abstract

BACKGROUND AND OBJECTIVE: Dental caries in young children is commonly untreated and represents a public health problem. Dental caries in children is reported to affect their anthropometric outcomes, but the evidence is conflicting. Some studies found no association, whereas others found that caries was associated with underweight or overweight. The objective was to assess the relationship between dental caries status and height and weight in 6- to 8-year-old Saudi children with high caries prevalence.

METHODS: This study was a cross-sectional survey in schoolchildren aged 6 to 8 years attending military primary schools in Jeddah, Saudi Arabia. Caries status was assessed by using the dmft (decayed, missing, filled, teeth [primary teeth]) index. Height and weight were assessed by using z scores of height-for-age (HAZ), weight-for-age (WAZ), and BMI-for-age (BAZ) calculated by World Health Organization standardized procedures. Relationships between caries and HAZ, WAZ, and BAZ were assessed by using regression models.

RESULTS: A total of 417 of the 436 eligible schoolchildren with complete data were included, with a response rate of 95.6%. Their mean dmft index was $5.7 \pm 4.2$. There was an inverse linear relationship between caries status and children’s HAZ, WAZ, and BAZ and significantly lower anthropometric outcomes for children at each consecutive group with higher levels of caries. The associations remained significant after adjusting for dental, social, and demographic variables.

CONCLUSIONS: The inverse linear association between dental caries and all anthropometric outcomes suggests that higher levels of untreated caries are associated with poorer growth in Saudi schoolchildren. Pediatrics 2014;133:e616–e623

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Key words: height, weight, BMI, children, caries

Abbreviations

- BAZ—BMI-for-age
- dmft—decayed, missing, filled, teeth (primary teeth)
- HAZ—height-for-age
- WAZ—weight-for-age
- WHO—World Health Organization

Dr Alkarimi conceptualized and designed the study, carried out the analyses, and drafted the initial manuscript; Drs Watt and Sheiham conceptualized and designed the study and reviewed and revised the manuscript; Dr Pikhart contributed to the study design and data analysis and interpretation and reviewed and revised the manuscript; Dr Tsakos conceptualized and designed the study, contributed to data analysis and interpretation, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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There is increased interest in the relationship between caries and growth in young children and mechanisms whereby caries may affect growth. Evidence linking caries in primary teeth and children’s anthropometric outcomes in cross-sectional studies is contradictory in terms of both the presence and the direction of the association. Some studies report a relationship between caries and poor growth.1–9 Two theories may explain this relationship (Fig 1). The first theory is that the direct impact of extensive untreated caries and associated pain and inflammation on the child’s ability to eat may result in undernutrition and growth impairment.1,10–14

The second theory includes the indirect effects of untreated caries and different body responses to chronic dental infection. Three mechanisms are suggested. The first concerns immune responses. Infected dental pulp may affect immunity and erythropoiesis,15–17 which may result in anemia18 and influence bone remodeling.19,20 Sleep patterns,21,22 and food intake.23 This mechanism is supported by results of a randomized controlled trial showing that treatment of severe caries in children aged 6 to 7 years significantly improved their appetite.24 The second mechanism is related to endocrine responses. The interruption of slow-wave sleep due to pain and infection may lead to impairment of growth hormone secretion.25 The third mechanism is linked to metabolic responses. Infections and related inflammation might result in micronutrient undernutrition through increasing energy expenditure and metabolic demands and impaired nutrient absorption.26

In contrast to the studies reporting a relationship between caries and poor growth, some studies did not find any relationship between anthropometric outcomes and caries26–29 or reported that caries is related to overweight.30–32 This inconsistency is also observed in findings from randomized controlled trials and nonrandom longitudinal studies.9,11,24,33–35 These inconsistent associations could be due to methodologic limitations, different caries definitions and detection methods, relying only on BMI, and using unadjusted formulas to calculate BMI rather than the age- and gender-adjusted World Health Organization (WHO)–recommended growth references.4,26,30–38 Another limitation is the failure to include the full range of BMI categories in the sample.37,38 In addition, most studies only focused on 1 direction of the association, either underweight or overweight, ignoring other possibilities.4,26,28,37–39

Interestingly, a recent systematic review showed a significant association between obesity and caries when BMI-for-age (BAZ) centiles were reported and nonsignificant findings when z scores or nonstandardized scales were reported.29 To date, no study has examined the relationship between caries and anthropometric outcomes in young children with high levels of untreated caries using height and weight as continuous variables and where no cutoff points for the diagnosis of underweight and overweight are used. Therefore, a study was conducted with the objective of assessing the nature of the relationship between different levels of caries and height and weight among 6- to 8-year-old Saudi schoolchildren. No assumptions were made on the direction of this association.

METHODS

The sample consisted of all schoolchildren aged 6 to 8 years in the first-year class (grade 1) of all military primary schools in Jeddah, Saudi Arabia. Children with parasitic infections at the time of the survey and children whose caregivers did not give consent were excluded. Children of military personnel were selected because they had the highest prevalence of caries in Saudi Arabia.40 Parents were asked to complete a sociodemographic and health status questionnaire. A pilot study was conducted in 55 randomly selected children to test the feasibility of all clinical examinations.

The research was approved, managed, and monitored by the Research and Ethics Committee of the King Fahad Armed Forces Hospital. Parental permission was obtained from the child’s legal caregivers.

Measurements

Anthropometric Measurements

Anthropometric measurements were performed by using the Food and Nutrition Anthropometric Indicators Measurement Guide.41 A skilled nurse, blinded to the child’s dental status, carried out all anthropometric measurements. Measurements for height and weight were made to the nearest 0.1 cm and 0.1 kg, respectively. All anthropometric measures were performed in children without shoes and wearing light clothes. Height was measured by using a portable Harpenden pocket stadiometer (Chasmors Ltd, London, United Kingdom). Weight was measured by using a precalibrated digital Seca scale (model 767; Seca GmbH, Hamburg, Germany). All children were weighed at the same time of day (7:30–8:50 AM) and in the same relation to their eating time (before morning break). Three readings for both height and weight were taken for each child. The median of these readings was used for the analysis. Height and weight were assessed by using the z scores of height-for-age (HAZ), weight-for-age (WAZ), and BAZ.42 The calculation of z scores for height, weight, and BMI was based on the international reference standards for the assessment of nutritional status for a specific age and gender and were automatically
managed by using the WHO AnthroPlus software, which holds the WHO Reference 2007 for ages 5 to 19 years.\(^4\) Age was calculated as the difference between the date of measurement and the date of birth, which was obtained for all children from their school files. WAZ, HAZ, and BAZ were used as indicators for present and past nutritional status. A cutoff of less than \(-2\) SDs was used to report underweight and stunting, whereas a cutoff of more than \(+2\) SDs was used to report obesity.\(^4\)

**Dental Measurements**

Caries was assessed by using the decayed, missing, filled, teeth (primary teeth) (DMFT) index (\(d = \) decay to cavitation, \(m = \) missing due to caries, \(f = \) filled restoration, \(t = \) total number of primary teeth) and followed the WHO criteria and coding.\(^4\) Due to the age of the sample and the subsequent low prevalence of caries in permanent dentition, the emphasis was on caries experience in the primary dentition. Caries was recorded at the cavitation level. Dental examinations of children were conducted in daylight by using a disposable dental mirror. No radiographs were taken. A trained dentist who had no previous knowledge about the study rationale conducted the clinical examinations. The reproducibility of clinical dental data was checked by reexamination of 51 (12\%) children. The \(\kappa\) score for caries measurements was 0.81, representing almost perfect agreement.\(^4\)

**Statistical Analyses**

The variables considered as covariates were selected on the basis of the scientific literature on the associations under study. Before constructing multiple regression models, correlations between the variables were checked with a correlation matrix. Accordingly, the variables chosen and used in the multiple regressions were age, gender, parent’s educational levels, and number of teeth present.

Differences in continuous outcomes such as differences in \(z\) scores of weight and height were assessed by using a \(t\) test for normally distributed independent data. Where continuous variables exhibited nonnormal distributions, the Mann-Whitney test was used instead. The Jonckheere-Terpstra test was used for testing differences between \(\geq 2\) means in nonparametric ordered data. Analysis of variance was carried out initially to study the association between DMFT groups and HAZ, WAZ, and BAZ. We used analysis of covariance in the next step to further control for possible confounders. Means with 95\% confidence intervals were calculated. All analyses were performed by using Stata 10.0 (StataCorp, College Station, TX).
RESULTS

Demographic Variables
Four hundred and seventeen (95.6%) of the 436 eligible children were included. The mean age of the participants was 82.1 (±5.8) months, and 42.0% were boys. In terms of parental education, 22.3% of fathers and 18.2% of mothers were educated to the university level or higher (Table 1). There is no accepted method for the assessment of socioeconomic position in Saudi Arabia. Therefore, gross national income per capita ($24 700 per year or $2058 per month) was considered in deciding the most appropriate categorization of children’s socioeconomic position. Because we wanted to include a low socioeconomic position group, we chose a considerably lower income cutoff for this purpose. More specifically, children whose families had a monthly income between 5000 and 10 000 Reyals (≅$1333–$2663) were considered the low-income group (11.8%), those with a monthly income between 26.3% of children had dmft in 1 to 4 teeth, whereas 396 (95.2%) were caries-free in their permanent teeth. Untreated decay (d) accounted for 89.5% of the dmft; a mean of 5.1 of a dmft of 5.7 represented untreated decay (d). Of the 363 (87.1% of the whole sample) with caries in the primary dentition, 286 (78.8%) had only unrestored caries, 9 (2.5%) had only fillings, and 68 (18.7%) had unrestored caries and fillings. Because there is no accepted classification for caries severity for this age group, 2 classifications were used to assess the inverse-graded association. First, the data were divided into 3 groups with comparable group sizes (tertiles): 28.5% of children had dmft in 0 to 2 teeth, 29.8% had dmft in 3 to 6 teeth, and 41.4% had dmft in ≥7 teeth. We also used a dmft variable with 4 categories. For that, caries-free children formed a distinct group and children with caries were divided into 3 groups with similar numbers of subjects (approximate tertiles): 12.9% of children were caries-free, 31.8% had dmft in 1 to 4 teeth, 28.9% had dmft in 5 to 6 teeth, and 28.3% had dmft in ≥7 teeth. Both classifications were used in the analysis to check for any differences (Table 3).

Anthropometric Outcomes
On the basis of the WHO reference values, 7.0% of children were determined to be overweight, 6.0% were stunted, and 10.1% were overweight, and 9.4% were obese. Mean (±SD) HAZ, WAZ, and BAZ were −0.55 ± 0.98, −0.31 ± 1.39, and −0.01 ± 1.4, respectively.

Dental Caries Status
The mean (±SD) number of primary teeth present was 16.2 ± 2.9. The mean dmft was 5.7 ± 4.2 teeth, and the median was 5.0 teeth (Table 2). Only 54 (12.9%) children were caries-free in their primary teeth, whereas 396 (95.2%) were caries-free in their permanent teeth. Untreated decay (d) accounted for 89.5% of the dmft; a mean of 5.1 of a dmft of 5.7 represented untreated decay (d). Of the 363 (87.1% of the whole sample) with caries in the primary dentition, 286 (78.8%) had only unrestored caries, 9 (2.5%) had only fillings, and 68 (18.7%) had unrestored caries and fillings. Because there is no accepted classification for caries severity for this age group, 2 classifications were used to assess the inverse-graded association. First, the data were divided into 3 groups with comparable group sizes (tertiles): 28.5% of children had dmft in 0 to 2 teeth, 29.8% had dmft in 3 to 6 teeth, and 41.4% had dmft in ≥7 teeth. We also used a dmft variable with 4 categories. For that, caries-free children formed a distinct group and children with caries were divided into 3 groups with similar numbers of subjects (approximate tertiles): 12.9% of children were caries-free, 31.8% had dmft in 1 to 4 teeth, 28.9% had dmft in 5 to 6 teeth, and 28.3% had dmft in ≥7 teeth. Both classifications were used in the analysis to check for any differences (Table 3).

Associations Between Caries Levels and WAZ, HAZ, and BAZ
Table 3 displays the results of multiple regression analyses showing the means of anthropometric indices by caries status groups, before and after adjustment for covariates (gender, age, father’s and mother’s educational levels, and number of teeth). Using dmft tertile classification, unadjusted mean HAZ scores were −0.32, −0.45, and −0.78 (P < .001). The unadjusted mean Z scores were higher for each group with lower levels of caries. This strong association remained highly significant even after controlling for other covariates (adjusted mean HAZ scores were −0.32, −0.44, and −0.79; P < .001). A negative linear association was detected between unadjusted mean WAZ scores and caries categories (P < .001). After adjusting for confounders, mean WAZ scores were 0.12, −0.31, and

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency, N</th>
<th>Relative Frequency, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>175</td>
<td>42.0</td>
</tr>
<tr>
<td>Female</td>
<td>242</td>
<td>58.0</td>
</tr>
<tr>
<td>Father’s educational level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannot read or write</td>
<td>5</td>
<td>1.2</td>
</tr>
<tr>
<td>Primary school</td>
<td>31</td>
<td>7.4</td>
</tr>
<tr>
<td>Secondary school</td>
<td>102</td>
<td>24.5</td>
</tr>
<tr>
<td>High school level</td>
<td>150</td>
<td>36.0</td>
</tr>
<tr>
<td>University degree</td>
<td>72</td>
<td>17.3</td>
</tr>
<tr>
<td>Above bachelor’s degree</td>
<td>21</td>
<td>5.0</td>
</tr>
<tr>
<td>Missing data</td>
<td>36</td>
<td>8.6</td>
</tr>
<tr>
<td>Mother’s educational level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannot read or write</td>
<td>31</td>
<td>7.4</td>
</tr>
<tr>
<td>Primary school</td>
<td>80</td>
<td>19.2</td>
</tr>
<tr>
<td>Secondary school</td>
<td>97</td>
<td>23.3</td>
</tr>
<tr>
<td>High school level</td>
<td>95</td>
<td>22.8</td>
</tr>
<tr>
<td>University degree</td>
<td>75</td>
<td>18.0</td>
</tr>
<tr>
<td>Above bachelor’s degree</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Missing data</td>
<td>38</td>
<td>9.1</td>
</tr>
<tr>
<td>Family monthly income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low income: &lt;5000 Reyals (&lt;$1332)</td>
<td>49</td>
<td>11.8</td>
</tr>
<tr>
<td>Middle income: 5000–10 000 Reyals (≅$1332–$2663)</td>
<td>194</td>
<td>46.5</td>
</tr>
<tr>
<td>High income: &gt;10 000 Reyals (&gt;=$2663)</td>
<td>133</td>
<td>31.9</td>
</tr>
<tr>
<td>Missing data</td>
<td>41</td>
<td>9.8</td>
</tr>
</tbody>
</table>
The same pattern of inverse linear relationship between caries categories was detected in BAZ after controlling for covariates. The adjusted mean BAZ values were 0.40, −0.12, and −0.21 (P = .001). To place the significance of the z score variation into perspective, for a 6-year-old girl in the highest caries group, the mean difference in height, weight, and BMI from WHO normal values was 3.3 cm, 1.2 kg, and 2.7 percentiles, respectively. There was a similar inverse-graded association between caries in both unadjusted and adjusted models for WAZ, HAZ, and BAZ scores when the analyses were repeated with the dmft second classification (caries-free and tetrile classification). For each category with a higher prevalence of caries, the adjusted mean WAZ, HAZ, and BAZ scores were lower. This result indicates that the inverse-graded relationship was evident regardless of the dmft classification used.

**DISCUSSION**

This cross-sectional survey revealed a significant and robust inverse linear association between caries experience in 6- to 8-year-old children and HAZ, WAZ, and BAZ. The graded association remained highly significant after adjusting for demographic, dental, and social variables. Although some studies reported an inverse relationship between anthropometric outcomes and caries status, no previous study has reported an inverse-graded relationship. There are certain limitations when comparing the present study with previous studies. First, all previous community-based studies either used categories such as underweight, overweight, and obesity or unstandardized categories such as obese and nonobese or at risk of underweight and normal weight depending on the distribution of their anthropometric measures whereas the current study used all anthropometric outcomes as continuous variables. The reason for not using categories was that the objective was to study the relationship between caries and anthropometric measures by using all of the available data and examining the whole distribution rather than categorizing data and making assumptions about the direction of the relationship. Whereas categorization is sometimes needed, it undoubtedly results in loss of information. For example, Granville-Garcia et al assessed the relationship between caries in obese and nonobese Brazilian children and found that there was no association between obesity and caries. On the other hand, they reported a significant association between high caries levels and not being obese. Due to their categorization and lack of information, it was difficult to assess whether the nonobese children were normal or underweight. Ngoenwiwatkul and Leela-adisorn categorized their data into 2 groups, BMI <15th percentile and BMI ≥15th percentile, because they had no underweight children and 45% of children were in the low-weight percentile category (6th percentile < BAZ < 15th percentile). This categorization made study comparisons difficult. In addition, they could not assess linear associations in their data.

A graded association between dmft and BMI was detected in a Turkish study in a similar age group and caries prevalence to the current study, but the authors did not control for confounders. Only tests for correlations were performed to show the presence of an inverse association between caries status and anthropometric outcomes. This inverted linear relationship between caries and BMI was also evident in an Australian longitudinal study. Interestingly, a Swedish study showed an inverted relationship between BMI categories (combined underweight and low-weight group, normal-weight group, and combined high-weight and obese group) and untreated caries (d) but not for decayed, extracted, filled, teeth (primary teeth) (def) index. A possible explanation for the difference in findings for untreated decay (d) and deft may be that the inverted relationship exists only when untreated decay (d) accounts for a high proportion of the dmft. In the current study, untreated decay (d) accounted for almost 90% of the dmft. Therefore, the inverted relationship was also evident when dmft was used. This finding suggests that a high filling (f)-to-dmft ratio in some studies may have biased the results toward a positive relationship between dmft and a high BMI. Future studies should report the numbers of decayed teeth (d) and filled teeth (f).

A second limitation in comparing our study with other studies is that most studies used different indices and definitions of caries. For example, the American Academy of Pediatric Dentistry criteria include noncavitated lesions in the definition of severe early childhood caries in young children, whereas the WHO criteria for caries include only cavitated lesions. Studies using different criteria will result in

### TABLE 2 Distribution of the dmft, dt, mt, and ft

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of primary teeth</td>
<td>16.2 ± 2.9</td>
<td>17.0</td>
<td>5.0</td>
<td>20.0</td>
</tr>
<tr>
<td>dmft</td>
<td>5.7 ± 4.2</td>
<td>5.0</td>
<td>0.0</td>
<td>20.0</td>
</tr>
<tr>
<td>dt</td>
<td>5.1 ± 4.1</td>
<td>5.0</td>
<td>0.0</td>
<td>16.0</td>
</tr>
<tr>
<td>mt</td>
<td>0.2 ± 0.8</td>
<td>0.0</td>
<td>0.0</td>
<td>9.0</td>
</tr>
<tr>
<td>ft</td>
<td>0.4 ± 1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

N = 417. dt, decayed teeth; ft, filled teeth; mt, missing teeth.
TABLE 3 Association Between Anthropometric Outcomes and dmft

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentage</th>
<th>WHO HAZ</th>
<th>WHO WAZ</th>
<th>WHO BAZ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unadjusted Mean (95% CI)</td>
<td>Adjusted Mean (95% CI)</td>
<td>Unadjusted Mean (95% CI)</td>
</tr>
<tr>
<td>Tertile classification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dmft ≤2 (lowest-caries group)</td>
<td>28.5</td>
<td>-0.32 (−0.50 to −0.15)</td>
<td>-0.32 (−0.48 to −0.14)</td>
<td>0.14 (−0.10 to 0.30)</td>
</tr>
<tr>
<td>dmft = 3–6</td>
<td>30.1</td>
<td>-0.45 (−0.62 to −0.28)</td>
<td>-0.44 (−0.60 to −0.27)</td>
<td>-0.35 (−0.59 to −0.12)</td>
</tr>
<tr>
<td>dmft ≥7 (highest-caries group)</td>
<td>41.4</td>
<td>-0.78 (−0.92 to −0.63)</td>
<td>-0.79 (−0.94 to −0.68)</td>
<td>-0.61 (−0.81 to −0.40)</td>
</tr>
<tr>
<td>P for trend</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Caries-free and tertile classification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dmft = 0 (caries-free group)</td>
<td>12.9</td>
<td>0.27 (−0.53 to −0.01)</td>
<td>0.24 (−0.50 to −0.01)</td>
<td>0.05 (−0.31 to 0.42)</td>
</tr>
<tr>
<td>dmft = 1–4</td>
<td>31.8</td>
<td>−0.37 (−0.53 to −0.20)</td>
<td>−0.37 (−0.54 to −0.21)</td>
<td>−0.05 (−0.28 to 0.18)</td>
</tr>
<tr>
<td>dmft = 5–8</td>
<td>28.9</td>
<td>−0.68 (−0.83 to −0.50)</td>
<td>−0.68 (−0.85 to −0.51)</td>
<td>−0.50 (−0.75 to −0.25)</td>
</tr>
<tr>
<td>dmft ≥9 (highest-caries group)</td>
<td>26.3</td>
<td>−0.77 (−0.93 to −0.59)</td>
<td>−0.77 (−0.95 to −0.59)</td>
<td>−0.62 (−0.88 to −0.38)</td>
</tr>
<tr>
<td>P for trend</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

N = 417. CI, confidence interval.

*Analysis of variance.

b Analysis of covariance (adjusted for gender, age, father’s and mother’s educational levels, and number of teeth present).

Due to the cross-sectional study design, definitive information about cause-and-effect relationships cannot be derived.

Sixth, the samples used in some studies included different age groups and ethnic backgrounds. For the reasons outlined above, there are doubts over the reliability of clinical measures and no study indicated the apparently contradictory findings were due to methodologic inconsistencies or are a true reflection of differences.

Seventh, the apparently contradictory findings were due to methodologic inconsistencies or are a true reflection of differences.

However, the current study is that the sample was not representative of Saudi children. Consequently, it is difficult to extrapolate findings to the Saudi child population. Therefore, our aim was not to have a nationally representative sample for such comparisons or to assess the association between caries and anthropometric outcomes in a nationally representative sample of Saudi children. Consequently, it is difficult to extrapolate findings to the Saudi child population. Therefore, our aim was not to have a nationally representative sample for such comparisons or to assess the association between caries and anthropometric outcomes in a nationally representative sample of Saudi children. Consequently, it is difficult to extrapolate findings to the Saudi child population. 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CONCLUSIONS

There was an inverse-graded association between all anthropometric outcomes and caries levels in 6- to 8-year-old Saudi children. Children at each higher level of caries had significantly lower height and weight outcomes than those with lower caries levels. Future longitudinal studies can help determine whether there is a cause-and-effect relationship between caries levels and poor growth.

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