in the primary dentition and body weight were published in 2017 and, thus, were not included in that systematic review.[22,28-31] ECC has some unique characteristics from the dental perspective, such as its clinical expression and association with maternal oral streptococci levels and nocturnal feeding with sugar-containing beverages.[3] Also, ECC affects preschool children whose weight status can have a significant effect in their development, particularly in cases of obesity or failure to thrive. Thus, a separate review is necessary to investigate the relationship of ECC to the body weight of preschool children.

The purposes of this study were to: (1) examine the association between body weight status and caries experience status; and (2) determine if overweight, obese, or underweight children are at a greater risk of developing early childhood caries compared to normal-weight children.

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Methods

This review was prepared following PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines.[32] The protocol for this systematic review was registered in the PROSPERO international register for systematic reviews (CRD42018114608). No other studies on this topic were registered in PROSPERO.

Eligibility criteria. Inclusion and exclusion criteria were specified prior to the study. No date or language restriction was applied during the search. Studies included in this systematic review and meta-analysis were required to: (1) have nonsyndromic preschool children (zero to six years old) as study participants; (2) report body weight; and (3) report caries experience index. Studies whose participants were older children in a mixed dentition, teenagers, and adults were excluded from analysis. Studies that were nondental caries-specific, did not include underweight and overweight groups, or investigated the effects of dental rehabilitation, educational programs, or malnourishment on weight were also excluded. Finally, review articles, systematic reviews, and authors' replies were not included in the analysis.

Search strategy. A literature search of PubMed, Google Scholar, and Cochrane databases was conducted by one author and checked by a second author in April 2018. MeSH terms used in the search included "early childhood caries," "body mass index," "overweight," "underweight," and "obesity." All articles identified in the search were included in the screening process after duplicate studies were excluded. The titles and abstracts of the articles were first screened for relevance. In cases where the title and abstract failed to provide sufficient information, the full text was reviewed to assess for relevance. To ensure that no relevant studies were missed in the initial search, the reference lists of the remaining articles were then hand-searched and subsequently screened. Additional studies identified through this process were added to the pool of full-text articles to be evaluated. This pool was then assessed for eligibility for both qualitative and quantitative review.

Data collection. Data items were extracted from each study by two authors and consisted of: (1) publication information (journal, title, authors, date, and country); (2) sample characteristics (sample size, age, and gender of the participants); (3) weight and caries indices used; and (4) qualitative and quantitative results. A Review Manager 5.3 software (Nordic Cochrane Centre, Copenhagen) data extraction form was used for this purpose. For the quantitative review, a BMI was used that standardized into categories of "underweight" (BMI-for-age percentile less than five), "normal weight" (BMI-for-age percentile between five and 85), "overweight" (BMI-for-age percentile between 85 and 95), and "obese" (BMI-for-age percentile greater than 95).[33] Regarding caries, the mean and standard deviation (±SD) of the reported decayed, missing, and filled teeth/surfaces (**dmft/dmfs**) index, was retrieved.

Risk of bias within studies. The National Institute of Health (**NIH**) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was used to assess risk of bias in individual studies.[34] Each study was assessed for clear presentation of the: (1) research question; (2) study population; (3) recruitment criteria; (4) justification of the sample's size; (5) different levels of the exposure of interest; (6) exposure measures and assessment; (7) existence of repeated measurements; (8) outcome measures; and (9) adjustment of cofounders. Four criteria of the tool were not included in the assessment, as all of the included studies were cross-sectional and these criteria would all be answered with a "no" or "nonapplicable." However, these criteria were included in the presentation of the risk of bias. Based on these criteria, two of the authors rated each study as good, fair, or poor. Studies rated as "poor" were considered to be of high risk for bias, while "good" rated studies were considered to be of low risk for bias.

Summary measures. The primary outcome measured was the mean difference of dmft/dmfs between the four different BMI categories. For studies that presented results in more BMI categories, the results were combined accordingly to the four BMI categories. I^2 test for homogeneity and chi-square test were used to assess heterogeneity between studies at the $P<0.10$ level. Random-effects meta-analyses were conducted by calculating the mean difference and the associated 95 percent confidence intervals (**CI**). All analyses were performed using Review Manager 5.3 software.

Risk of bias across studies. Publication bias was assessed using standard funnel plots. Quality assessment of the evidence of the meta-analysis for each outcome was performed using the Grading of Recommendations Assessment, Development, and Evaluation (**GRADE**) system.[35] The criteria were the study design, risk of bias, inconsistency, indirectness, imprecision, publication bias, and upgrading criteria such as effect magnitude, dose response, and plausible confounders. Based on these criteria, the quality of evidence for each one of the outcomes was evaluated as high, moderate, low, or very low.

Results

Study selection. A total of 293 articles were identified through the search of the databases (Figure 1). After removing six

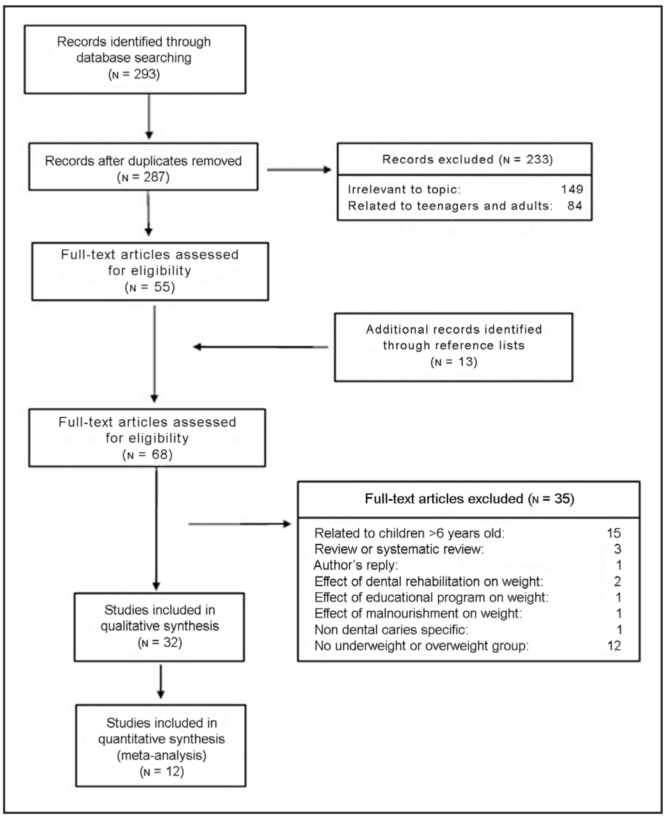

Figure 1. Flow diagram of study selection.

Table 1. CHARACTERISTICS OF INCLUDED STUDIES

Author	Date	Country	Participants	Outcome measures	Results
Miller et al.[26]	1982	UK	1,632 children (815 boys, 817 girls), mean age=5.9 years	Comparison of weight (Tanner's weight percentiles 1-3, 4-10, 11-25, 26-50, 51-75, over 75) with caries severity (needing extractions vs. needing restorations)	Children needing extractions (31.3% below 25^{th} percentile) weighted less than the group requiring dental restorations (17.1% below 25^{th} percentile) ($P<0.001$), most significant among girls
Acs et al.[18]	1992	USA	330 children (198 boys, 132 girls), mean age=3.2 years	Effect of ECC (dmft=0 vs. >0) on body weight (percentile categories <5, 5<x<10, 10<x<25, 25<x<50, 50<x<75, 75<x<90, >90)	ECC associated with lower weight ($P<0.005$); 8.7% of ECC children were underweight vs. 1.7% of caries-free children; underweight children with ECC were significantly older than normal weight children ($P<0.01$)
Ayhan et al.[20]	1996	Turkey	126 children (63 boys, 63 girls), mean age=4.0 years	Effect of ECC (dmft=0 vs. >0) on body weight percentile, height percentile and head circumference (cm)	ECC associated with lower weight and height ($P<0.001$); 7.1% of ECC children were underweight vs. 0.7% of caries-free children
Chen et al.[36]	1998	Taiwan	5,133 children (2,822 boys, 2,311 girls), 3 years old	Association between BMI percentile (>95^{th}, 75^{th}-95^{th}, 25^{th}-75^{th}, 5^{th}-25^{th}, <5^{th}) and caries prevalence (dmft index)	No statistically significant association between BMI and caries prevalence; caries prevalence: under-weight=56.8%, normal=55.4%, obese=50.9%
Reifsnider et al.[15]	2004	USA	104 children (59 boys, 45 girls), mean age = 1.4 years	Association between BMI and caries prevalence (dmft=0 vs. >0)	Children with a greater degree of caries experience tended to have higher BMI than those with less caries ($P<0.05$)
Macek et al.[45]	2006	USA	1719 children, age range = 2-5 years	Association between BMI ("underweight," "normal," "at risk of overweight," "overweight") and caries prevalence (dmft=0 vs. >0)	No statistically significant association between BMI-for-age and caries prevalence; caries prevalence: underweight=18.0%, normal=28.1%, at risk of overweight=26.9%, overweight=36.1%
Oliveira et al.[43]	2008	Brazil	1,018 children (519 boys, 499 girls), age range = 1-5 years	Association between nutritional status (WAZ, HAZ, WHZ, BMZ) social factors and caries prevalence (dmfs=0 vs. >0 and >6)	Children with lower weights were more prone to caries (OR=3.20) than higher weight children (OR=0.58) compared to normal weight children ($P=0.007$and $P=0.046$, respectively)
Floyd[47]	2009	New Zealand	577 children (298 boys, 279 girls), 6 years old	Association between BMI (kg/m2) and height with caries prevalence (dmft index) in two areas with different socioeconomic levels	ECC associated with lower BMI ($P=0.036$) in the low socioeconomic area, whereas no statistically significant association was found in the high socioeconomic area
Sheller et al.[37]	2009	USA	293 children (162 boys, 131 girls), mean age = 4.1 years	Association between BMI ("underweight," "normal," "at risk for being overweight," "overweight") and caries prevalence and severity (dmft index and number of pulp-involved teeth)	No statistically significant association between BMI and caries prevalence; caries prevalence: underweight=11%, normal=69%, at risk of overweight=9%, overweight=11%; underweight children had more pulp-involved teeth compared to normal weight children ($P=0.52$)
Ismail et al.[44]	2009	USA	788 children (372 boys, 416 girls), mean age=2.6 years	Association between weight percentile (0-26.9%, 27-56.4%, 56.7-84.2%, 84.3-100%) and other family-level factors with caries prevalence (dmfs=0 vs. 2<7, 3≥7)	Caries associated with higher body weight ($P=0.03$)
Gaur and Nayak[21]	2011	India	100 children (50 boys, 50 girls), mean age = 5.4 years	Effect of ECC (dmft=0 vs. >6) on growth parameters (BMI, weight, height, head circumference) and QoL in children from low socioeconomic families	ECC associated with lower weight ($P=0.011$); mean weight of ECC children was 15.5 vs. 16.3 of caries-free children; ECC children also had a lower QoL score, which improved after dental rehabilitation
Campos et al.[39]	2011	Brazil	491 children (232 boys, 259 girls), age range = 5 months-6 years	Spatial dependence between BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmft index)	No statistically significant association between caries and BMI; average dmft was 1.22±2.23, 9.4% were underweight, 59.5% were normal, 17.5% were overweight, 13.7% were obese

Table 1. CONTINUED

Author	Date	Country	Participants	Outcome measures	Results
Trikaliotis et al.[16]	2011	Greece	361 children (183 boys, 178 girls), mean age=4 years	Association between BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmfs index)	Overweight children had statistically significantly larger dmfs than normal weight (*P*<0.001) and underweight children (*P*=0.015); mean dmfs: underweight=1.02±2.41, normal=0.74±2.24, overweight=1.88±4.28, obese=0.80±2.53
Vania et al.[24]	2011	Italy	830 children (435 boys, 393 girls), mean age=4.6 years	Association between BMI ("underweight," "normal," "at risk for being overweight," "overweight") and caries prevalence (dmft=0 vs. >0, ECC categorized into non-cavitated lesions, cavitated lesions, and severe ECC)	Significantly, more children in the ECC group were underweight than in the control group (10% vs. 4.94%)
Norberg et al.[23]	2012	Sweden	920 children (466 boys, 454 girls), 5 years old	Association between BMI ("underweight," "low weight," "normal weight," "high weight," "obese") and caries prevalence (dmft index)	Higher caries prevalence in underweight (mean dmft=2.00) and light weight children (mean dmft=1.27) than normal weight children (mean dmft=0.65; *P*=0.010 and *P*=0.025, respectively)
Yen and Hu[38]	2013	Taiwan	329 children (175 boys, 154 girls), mean age=4.8 years	Association between BMI ("lean," "underweight," "normal," "overweight," "obese"), weight-to-height index (WHI), triceps skinfold thickness, body fat (%), and caries prevalence (dmft index)	The BMI (15.88±1.83 vs. 15.73±1.67), WHI index (0.99±0.14 vs. 0.97±0.13), body fat (16.87±4.50 vs. 16.44±4.51), and triceps skinfold (10.20±3.34 vs. 9.99±2.77) were not significantly different between the caries-free group and the caries group
Powell et al.[14]	2013	USA	215 children (119 boys, 96 girls), mean age=4.2 years	Association between BMI ("underweight/normal" vs. "overweight/obese") and caries prevalence (dmft=3-6, 7-10, >10)	Overweight children (*P*<0.001) had higher prevalence of caries than normal weight or underweight children
Bagherian and Sadeghi[10]	2013	Iran	400 children (211 boys, 189 girls), mean age=4.6 years	Association between BMI ("underweight," "normal," "at risk of overweight," "overweight") and caries prevalence (dmfs index)	Higher caries prevalence in overweight (mean dmfs=10.39) than normal weight children (mean dmfs=8.84) or underweight children (mean dmfs=4.89; *P*=0.001)
Bhoomika et al.[11]	2013	India	200 children (100 boys, 100 girls), age range=3-6 years	Association between BMI ("underweight," "normal," "at risk of overweight," "overweight") and caries prevalence (dmft=0 vs. >0)	ECC associated with higher BMI (*P*<0.05); 10% of ECC children were overweight vs. 3% of caries-free children
Costa et al.[40]	2013	Brazil	303 children (139 boys, 164 girls), mean age=5.7 years	Association between BMI ("severely thin," "thin," "adequate," " overweight," "obese") and caries prevalence (dmft=0 vs. >0 and >6)	No statistically significant association between caries and BMI; average dmft was 2.5±3.2, and mean BMI was 15.9±2.2
dos Santos et al.[42]	2014	Brazil	320 children, mean age=3.6 years	Association between BMI ("underweight," "normal," "overweight," "obese"), perinatal variables and family income with caries prevalence (dmft=0 vs. >0)	Prevalence of ECC was related to low family income, low birth weight, infant obesity, and shorter gestational age (*P*<0.05).
Rodriguez et al.[46]	2015	Argentina	60 children (30 boys, 30 girls), mean age=4.9 years	Association between BMI ("underweight," "normal," "overweight," "obese"), salivary flow, and caries risk (dmft=0 vs. >0)	Normal weight children more likely to have caries than overweight children (56.7% vs.37%)
Khanh et al.[48]	2015	Vietnam	593 children (304 boys, 290 girls), mean age=4.1 years	Association between weight, height and BMI with caries prevalence (dmft=0 vs. 1<5, >5) and mouth pain	ECC associated with lower BMI (*P*=0.006). Mean BMI of caries-free children was 1.27 vs. 0.82 of the ECC children and 0.62 of the severe ECC children
Aluckal et al.[19]	2016	India	433 children (218 boys, 215 girls), mean age=2.8 years	Association between BMI ("underweight," "normal," "at risk of overweight," "overweight") and caries prevalence (dmft index)	Higher caries prevalence in underweight (mean dmft=2.55) than normal weight children (mean dmft=1.72) or overweight children (mean dmft=1.86; *P*=0.0035)

Table 1. CONTINUED

Author	Date	Country	Participants	Outcome measures	Results
da Silva et al.[41]	2016	Brazil	65 children, age range=2-5 years	Association between BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmft index)	No statistically significant association between caries and BMI; average dmft was 6.2±4.4, and mean BMI was 16.5±2.5
Davidson et al.[12]	2016	Canada	235 children (118 boys, 117 girls), mean age=3.6 years	Association between BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmft=0 vs. >0)	ECC associated with higher BMI (P=0.038); 69.0% of ECC children were overweight vs. 56.8% of caries-free children
Pikramenou et al.[13]	2016	Greece	2,180 children (1,173 boys, 1,007 girls), mean age=4.2 years	Association between BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmfs index)	Overweight children (P<0.001) and obese children (P=0.008) were more likely to have higher dmfs than normal weight or underweight children.
Antunes et al.[28]	2017	Brazil	488 children (247 boys, 241 girls), mean age=3.5 years	Association of MTR and MTRR genes with BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmft index)	Higher caries prevalence in underweight (mean dmft=2.19) than normal weight children (mean dmft=1.33) or overweight children (mean dmft=0.90; P<0.05); also, MTTR was correlated with both ECC and low BMI
Krishna et al.[22]	2017	India	350 children (188 boys, 162 girls), age range=3-6 years	Association between BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmft index)	Trend of higher caries prevalence in underweight group (P=0.066); mean dmft: underweight=4.96±4.09, normal=4.62±3.35, overweight=2.73±1.90, obese=4.49±3.08
Madsen et al.[29]	2017	Greenland	373 children (185 boys, 188 girls), 6 years old	Association between BMI ("thin," "normal," "overweight," "obese") and caries prevalence (dmft/DMFT=0 vs. >0)	Trend of higher caries prevalence in overweight and obese children (P=0.063); caries prevalence: thin=50.0%, normal=55.5%, overweight=64.1%, obese=73.7%
Mitrakul et al.[30]	2017	Thailand	100 children (51 boys, 49 girls), mean age=4.2 years	Association between BMI ("underweight," "normal," "overweight," "obese") and caries prevalence (dmft index)	No association between dmft scores and BMI (P=0.157); mean dmft: underweight=3.00±4.24, normal=5.77±4.87, overweight=4.20±4.43
Soares et al.[31]	2017	Brazil	285 children (131 boys, 154 girls), mean age=4.2 years	Effect of masticatory function, socio-economic status and dental caries (dmft index) on BMI ("underweight," "ideal," "overweight/obese")	Children with a greater degree of caries experience tended to have lower BMI than those with less caries (P=0.04)

* ECC=early childhood caries; dmft=decayed, missing, filled teeth; dmfs=decayed, missing, filled surfaces; BMI=body mass index; OR=odds ratio, WAZ=weight for age; HAZ=height for age; WHZ=weight-height for age; BMZ=body mass index for age; QoL=quality of life; WHI=weight-height index; MTR=5-methyltetrahydrofolate-homocysteine methyltransferase; MTRR=5-methyltetrahydrofolate-homocysteine methyltransferase reductase.

duplicate studies and 149 studies irrelevant to the topic or 84 related to children over the age of six years and adults, a total of 55 studies were considered for full-text assessment. Few studies were published in a language other than English and were excluded after translation of their title or abstract, as they did not fulfill other criteria. Another 13 studies were added from hand searching the reference lists of the full-text articles. Following full-text evaluation, 32 studies were included for qualitative assessment but only 12 provided sufficient data in the article that qualified for quantitative synthesis. Of these 12 studies, three presented results using the dmfs index[10,13,16] and were analyzed separately from the remaining nine studies that used the dmft index.[19,22,23,28,30,31,36-38]

Qualitative analysis: study characteristics. All included studies were cross-sectional and published between 1982 and 2017 (Table 1). A trend for more studies on the topic in the last 10 years was noted, as 27 of the 32 selected studies were published from 2008 onward. Most studies originated from Brazil,[28,31,39-43] India,[11,19,21,22] and the United States[14,15,18,37,44,45]; European countries have also published data on this topic[13,16,23,24,26] (Table 1).

The median sample size of the included studies was 355, and most had a sample of 100 to 500 children (Table 1). Five studies had a sample of 100 children or less,[11,21,30,41,46] six studies had a sample of 500 to 1,000 children,[23,24,29,44,47,48] and four studies had more than 1,000 children included in the study.[13,24,36,43] The total number of participants in all studies included in the systematic review was 21,351 patients; 11,272 of them were included in the meta-analysis. All studies included children of both genders, 47.13 percent of the participants were boys and 43.01 percent of them were girls. The percentages including only data from the studies of the meta-analysis were 53.47 percent and 46.53 percent, respectively. The age range of the participants varied from five months to six years old, and the mean age was 4.22 years.

Regarding the outcome tested, most studies examined the association between BMI and caries experience (Table 1). Five studies tested the association of different or additional growth parameters besides BMI.[38,43,44,47,48] Four studies tested the effect of ECC on body weight and growth parameters,[18,20,21,31] and six studies included the SES level of the family in the analysis.[21,31,42-44,47] Fifteen studies compared growth parameters in children with caries and caries-free children,[11,12,15,18,20,21,24,29,40,42-46,48] one study compared children in need of extractions versus dental rehabilitation due to caries,[26] and the remaining 16 studies used the dmft/dmfs index for caries experience. Eight studies took into consideration the severity of dental caries in their analysis.[14,24,26,37,40,43,44,48]

Risk of bias within studies. Overall, 14 studies were assessed as good with low risk of bias, 16 as fair with moderate risk of bias, and two as poor with high risk of bias based on the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. The percentages of compliance for each item of the quality assessment tool across all included studies are presented in Figure 2. More specifically, the assessment on three criteria (exposure assessed prior to outcome measurement, sufficient timeframe to see, and effect and blinding of outcome assessors) indicated high risk of bias, as all of the included studies were cross-sectional and these criteria were answered with a "no" (i.e., 100 percent red columns, Figure 2; one criterion (follow-up rate) was answered as "non-applicable," indicating unclear risk of bias (i.e, 100 percent yellow, Figure 2). Of the other criteria, all of the studies presented the research question and the study population, most of them presented the recruitment criteria, different levels of exposure, exposure measures, and outcome measures decreasing the risk of bias. The criteria that increased the risk of bias of the included studies were the lack of presentation of the participation rate, sample justification, repeated exposure assessment, and statistical analyses used.

Results of individual studies. Eleven studies indicated that underweight children have more caries,[18-24,26,28,31,43,48] 11 studies found a nonsignificant difference in caries experience between overweight and underweight children,[29,30,36-41,45-47], and nine studies indicated that overweight/obese children have more caries[10-16,42,44] (Table 1). Also, the association between ECC prevalence and being underweight was found more significant in older children[18] and girls.[26]

Quantitative analysis: synthesis of the results. The outcome of interest was tested using the dmf index in two different ways of assessment: that of the number of teeth (dmft) affected and that of the number of carious surfaces (dmfs). Both syntheses consisted of comparisons between the different BMI groups. Of all the studies that were included in the meta-analysis, 10.57 percent of the participants in total were considered underweight, 68.09 percent were considered normal, 15.05 percent were considered overweight, and 6.28 percent were considered obese. Based on the results of the nine studies that used the dmft index,[19,22,23,28,30,31,36-38] overweight/obese children are at a statistical significant greater risk of having ECC (Figure 3). No

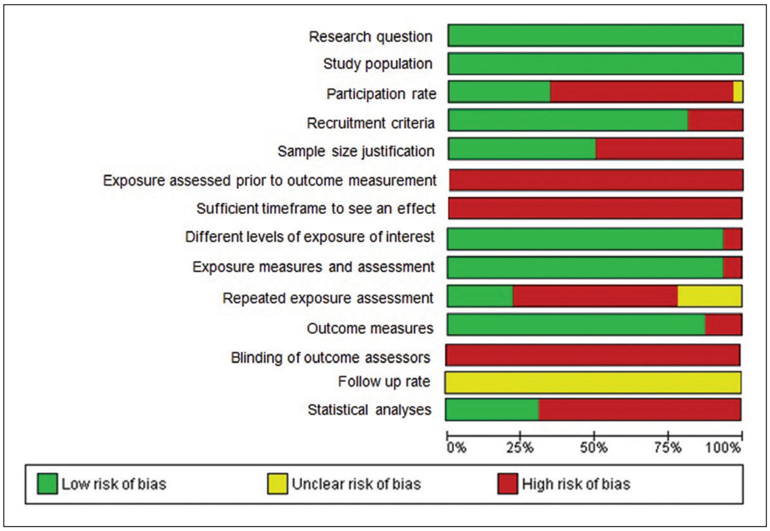

Figure 2. Risk of bias within studies. Percentages of compliance for each item of the NIH quality assessment tool across all included studies. The criteria answered with a "no" are presented with red indicating high risk of bias. The criteria answered as "nonapplicable," are presented with yellow indicating unclear risk of bias.

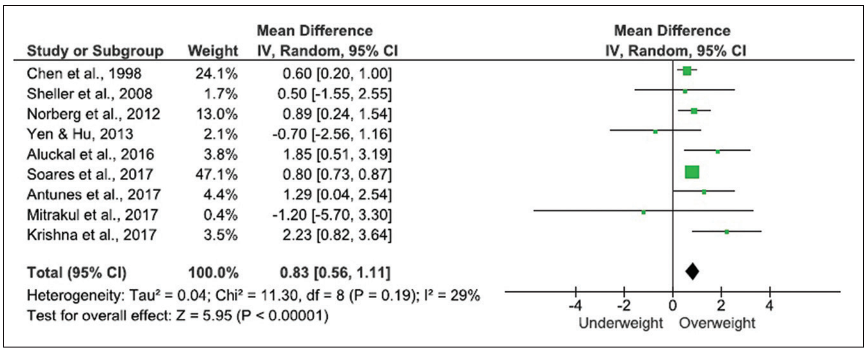

Figure 3. Forest plot comparing the decayed, missing, and filled teeth (dmft) index between overweight and underweight zero- to six-year-olds.*

* df=degrees of freedom; CI=confidence interval.

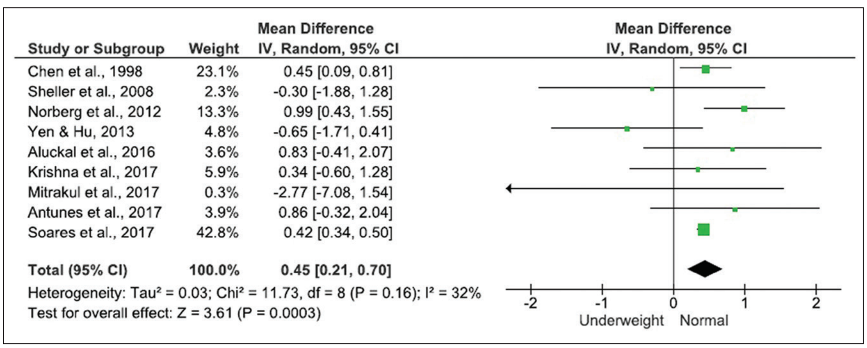

Figure 4. Forest plot comparing the decayed, missing, and filled teeth (dmft) index between normal and underweight zero- to six-year-olds.*

* df=degrees of freedom; CI=confidence interval.

statistically significant heterogeneity was found on this synthesis (overweight: I^2 equals 29 percent, P=0.19; obese: I^2 equals zero percent, P=0.96; Figure 3). The comparison between children with normal BMI and underweight or overweight children was also found statistically significant (Figures 4 and 5), indicating that children with higher weight are at greater risk of having ECC. More specifically, underweight children (N equals 806) have a significantly lower dmft index than normal weight children (N equals 5,653; mean difference equals 0.45, 95 percent CI [**95% CI**] equals 0.21,0.70, P<0.001, I^2 equals 32 percent; Figure 4). Overweight children (N equals 1,338) have a significantly higher dmft index than normal weight children (N equals 5,653; mean difference equals -0.39, 95% CI equals -0.64 to -0.14, P=0.002, I^2 equals 62 percent; Figure 5). Obese children (N equals 529) have similar dmft index to normal weight children (N equals 5,486; mean difference equals -0.07, 95% CI equals -0.31 to 0.17, P=0.57, I^2 equals zero percent; Figure 6). Underweight children (N equals 806) have a significantly lower dmft index than overweight children (N equals 1,338; mean difference equals 0.83, 95% CI equals 0.56 to 1.11, P<0.01, I^2 equals 29 percent; Figure 3). Finally, underweight children (N equals 707) have a significantly lower dmft index than obese children (N equals 529; mean difference equals 0.62, 95% CI equals 0.27 to 0.97, P<0.001, I^2 equals zero percent; see **Electronic Appendix: Figure 7**).

Considering the results of the three studies assessing caries with the dmfs index,[10,13,16] no difference was found on the ECC prevalence between overweight/obese and underweight children (see **Electronic Appendix: Figures 8 and 9**). No significant statistical heterogeneity was evident on the synthesis of the overweight versus underweight comparison (I^2 equals 54 percent, P=0.11; Figure 8). However, statistically significant heterogeneity was detected on the synthesis between the obese and underweight group (I^2 equals 82 percent, P<0.05; see **Electronic Appendix: Figure 9**). The comparison between the normal weight children and the other three groups was not statistically significant either. More specifically, the dmfs index did not differ between underweight children (N equals 385) and normal weight children (N equals 2019; mean difference equals -0.23, 95 percent CI equals -1.15 to 0.69, P=0.62, I^2 equals 73 percent; see **Electronic Appendix: Figure 10**), overweight children (N equals 358), and normal weight children (N equals 2019; mean difference equals 0.14, 95% CI equals -0.12 to 0.41, P=0.28, I^2 equals zero percent; see **Electronic Appendix: Figure 11**), or obese children (N equals 179) and normal weight children (N equals 2019; mean difference equals 0.35, 95% CI equals -0.09 to 0.79, P=0.12, I^2 equals zero percent; see **Electronic Appendix: Figure 12**). Also, dmfs did not differ between underweight (N equals 385) and overweight children (N equals 358) (Mean difference equals -0.77, 95% CI equals -2.14 to 0.60, P=0.27, I^2 equals 54 percent), or between underweight (N equals 385) and obese children (N equals 179; mean difference equals -1.73, 95% CI equals -3.57 to 0.83, P=0.22, I^2 equals 82 percent; see **Electronic Appendix: Figures 8 and 9**).

Risk of bias across studies. Statistically significant heterogeneity on the syntheses related to the research questions was only found for the dmfs studies comparing the underweight and obese groups (I^2 equals 82 percent, P<0.05; see **Electronic Appendix: Figure 9**). However, publication bias could not be evaluated, as there were only three studies combined in this synthesis, and for this reason, no funnel plots are presented.

Based on the GRADE assessment, the quality of evidence for the meta-analysis using dmft index was found to be moderate (see **Electronic Appendix: Table 2**), while the evidence for the dmfs index was assessed to be of very low quality (see **Electronic Appendix: Table 2**).

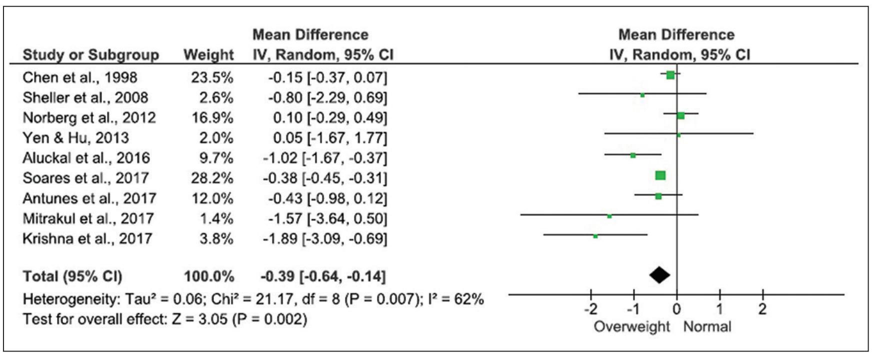

Figure 5. Forest plot comparing the decayed, missing, and filled teeth (dmft) index between normal and overweight zero- to six-year-olds.*

* df=degrees of freedom; CI=confidence interval.

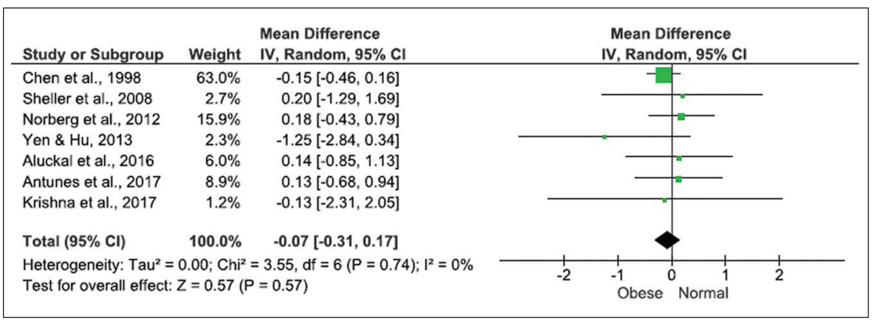

Figure 6. Forest plot comparing the decayed, missing, and filled teeth (dmft) index between normal and obese zero- to six-year-olds.*

* df=degrees of freedom; CI=confidence interval.

Discussion

The results of the present meta-analysis suggest that overweight and obese preschool children are at greater risk of having early childhood caries. However, this finding should be interpreted with caution due to the risk of bias of cross-sectional studies. The present study followed the PRISMA guidelines, in contrast to previous systematic reviews, and was the only one registered in the PROSPERO database on this topic. Studies that follow the PRISMA guidelines and are registered in PROSPERO have been found to be of higher quality,[32, 49] which is one of the strengths of the present study.

The purpose of the study was to test the association of caries and body weight in preschool children. Previous systematic reviews have tested this association in older children and adolescents.[27,50,51] However, ECC has unique characteristics both from a clinical and etiologic perspective and may have severe consequences in the child's development. More specifically, ECC has been associated with an increased risk for caries in the permanent dentition, increased need for treatment under general anesthesia, and failure to thrive.[3] For this reason, only studies reporting separate data for preschool children were included in this systematic review, whereas, studies that included older children, teenagers, and adults were excluded from analysis. Also, many studies have tested the association of being obese/overweight with caries[51] or compared underweight or overweight children with normal weight children individually.[27] However, the purpose of this review was to test if children with ECC are at higher risk of being overweight or underweight. Thus, only studies that included both underweight and overweight groups were included in the present review.

For assessment of the risk of bias, we used the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies[34] as all of the included studies had a cross-sectional design. Although this is an accredited tool to assess risk of bias of cross-sectional studies, this design by default has an increased risk of bias.[52] Also, quality assessment of the outcomes was performed using the GRADE tool, which is considered important to evaluate the quality of the evidence presented in each meta-analysis.[35]

The results of the included studies in the qualitative analysis were inconsistent, as 11 studies indicated that underweight children have more caries,[18-24,26,28,31,43,48] 11 studies found a nonsignificant difference in caries experience between overweight and underweight children,[29,30,36-41,45-47] and nine studies indicated that overweight/obese children have more caries,[10-16,42,44] (Table 1). This heterogeneity between studies has also been reported in previous systematic reviews[50,51] and could be associated with the multiple confounding factors that influence both ECC and body weight.

Although this systematic review included only studies with preschool children, the age of the participants varied between them. One study reported that older children with high caries experience were underweight.[18] In addition, other studies also reported that children with severe ECC and pulp-involved teeth were at higher risk of being underweight.[26,37] It is known that caries experience increases with age and can be assumed that, if left untreated, could result in pain and less food consumption. Thus, studies that included older preschoolers may report higher association of ECC with being underweight whereas studies with younger participants may report an association of ECC with being overweight or obese.

Another confounding factor that can explain the discrepancies between the studies is the SES level of the participants. It has been found that both ECC and obesity increase in children with low SES family level.[53] Thus, based on the SES level of the participants in different studies, the results may vary. Most of the studies that included the SES in their analysis found that children of low SES were underweight and had higher levels of ECC.[21,31,47] Also, culture and race can have an effect on the body weight and caries as a result of genetic and environmental factors.[54,55] The studies selected in this systematic review originated from 15 different countries and, as a result, the findings for each study may vary due to cultural and racial differences.

The meta-analysis of the three studies[10,13,16] that used the dmfs index did not find any differences in ECC prevalence between overweight and underweight children. This finding could be attributed to the different confounding factors, as explained earlier. However, this analysis presented some heterogeneity, which could not be explored further as only three studies were included. Also, based on the GRADE assessment, the evidence of this synthesis was found of low quality and, thus, cannot be trusted to derive any conclusions.

The results of the meta-analysis of the nine studies[19,22,23,28,30,31,36-38] that used the dmft index found that overweight/obese children are at a significantly greater risk statistically of having ECC. Based on the GRADE assessment, the evidence of this synthesis was found to be of moderate quality, suggesting this outcome more trustworthy. Similar results have been found in the secondary analyses of a previous systematic review.[27] ECC has been strongly correlated with specific feeding practices, such as nocturnal bottle feeding with sugar-containing drinks such as milk, formula, and juice.[3] Obesity has also been associated with consumption of sugar-sweetened beverages in addition to high fat diet and less exercise.[7] In addition, both obesity and ECC are considered chronic diseases of multifactorial etiology that have severe public health effects.[56] More specifically, they are both associated with low SES level and result in increased medical costs.[3,53,56] Besides the common ground in the etiology of these two diseases, the association found in this study can help develop public health programs and strategies that will target both ECC and obesity. This way, the cost can be diminished while the effectiveness and target population increases.

One of the limitations of the present study is the inclusion of cross-sectional studies, which are considered of lower quality as they present higher risk of bias and lower the quality of evidence. Another limitation is the fact that studies varied in regard to the sample's SES, age, culture, and other aspects that could be considered confounding factors. Also, the sample size varied significantly among the studies as well as the index used for reporting body weight, BMI, and caries.

The results of this systematic review and meta-analysis suggest that longitudinal studies that will examine the growth parameters and caries in different intervals are necessary in order to draw stronger conclusions. Also, the association that was found between overweight children and ECC suggests that public health programs targeting ECC and obesity are necessary and can help prevent these two diseases with less cost.

Conclusions

1. The results of the included studies from the current literature were inconsistent.
2. The present meta-analysis suggests that overweight and obese preschool children are at greater risk of having early childhood caries.
3. However, this finding should be interpreted with caution, as all of the included studies were cross-sectional, presented moderate quality of evidence, and have a relatively high risk of bias.

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Supplemental Electronic Appendix

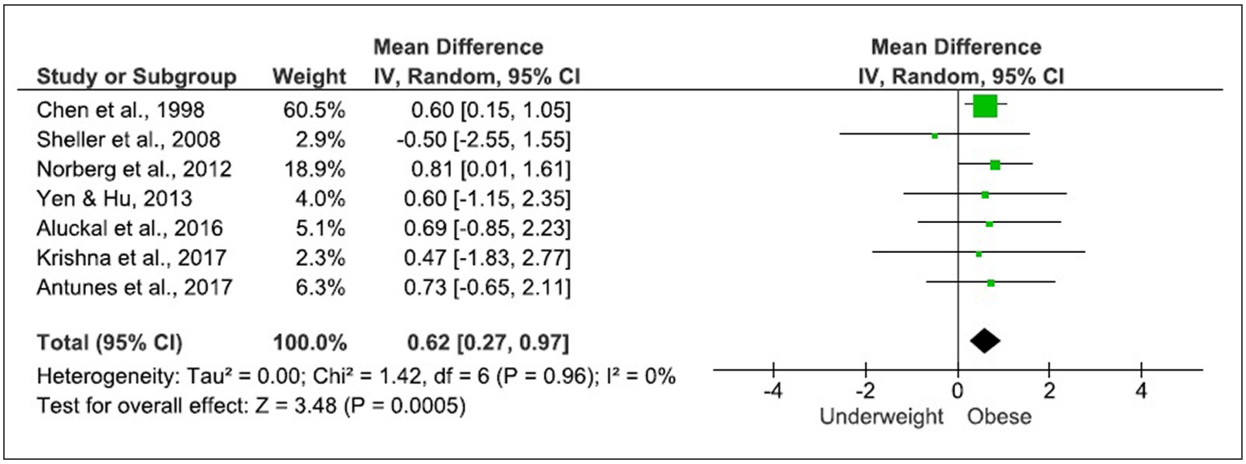

Figure 7. Forest plot comparing the decayed, missing, and filled teeth (dmft) index between underweight and obese zero- to six-year-olds.*
* df=degrees of freedom; CI=confidence interval.

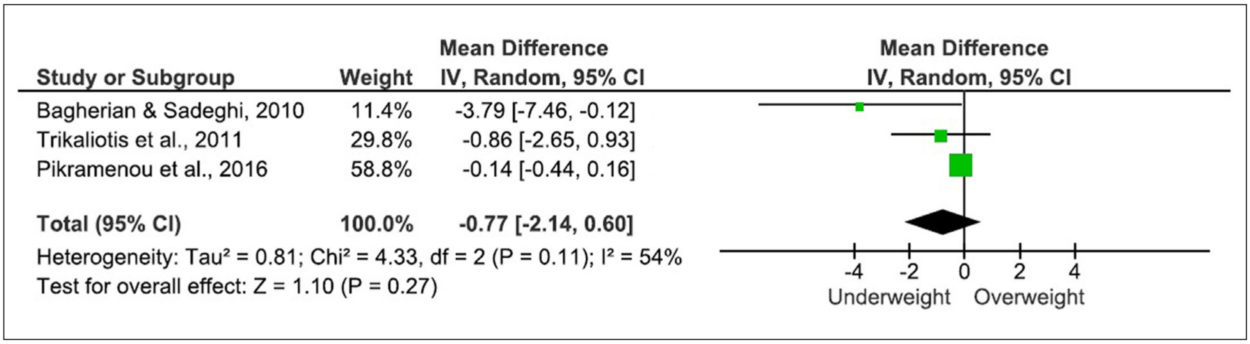

Figure 8. Forest plot comparing the decayed, missing, and filled surfaces (dmfs) index between overweight and underweight zero- to six-year-olds.*
* df=degrees of freedom; CI=confidence interval.

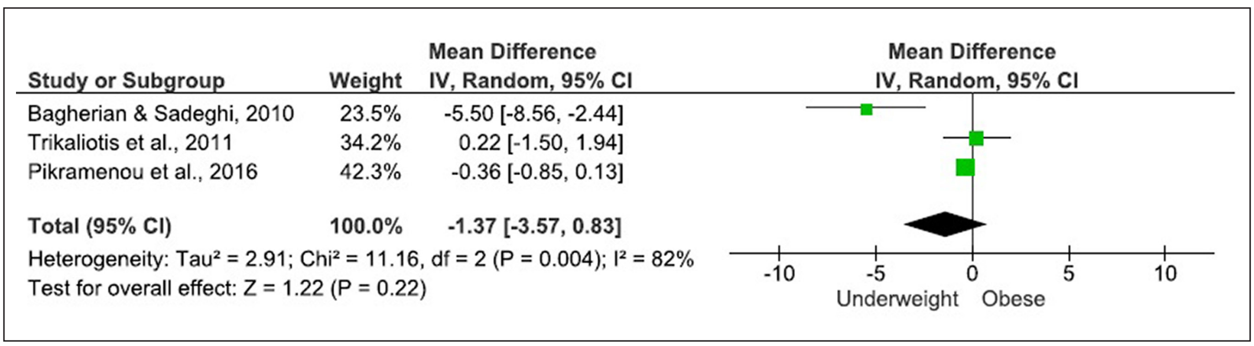

Figure 9. Forest plot comparing the decayed, missing, and filled surfaces (dmfs) index between underweight and obese zero- to six-year-olds.*
* df=degrees of freedom; CI=confidence interval.

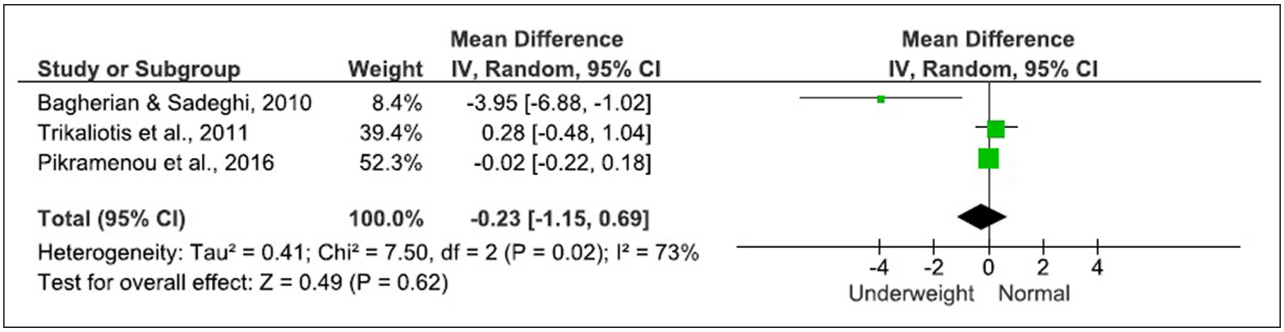

Figure 10. Forest plot comparing the decayed, missing, and filled surfaces (dmfs) index between normal and underweight zero- to six-year-olds.*
* df=degrees of freedom; CI=confidence interval.

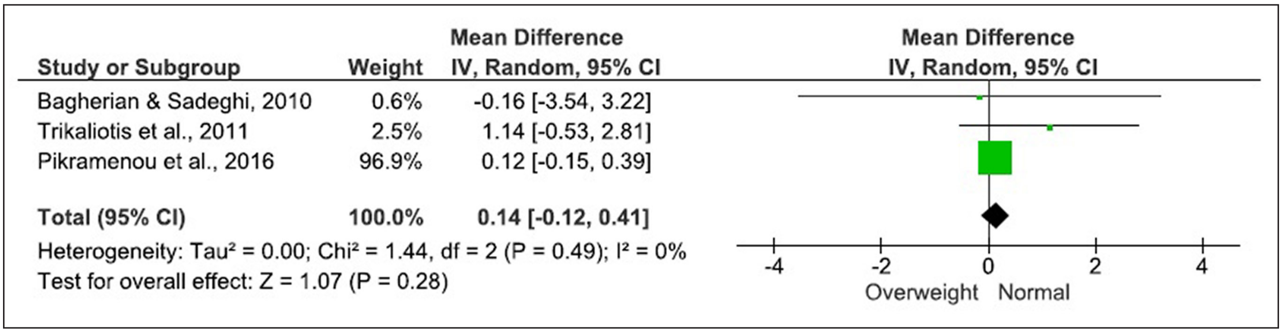

Figure 11. Forest plot comparing the decayed, missing, and filled surfaces (dmfs) index between normal and overweight zero- to six-year-olds.*
* df=degrees of freedom; CI=confidence interval.

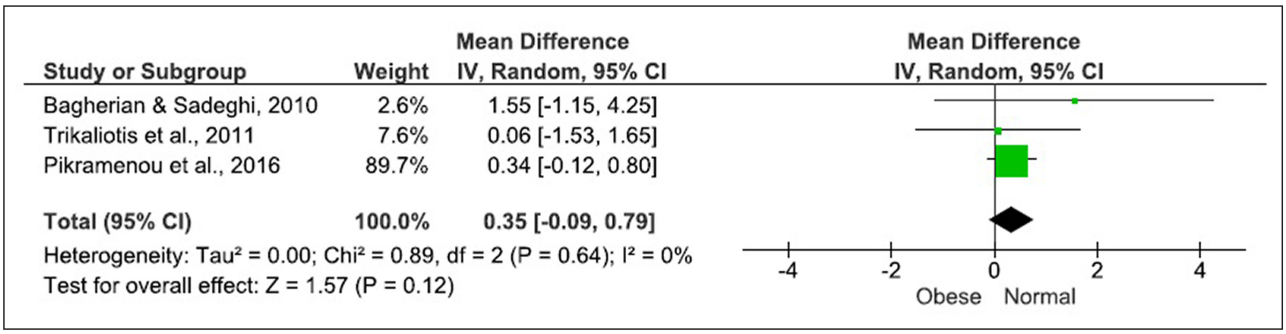

Figure 12. Forest plot comparing the decayed, missing, and filled surfaces (dmfs) index between normal and obese zero- to six-year-olds.*
* df=degrees of freedom; CI=confidence interval.

Table 2. OUTCOME QUALITY OF EVIDENCE OF THE META-ANALYSIS USING THE GRADE SYSTEM *

No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Other	Quality
Outcome: dmft higher in overweight children compared to underweight children								
9	Cross-sectional	Serious (3 of the 9 studies were evaluated with moderate risk)	Not serious	Not serious	Not serious	Undetected	No plausible confounding	Moderate
Outcome: dmfs higher in overweight children compared to underweight children								
3	Cross-sectional	Very serious (all 3 studies were evaluated with moderate risk of bias)	Serious (I^2=56%)	Not serious	Not serious	Strongly suspected	—	Very low

* dmft= decayed, missing, filled teeth; dmfs=decayed, missing, filled surfaces.