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RESEARCH REPORT

Links Between Sugar and Dental Decay in US Children from Low-Income Families

Results of a Systematic Review

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Abstract

Objective: This systematic review examined the association between the consumption of sugar and other carbohydrates with dental caries incidence or prevalence in children and adolescents from low-income families within the United States.

Methods: Eligible studies included children aged 6–20 from low-income families living in the US, measured the consumption of sugar and/or carbohydrates, and assessed dental caries incidence or prevalence in primary or permanent teeth.

Results: A total of 77 studies were found and evaluated, and four met the inclusion criteria. One study showed a 40 g/day increase in added sugar intake was associated with a 6.4% increase of dental caries lesions (95% confidence interval (CI) = 1.2%–11.6%; $p = 0.02$). A second study showed the mean number of tooth surfaces with dental caries lesions was 59% higher for those in the highest quartile for sugar-sweetened beverage consumption (SSB) than those in the lowest quartile (mean ratio = 1.59 (95% CI = 1.15–2.20; $p < 0.01$). A third study supported an association between dental caries prevalence and consuming SSBs >4 times a week (prevalence risk ratio: 2.40 (95% CI = 1.30–4.44; $p < 0.01$)). The final study showed dental caries experience increased 22% (adjusted prevalence ratio = 1.2 (95% CI = 1.1–1.3; $p < 0.05$)) for every additional reported serving of SSB consumed per day.

Conclusions: All four studies concluded that there was a positive association between sugar and dental caries experience in children from low-income families. Further work is needed to address this disease and reduce oral health disparities in American children from low-income families.

Introduction

Dental caries, or dental decay, is one of the most prevalent human diseases, affecting 97% of the global population throughout their lifetime.[1] Dental caries is considered a multifactorial condition as the disease process involves the interplay of oral microorganisms, acids, tooth properties, salivary flow, fluoride, and the frequency and duration of consumption of sugar and specific simple carbohydrates.[2,3] Whether the dental caries process progresses, halts, or reverses is dependent on a balance of these factors.

Fermentable carbohydrates, or carbohydrates that can be anaerobically broken down by microbes to produce energy, are a triggering factor in the dental caries process, causing the demineralization of enamel and/or dentin. This is when the cariogenic bacteria produce acid throughout the carbohydrate fermentation process.[4,5,6,7] If left untreated, dental caries can cause pain, infection, and tooth loss that can result in missed school or workdays, hospital stays, and in rare cases, death. The association of dental caries with excessive sugar intake was affirmed in 2003 by a World Health Organization (WHO) expert panel, whose members reviewed the strength of evidence linking dietary factors to dental caries and reported an increased risk of dental caries associated with frequent and total intake of added sugars.[8,9]

Understanding the role of diet, demographics, and environmental factors in contributing to increased dental caries rates in children is essential to improve children's oral health.[10,11,12] People living in poverty experience poor health at a higher rate than those not living in poverty, and these health disparities extend to oral health.[6,13–15] The costs to treat dental caries among young children can be substantial if extensive procedures and/or general anesthesia in an operating room are required.[16,17]

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A high percentage of US children now have dental coverage.[18,19] In 2013, an estimated 87.8% of children had dental coverage, a 9.5% increase since 2003.[20] This increase is largely attributed to increased enrollment in Medicaid and the Children's Health Insurance Program's coverage of pediatric dental care since 2009. As dental coverage increased, so have rates of children's dental visits. However, despite improvements in access to dental visits and treatment, only about half of children covered by Medicaid see a dentist in any given year. Overall, there has been no subsequent change in the incidence or prevalence of dental caries.[21,22] Therefore, to fight this preventable disease's core etiology, the battle must start upstream, considering causative factors. Specifically, the goal of this systematic review is to examine the association between consumption of added sugar and/or carbohydrates and the incidence and prevalence of dental caries in US children from low socioeconomic backgrounds.

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Methods

This systematic review data collection methodology was simplified from Cochrane's and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[23,24] For inclusion in this review, studies needed to meet the following criteria:

Inclusion criteria: Studies involving human children aged 6–20, describing family income level, conducted within the United States, measuring the consumption of sugar and/or carbohydrates, and including an indicator of dental caries incidence or prevalence.

Exclusion criteria: Studies involving animals, laboratory studies, studies with individuals over 20 years old or under 6 years old, studies not including mention of family income level, studies conducted outside of the United States, studies that did not measure the consumption of sugar and/or carbohydrates, and studies including neither dental caries incidence nor prevalence assessment. Please see Appendix A for the specific search terms used to identify eligible studies.

Identification of Abstracts

Citations within identified papers were assessed for additional studies. Titles and abstracts of studies identified from the search were independently screened by one contributor (CD) based on the inclusion/exclusion criteria. A second contributor (LH) independently reviewed a randomly selected 10% of abstracts from the initial contributor. The two contributors then compared their screenings of these selected abstracts for calibration. The full-text review was conducted independently by the same contributor against the criteria. The flow diagram summarizing included and excluded studies is shown as Figure 1.

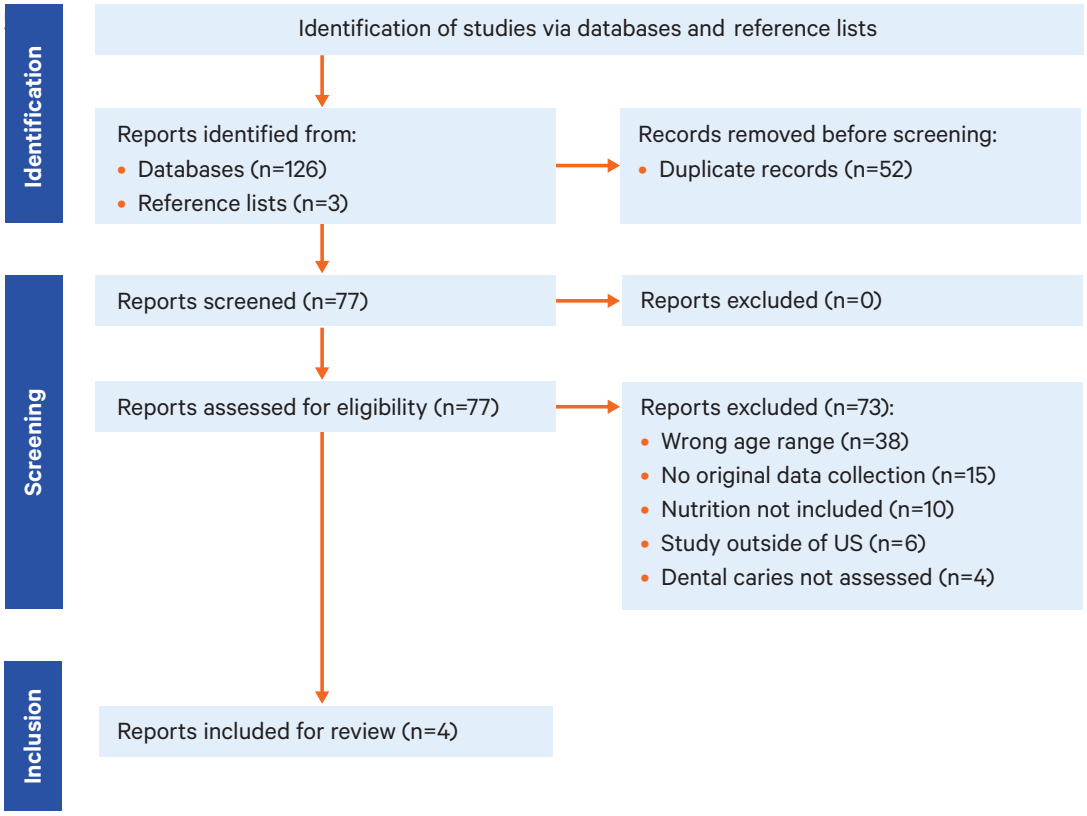
Data Extraction

Two contributors (CD, LH) independently extracted data from included studies using the Cochrane[23] data collection form for intervention reviews RCTs and non-RCTs. One of the contributors (CD) reviewed all the articles using the Cochrane form while the other (LH) independently reviewed a random selection of 10% of identified articles. All articles were saved to a shared folder, and the authors worked from separate data extraction forms to reduce the risk of influencing results.

Data Synthesis

A narrative summary was created for each study that met the eligibility criteria. If at least two studies had the same outcome in a combinable format, a meta-analysis would be conducted. Because of the heterogeneity of the outcomes, a meta-analysis was not conducted.

Figure 1. PRISMA table summarizing included and excluded articles



Results

One hundred and twenty-six articles were identified from the PubMed search. Of these identified articles, 52 were duplicated studies, resulting in 74 articles. One article found in the initial search met all inclusion and exclusion criteria and was included in the systematic review. The initial inclusion criterion for age was 6–12 years; however, in conducting the search, we discovered that only one of the articles reviewed met all inclusion and exclusion criteria. By extending the age range to 6–20 years, we were able to include three additional articles in the review without changing any additional inclusion or exclusion criteria, resulting in 77 articles reviewed. These additional articles were identified within the references of the original article. Altogether, four articles were included in the systematic review (Figure 1). All four studies were cross-sectional in design.

Dental Caries and Sugar Consumption

A study of 51 Alaska Native Yup'ik children aged 6–17 in the Bethel and Yukon-Kuskokwim Delta regions by Chi and colleagues compared the incidence of dental caries lesions by tooth surface to the level of sugar consumed as estimated from carbon-13 isotope levels in 1 cm hair clippings from close to the scalp.[25] Each centimeter of hair corresponds to approximately one month of growth and reflects about 1–2 months' worth of sugar intake. The study authors also administered a parent survey, and all participants received a dental exam. In this study, the mean proportion of tooth surfaces with dental caries lesions per participant was 30.8% (standard deviation (sd) = 23%; range: 3%–94%). The mean added sugar intake was 193 g/day (sd = 43.6; range = 105.6–324.3 g/day). A 40 g/day increase in added sugar intake was associated with a 6.4% increase in the proportion of tooth surfaces with dental caries lesions (95% confidence interval (CI) = 1.2%–11.6%; p = 0.02) and a 24.2% increase in dental caries incidence (95% CI = 10.6%–39.4%; $p < 0.01$).[24]

Laurence and colleagues conducted a study that included 545 children aged 12–17 years old that resided in Washington, DC, or Nashville, Tennessee.[5] The study authors examined the association between sugar-sweetened beverage (SSB) consumption (including sodas, lemonade, sweet tea, etc.) and dental caries among Black children classified as underserved by the District of Columbia or the state of Tennessee. In this study, among those brushing once a day or less, for those in the highest quartile for SSB consumption, the mean number of surfaces with caries lesions was 59% higher than those in the

lowest quartile for SSB (mean ratio = 1.59; 95% CI = 1.15–2.20, $p < 0.01$). For those in the highest quartile of SSB consumption, the estimated odds of children remaining dental caries–free was 76% lower (odds ratio = 0.24; 95% CI = 0.09–0.61, $p < 0.01$) than for those in lower quartiles of SSB. The mean values for decayed, missing, and filled surfaces (DMFS) scores across all beverage types were similar, and statistical testing found no significant differences among each beverage group (SSB, sugar-free beverages, 100% juice, and milk).[5]

In a study by Lee and colleagues, 116 children and young adults aged 7–20 who had special healthcare needs (CSHCN) and were part of the Washington State Medicaid program were examined for dental caries prevalence.[26] All caregivers of participating CSHCN enrollees completed a questionnaire, and all children received a dental screening. In this study, of the 116 participants, over half (62.9%) had at least one pre-cavitated, decayed, missing, or filled (PDMF) surface and 16% had at least some untreated decay. In terms of diet, 40.5% of caregivers reported their CSHCN consumed eight or more sweet snacks and 27.6% consumed >4 servings of SSBs per week. The mean number of PDMF surfaces was 6.4 ± 9.4 (range: 0-49). Consuming SSBs >4 times a week was significantly associated with dental caries prevalence (prevalence risk ratio = 2.40; 95% CI = 1.30–4.44; $p < 0.01$).[26]

Wilder and colleagues conducted a study that included 2,944 third-grade children aged 8 to 9 years old residing in Georgia.[27] Parents of eligible children completed a supplemental survey about their child's daily SSB consumption. Participating children received a dental screening to assess presence of treated and untreated dental caries. In this study, after adjusting for sociodemographic factors and maternal oral health characteristics, dental caries experience increased 22% (adjusted prevalence ratio = 1.2; 95% CI = 1.1–1.3; $p < 0.05$) for every additional reported serving of SSB the children consumed per day. The mean number of SSBs consumed per day among children in the study was 1.7 servings. The unadjusted prevalence ratio for the relationship between SSB consumption and dental caries experience was 1.3 (95% CI = 1.2–1.5; $p < 0.001$).[27]

Discussion

Each study included in this review concluded there is a strong association between sugar consumption and dental caries experience in children from low-income families in the US. All studies looked specifically at sugar-sweetened beverages and sugary snacks within this specific audience. The Chi study noted that added sugar intake was significantly and positively associated with tooth decay in Yup'ik children. The study authors recommend further use of hair biomarkers to continue to measure and assess sugar intake to improve the oral health of Alaska Native children.[25] In the Laurence study, the authors concluded that SSBs were the dietary item most closely associated with dental caries in underserved children, and that the large public health burden of excess SSB consumption needs to be further addressed.[5] The Lee study found CSHCN residing in the US have a high dental caries prevalence and consumed significantly more sugar-sweetened beverages and snack servings per day.[26] Finally, the Wilder study concluded, in addition to the link between SSB consumption and dental caries experience, that proper health messages about SSBs from dentists, physicians, and other health care providers, as well as policy approaches at the school, state, and national level to limit consumption of SSBs, may collectively impact both the development of dental caries and obesity, leading to overall better health for children.[27]

The public health burden caused by excess sugar consumption needs to be further addressed by health providers and through policy at school, state, and national levels.

The public health burden caused by excess sugar consumption needs to be further addressed by health providers and through policy at school, state, and national levels. Many interventions focus on factors such as oral hygiene, specifically brushing and flossing and fluoride used to reduce dental caries. However, modifying these factors would not be necessary if there were a broader understanding of a key causal player in the development of dental caries — added sugars.[3]

There is a need for wide adoption of evidence-based behavioral interventions by oral health care and other health professionals that help families improve dietary intake in children, such as motivational interviewing.[28] Motivational interviewing (MI) is a structured technique used by health professionals to engage their patients in goal-setting around behavior change.[29] MI has been shown to encourage alcohol and tobacco cessation among dental patients[30] and to improve health outcomes for other sugar-associated diseases.[31] MI can be utilized to help patients better understand that added sugar consumption is a contributor to dental caries and to encourage patients' behavior change.

One recommendation is for providers to communicate behavior change through nutritional counseling, in addition to encouraging patients to brush and floss. Brushing and flossing are considered protective risk factors against dental caries development, along with consuming fluoridated water and receiving topical applications of fluoride regularly.[32] The effects of added sugar consumption (a risk factor for dental caries) must be limited to be outweighed by protective factors. Limiting consumption of added sugar using motivational interviewing can lead patients to better oral health outcomes in the long term. This style of communication has been shown to help prevent dental caries,[28] therefore mitigating sugar consumption should be a focus of the communication, as it may be more impactful if providers encourage their patients to remove the cause of the disease rather than rely on preventive actions that have limited impact.

While interventions at the individual level can help reduce dental caries severity for groups of people at one time, community-level interventions will impact a broader audience. The Healthy Corner Store Initiative[33,34] is a community-level intervention that can help reduce the intake of sugar and ultimately decrease the rate of dental caries among children from low-income families. This initiative was introduced with the aim of supporting corner store owners committed to increasing their store inventory of healthy food and simultaneously encouraging customers to make healthier food choices. This program offers a solution to improving food access across the country where corner stores are a dependable source of food for families, especially those experiencing poverty and transportation barriers.

An example of a policy intervention includes the implementation of taxes on SSBs. The implementation of this tax aims to reduce the purchase of sugary drinks, thus reducing the rate of dental caries. In Philadelphia, Pennsylvania,[35] Mexico,[36] and Berkeley, California,[37] enactment of such a tax was associated with a drop in the number of SSBs sold. With a significant reduction in added sugar intake, studies have modeled a significant decrease in dental caries incidence.[38]

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Another potential means of addressing dental caries experience related to added sugar consumption includes medical-dental integration, in which oral health providers and physicians collaborate closely to improve the oral and overall health of their patients.[39] Bridging the gap between medical and dental care can not only help to reduce dental caries, but also help reduce other long-term issues that can arise from added sugar and overprocessed carbohydrate consumption, such as obesity and diabetes.

Lastly, improving accessibility to dental providers for preventive treatments for children like fluoride should be further prioritized. This can be accomplished by increasing the number of dental teams available in underserved areas or dental deserts, deploying dental team members into the community for place-based care provision, increasing acceptance of patients with Medicaid coverage in dental offices, and improving dental benefits provided by Medicaid.

Limitations

One limitation of this systematic review is that only English language papers were screened and reviewed; other databases besides PubMed may have provided additional relevant articles. Secondly, only dental caries was used as an outcome; there are numerous other outcomes that could be explored in both the oral health and overall health space. Because of heterogeneity in reporting of dental caries outcomes, a meta-analysis was not conducted.

Conclusion

All four studies included in this review concluded that there is a positive association between consumption of added sugar and dental caries. To address this disease and further reduce oral health disparities in low-income children, dental teams should explore motivational interviewing to include discussion about the underlying causes of dental caries. Additional solutions include implementing taxes on SSBs, incorporating medical-dental integration, and breaking down barriers to dental care so children can access preventive care that includes nutritional counseling. Additionally, implementation of programs like Healthy Corner Stores across the US would provide children and their families better food alternatives. The public health burden of excess added sugar consumption needs to be further addressed by providers in the dental and medical space, as well as through policy at the school, state, and national levels for better overall health. Additionally, there is a need for further studies to increase the homogeneity of the study results, and to enable a future meta-analysis to bolster confidence in these findings.

All four studies included in this review concluded that there is a positive association between consumption of added sugar and dental caries.

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Appendix A

Search terms used to identify eligible studies

A search strategy was developed by the contributors (CD, LH) for English language papers and performed in PubMed with the following query: (((((“low-income”[All Fields] OR “low-Income”[All Fields] OR (“Federal Poverty Level”[All Fields] OR “child poverty”[All Fields] OR “poverty”[All Fields])) AND (“Child”[All Fields] OR “Children”[All Fields] OR “Pediatric”[All Fields])) AND (“Nutrition”[All Fields] OR “Sugar”[All Fields] OR “Carbohydrates”[All Fields])) AND (“Oral Health”[All Fields] OR “Dental Health”[All Fields] OR “Oral Hygiene”[All Fields] OR “Dentition”[All Fields])) AND (“Caries”[All Fields] OR “Cavities”[All Fields] OR “Cavity”[All Fields] OR “Carious Dentin”[All Fields] OR “Dental Decay”[All Fields] OR “Dental White Spots”[All Fields] OR “Tooth Demineralization”[All Fields] OR “Initial Caries Lesions” [All Fields])) AND (“United States”[MeSH Terms] OR (“United”[All Fields] AND “States”[All Fields]) OR “United States”[All Fields] OR (“Americas”[All Fields] OR “Americas”[MeSH Terms] OR “American”[All Fields] OR “America”[All Fields]) OR (“American”[All Fields] OR “Americans”[All Fields] OR “Americanization”[All Fields] OR “Americanized”[All Fields] OR “Americans”[All Fields])))). Any articles suggested by PubMed as “Related” were additionally screened against the inclusion and exclusion criteria.

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