The Saudi Dental Journal 36 (2024) 533–538

Contents lists available at ScienceDirect

The Saudi Dental Journal

journal homepage: www.ksu.edu.sa
www.sciencedirect.com

Original Article

Dental decay in children and the link to weight status: A cross-sectional analysis of national school health data

Arwa Alhamed[a,b,*], Abdullah Al-Zeer[c,d], Fahad Alsaawi[d], Abdulrahman Alshaikh[d,e], Abrar Alzaher[e,f], Abdullah Alkattan[e,f], Noura Alrasheed[e,f], Khlood Sagor[e,f], Elham Alsalem[e,f], Mona Ibrahim[e,f,g], Amjad Alfaleh[e,f]

[a] College of Nursing, King Saud bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia
[b] King Abdullah International Medical Research Center, Riyadh, Saudi Arabia
[c] King Saud University, Riyadh, Saudi Arabia
[d] Lean Business Services, Riyadh, Saudi Arabia
[e] Ministry of Health, Riyadh, Saudi Arabia
[f] General Authority of School Health, Riyadh, Saudi Arabia
[g] Community, Environment and Occupational Medicine, Faculty of Medicine, Zagazig University, Egypt

ARTICLE INFO

Keywords:
"School-age Children"
"Dental Decay"
"Obesity"
Health disparities
Oral Health

ABSTRACT

Recent national reports have indicated an increasing trend of dental decay among school-aged children. National school-based data are required to guide decision-making to ensure effective public health efforts to manage dental decay. This study aimed to assess the prevalence of dental decay among school-age children in Saudi Arabia and explore the possible link between dental decay and weight status. This was a cross-sectional analysis of a national sample including 1,134,317 Saudi children in the 1st, 4th, 7th, and 10th grades who participated in a national school screening program. Data for weight, height, body mass index (BMI), dental decay prevalence, and decayed, missing, and filled teeth (DMFT) index were analysed. An independent *t*-test, one-way analysis of variance, and chi-square test were used to compare the means, while Pearson's r correlation and multiple linear regression were used to examine the relationships between the study variables. The prevalence of dental decay was 24.20%, and dental decay was the highest among female students (26.5%), students in primary school (25.9%), students living in the eastern region (35.2%), in the administrative capital (27.6%), and in rural areas (23.4%). Dental decay was the highest among students who were underweight. Female sex and living in rural areas significantly predicted higher DMFT while being overweight/obese significantly predicted lower DMFT. Dental decay is highly prevalent among underweight students, female students, and students living in rural areas and the eastern regions of Saudi Arabia. To reduce the prevalence of dental decay and related health disparities, dental health screening programs should be designed to detect dental decay early among children at high risk due to abnormal BMIs and sociodemographic factors. In addition, dental health screening and management programs should utilize standardized dental decay assessment methods and ethnically representative growth charts.

1. Introduction

Recent estimates indicate that untreated dental decay is prevalent worldwide, affecting approximately 621 million children (Kassebaum et al., 2015; Vos et al., 2010). In Saudi Arabia, dental decay is the most common cause of tooth extraction in people aged 10 to 30 (Alesia & Khalil, 2013). Previous reports suggest that the prevalence of dental decay ranges from 60 % to 94 % (Akpata & Al-Shammery, 1992; Al-

Abbreviations: BMI, body mass index; DMFT, decayed, missing, and filled teeth; MOH, Ministry of Health.

Peer review under responsibility of King Saud University. Production and hosting by Elsevier.

* Corresponding author at: King Saud bin Abdulaziz University for Health Sciences, Prince Mutib Ibn Abdullah Ibn Abdulaziz Rd, Ar Rimayah, Riyadh 14611, Saudi Arabia.

E-mail address: hamedar@ksau-hs.edu.sa (A. Alhamed).
@@arwa_a_alhamed (A. Alhamed)

https://doi.org/10.1016/j.sdentj.2024.01.008
Received 30 July 2023; Received in revised form 4 January 2024; Accepted 8 January 2024
Available online 10 January 2024

Shammery, 1999; Al Agili, 2014; Al-Wazzan, 2004; Al-Sadhan, 2006; Al-Dossary et al., 2010; Khan et al., 2013; Farooqi et al., 2015; Wyne et al., 2002; Wyane et al., 2004; Al-Dossari et al., 2004). Many behavioral and demographic risk factors were attributed to dental decay in Saudi children, such as the consumption of foods high in sugar (Alhabdan et al., 2018; Qadri et al., 2015) and high sweet preferences (Ashi et al., 2018). Additionally, low health literacy and adherence to good oral health practices such as brushing of teeth, using mouthwash, flossing, and visiting the dentist regularly starting before the age of two years were found to increase the risk of dental decay during childhood significantly (Aboubakr & Elkwatehy, 2021; Al-Agili & Farsi, 2020; Amin & Al-Abad, 2008; Alhabdan et al., 2018). Al-Agili and Farsi (2020) reported that poor oral health literacy was a perceived barrier to dental care among 82.3 % of a sample of 1,397 Saudi parents and that one in four children in Saudi had never visited the dentist. Alhabdan et al. (2018) found that approximately 55 % of children started brushing their teeth at five years of age or older, brushed less than once per day, and 72 % did not visit the dentist for regular checkups.

Socioeconomic and cultural factors contribute to dental decay in Saudi Arabia, such as low family income, low parental education, lack of dental coverage in medical insurance plans, and poor utilization of dental services (Alhabdan et al., 2018; Al Agili & Alaki, 2014; Al-Agili & Farsi, 2020; Aboubakr & Elkwatehy, 2021).

Dental decay and obesity share common risk factors such as unhealthy dietary behaviors (Al Shehri et al., 2020; Hooley et al., 2012). Previous studies have indicated a positive association between body mass index (BMI) and dental decay in children (Alswat et al., 2016; Hayden et al., 2013; Angelopoulo et al., 2019; Abu El Qomsan et al., 2017). In obese children, salivary flow increases, and taste becomes more profound, increasing the risk of dental decay (Modeer et al., 2011). Dental decay and obesity are major public health issues that affect the quality of life of individuals and increase healthcare expenditures (FDI World Dental Federation, 2015). Therefore, efforts to reduce the burden of oral diseases and obesity through public health interventions can address these shared risk factors (AlShammery et al., 2017).

Although there are several national reports on the prevalence of dental decay in Saudi Arabia, a school health data-based analysis is needed to guide decision-making and public health resource allocation. This study aimed to describe the prevalence of dental decay and assess the possible link between dental decay and weight status in a national sample of school-age children in Saudi Arabia.

2. Materials and methods

2.1. Design and sample

This study was based on secondary data analysis of a cross-sectional national sample including 1,134,317 children and adolescents living in Saudi Arabia who were part of the national school screening program established by the Saudi Ministry of Health (MOH). The national school screening program consists of a medical examination of school students to detect health problems early, refer them to concerned authorities, provide health awareness programs, and build a health database (MOH, 2019). Data were collected from 1st, 4th, 7th, and 10th grade students.

2.2. Measures

The data obtained for this study were limited to January 2020 and April 2022. Demographic data for age, sex, school grade, geographical regions, and type of cities were collected. Detailed description of the data collection procedures for the demographic data is provided in Alhamed et al. (2023).

Anthropometric data including weight, height, and BMI were collected. Height was measured in centimeters (cm) using a stadiometer, and weight was measured in kilograms (kg) using a scale calibrated by nurses from the Saudi Ministry of Health. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2), with percentiles calculated using Growth Charts for Saudi Children and Adolescents. BMI data were plotted on Saudi sex-specific percentile charts and categorized into five groups: underweight (less than the 5th percentile), normal weight (between the 5th and 85th percentiles), overweight (between the 85th and 95th percentiles), and obese (>95th percentile) (El Mouzan et al., 2016; MOH, 2007).

Dental decay data were collected at the school by dentists or dental hygienists via visual oral examination using a tongue depressor and a light source with aseptic precautions, following the World Health Organization (WHO) diagnostic criteria for oral health surveys (WHO, 2013). Permanent dentition was systematically assessed from the upper to the lower teeth and from right to left. The plaque was removed using a 4 × 4 gauze to improve the visualization of dental decay. Caries experience was assessed using the decayed, missing, and filled teeth (DMFT) index, with modified criteria for caries detection provided by the WHO (Cappelli & Mobley, 2008).

2.3. Statistical analysis

IBM Statistical Package for Social Sciences (SPSS) Statistics (version 26) was used for data analysis (IBM Statistics, 2019). The data were cleaned and cases with biologically implausible values for weight and height were excluded from the Saudi pediatric growth charts and age percentiles for weight, height, and BMI (El Mouzan et al., 2016). Chi-square test, independent *t*-test, and one-way analysis of variance were used to compare the means between categories and groups. Pearson's r product-moment correlation and multiple linear regression were used to examine the relationships among the study variables. Categorical variables, such as BMI category, city type, region, school grade, and sex, were dummy coded. Only variables that met multiple linear regression assumptions (Williams et al., 2019) were included in the regression analysis. Statistical significance was set at a 95 % confidence interval, with a two-tailed P-value < 0.005 for all test parameters.

2.4. Ethical considerations

Approval to conduct this study was obtained from the Institutional Review Board, and approval to utilize national school screening data was obtained from the Data Office in REDACTED. The dataset was then de-identified.

3. Results

In total 1,120,417 Saudi school-age children were included in the analysis after data cleaning. The mean age was 11.85 years with a standard deviation of 3.57 years. The descriptive sample characteristics for the study variables, including groups and mean differences, are presented in Tables 1, 2, and 3. Overall BMI categories and across the study variables were presented in Alhamed et al (2023). The prevalence of dental decay was 24.20 %. Data for the DMFT were only available for 9,881 cases, who were in primary school, living in governorate A and rural areas, and among students living in the eastern, northern, and western regions of Saudi Arabia. The overall mean DMFT was 1.3 with a standard deviation of 2.1. The highest mean DMFT was among female students (1.7 [2.2]), students living in rural areas (2.1 [2.1]), students living in the northern region (2.1 [2.2]), and underweight students (1.6 [2.4]). Dental decay was the highest among female students (26.5 %), in primary school (25.9 %), in the Eastern (35.2 %), and in administrative capitals (*27.6 %*), and underweight students (*30.1 %*). The lowest prevalence of dental decay was observed in the southern regions (15.1 %). All group differences in dental decay across sex, school grade, city type, region, and BMI were statistically significant (Table 3).

Among all study variables, being female ($r = [0.201]$, $p = [0.001]$), living in rural areas ($r = [0.223]$, $p = [0.001]$), and in the northern region ($r = [0.223]$, $p = [0.001]$) were positively correlated with DMFT.

Table 1
Descriptive sample characteristics for sex, school-grade, city types, region, body mass index, and dental decay (n = 1, 120, 417).

Variable	Frequency (%)
Sex	
Male	533,823 (47.6 %)
Female	586,594 (52.4 %)
School Grade	
Primary	50,791 (45.4 %)
Intermediate	292,316 (26.1 %)
Secondary	320,190 (28.6 %)
City Type	
Administrative capital	460,532 (41.0 %)
Governorate A	410,096 (36.6 %)
Governorate B	93,308 (8.3 %)
Rural	156,485 (14 %)
Region	
Central	297,457 (26.5 %)
East	175,693 (15.6 %)
North	126,667 (11.3 %)
South	200,242 (17.8 %)
West	320,358 (28.8 %)
Body Mass Index	
Underweight	33,404 (3 %)
Normal weight	850,856 (75.9 %)
Overweight	116,547 (10.4 %)
Obesity	119,610 (10.7 %)
Dental decay	
Has dental decay	270,914 (24.2 %)
No dental decay	849,503 (75.8 %)

Being overweight or obese (r = [-0.10], p = [0.001]), living in governorate A (r = [- 0.22], p = [0.001]), and living in the eastern region (r = [-0.16], p = [0.001]) were negatively correlated with DMFT (Table 4).

The overall regression model is statistically significant (R^2 = [0.101], F (278.605) = [40639.251], p = 0.001). Female sex significantly predicted higher DMFT (β = [0.215], p = [0.001), being overweight/obese significantly predicted lower DMFT (β = [-0.06], p = [0.001), living in rural areas predicted higher DMFT (β = [0.206], p = [0.001), and living in the eastern region predicted lower DMFT (β = [-0.05], p = [0.001) (Table 5).

4. Discussion

Compared with previous reports, our findings were reassuring as they reflected a decline in the prevalence of dental decay. Previous reports among children in Saudi Arabia have indicated a prevalence of dental decay ranging from 52 % to 94 % (Al Agili, 2014; Aboubakr & Elkwatehy, 2021; Alhabdan et al., 2018; Farooqi et al., 2015; Wyne et al., 2002, Wyne et al., 2004). This lower prevalence may be a reflection of increased adherence to good oral health practices in Saudi society, as well as the progress of MOH efforts toward achieving the WHO goals of reducing the global burden of dental decay (Aboubakr and Elkwatehy, 2021).

The highest prevalence of dental decay was observed among female students, consistent with the findings of Cheng et al. (2019). Teeth erupt earlier in girls than in boys, and thus girls have prolonged exposure to cariogenic products in the oral cavity (Klein and Palmer, 1970). In addition, genetic variations related to sex differences influence salivary flow and composition, enamel formation, dietary preferences, and the composition of pathogenic bacteria (Shaffer et al., 2015; Martinez-Mier & Zandona, 2013).

We found that the prevalence of dental decay was higher among children living in administrative capitals and rural areas, and among children living in the eastern regions. Regional differences in the prevalence of dental decay could be due to sociodemographic differences influencing dietary habits, family income, parental educational level, access to dental services, and fluoride levels due to variations in water sources (Al Dosari et al., 2010). Access to dental health services in rural

Table 2
Mean and standard deviation of body mass index across categories of sex, school grade, city types, regions, categories of body mass index, and dental decay.

Variables	Mean (Standard Deviation)	
	Body Mass Index	DMFT
N	1, 120, 417	9881
Overall	18.96 (4.9)	1.3 (2.1)
Sex		
Male	18.99 (5.03)	0.8 (1.8)
Female	18.96 (4.7)	1.7 (2.2)
Independent *t* test		
t(1,120, 415)	5.20***	
t(9879)		21.09***
School grade		
Primary	16.27 (3.3)	1.3 (2.1)
Intermediate	20.24 (4.4)	
Secondary	22.08 (5.05)	
One way ANOVA		
F(2, 1,120, 414)	207948***	
City type		
Admin Capitals	19 (4.7)	
Governorate A	18.46 (4.6)	1.0 (2.0)
Governorate B	18.49 (4.7)	
Rural	19.44 (5.08)	2.1 (2.1)
Independent *t* test		
t(9879)		51.05***
One way ANOVA		
F(3, 1,120, 413)	3137.80***	
Region		
Central	19.82 (5.1)	
East	19.15 (5.03)	0.9 (1.8)
North	18.7 (4.6)	2.1 (2.2)
South	18.6 (4.5)	
West	18.4 (4.8)	1.2 (2.1)
One way ANOVA		
F(4, 1,120, 409)	617.05***	
F(2, 9878)		720.05***
Body mass index categories		
Underweight	12.9 (1.5)	1.6 (2.4)
Normal weight	17.4 (3.1)	1.4 (2.1)
Overweight	23.14 (3.6)	1.1 (1.8)
Obese	27.58 (4.8)	0.9 (1.9)
One way ANOVA		
F(3, 1,120, 413)	415421.59***	
F(3, 9877)		22.53***
Dental decay		
Has dental decay	18.82 (4.9)	3.3 (2.1)
No dental decay	19 (4.8)	0.10 (0.59)
Independent *t* test		
t(1, 120, 415)	16.67***	
t(9879)		110.01***

Note. DMFT = Decayed, Missing, Filled Teeth. Significance of test parameters: *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001 (two-tailed), df = degrees of freedom, ANOVA = Analysis of variance. DMFT values were only available for cases in primary school, governorates A, rural areas, the eastern, northern, and western regions of Saudi Arabia.
Note. M = Mean, SD = Standard deviation, DMFT = Decayed, Missing, Filled Teeth.

areas is hindered by the high volume of patients and the limited number of facilities, contributing to regional disparities in dental decay (Alhabdan et al, 2021). However, studies comparing dental decay across different regions and city types in Saudi Arabia are limited (Al Ansari, 2014; Al Rafee et al., 2019).

The highest prevalence of dental decay was observed in underweight children. Evidence concerning the link between BMI and dental decay is largely inconclusive, and the direction of this relationship has not been well delineated (Ashi et al., 2019; Cheng et al., 2019; Paisi et al., 2019). Our findings are consistent with those of previous studies, suggesting that dental decay contributes to underweight status, and malnutrition contributes to dental decay (Ashi et al., 2019; Alghamdi and Almahdy, 2017; Alkarimi et al., 2014; Cheng et al., 2019; Yang et al., 2015). Children with dental decay experience pain and discomfort while eating,

Table 3
The overall prevalence of dental decay and across categories of sexes, school-grades, regions, city types, and body mass index.

Variable	Dental decay Frequency (percentages)
Overall	270,914 (24.1 %)
Sex	
Female	155,328 (26.5 %)
Male	115,586 (21.7 %)
X^2(1, 1, 120, 417)	3552.21***
School Grade	
Primary	131,784 (25.9 %)
Intermediate	66,087 (22.6 %)
Secondary	73,043 (22.8 %)
X^2(2, 1, 120, 417)	1584.95***
Region	
West	78,836 (24.6 %)
Central	75,047 (25.2 %)
East	61,907 (35.2 %)
South	30,477 (15.2 %)
North	24,647 (19.5 %)
X^2(4, 1, 120, 417)	22233.84***
City type	
Administrative capital	127,161 (27.6 %)
Governorates A	88,620 (21.6 %)
Governorate B	18,549 (19.9 %)
Rural	36,584 (23.4 %)
X^2(3, 1, 120, 417)	5432.03***
Body Mass Index Category	
Underweight	10,064 (30.1 %)
Normal weight	197,746 (23.2 %)
Overweight	31,784 (27.3 %)
Obese	31,320 (26.2 %)
X^2(3, 1, 120, 417)	1923.85***

Note. *p ≤. 05, **p ≤. 01, ***p ≤. 001 (two-tailed), df = degrees of freedom, .X^2 = Chi-square,
P value of Chi-square test (two tailed).

Table 4
Pearson R correlation analysis among the study variables and the Decayed, Missing, Filled Teeth index (n = 9881).

Variables	Decayed, Missing, Filled Teeth
Sex	0.201***
Age	0.04
Governorates A	-0.223***
Rural	0.223***
East	-0.162**
North	0.223***
Weight	-0.037
Body Mass Index	-0.085
Overweight/obese	-0.10***

Note. Significance of test parameters: *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001 (two-tailed).

Table 5
Regression analysis (n = 9880).

Variable	B	St error	β	t
Constant	0.720***	0.046		15.82
Female Sex	0.930***	0.041	0.215***	22.47
Overweight/obesity	-0.328***	0.050	-0.06***	−6.503
Rural	0.998***	0.05	0.206***	18.340

Note. Significance of regression coefficients: *p ≤. 05, **p ≤. 01, ***p ≤. 001 (two-tailed), df = degrees of freedom. B = unstandardized regression coefficients, St. error = Coefficient standard error, Beta = standardized regression coefficient.
Note. Significance of Pearson r parameter, *p ≤. 05, **p ≤. 01, ***p ≤. 001 (two-tailed).

which contributes to weight loss and malnutrition (Al Shehri et al., 2020; Cheng et al., 2019). However, malnutrition is associated with enamel hypoplasia and changes in saliva composition contributing to dental decay (Reyes-Perez et al., 2014), which also indicates that children with malnutrition have more severe forms of dental decay than obese children (Cheng et al., 2019). The highest prevalence of dental decay was found among female students, who had the highest prevalence of underweight status in our sample, suggesting an increased risk of dental decay.

Other studies have indicated that obesity in children is associated with reduced salivary flow and an increased sweet-taste threshold, which increases the risk of dental decay (Modeer et al., 2011). Owing to their multifaceted nature and shared risk factors such as dietary habits, a positive correlation between obesity and dental decay in children has been suggested (Alswat et al., 2016; Angelopoulo et al., 2019; Abu El Qomsan et al., 2017; Hayden et al., 2013).

The national school screening program implemented by the MOH is an excellent step toward early detection and cost-effective management of dental decay and obesity (Alhabdan et al., 2018; WHO, 2013b). Additionally, the national school screening program will greatly benefit from standardizing dental decay assessment methods and using ethnically representative BMI surveillance systems that capture all medical, demographic, economic, and sociocultural risk factors for dental decay using a biopsychosocial model. Using such a system will facilitate reporting and comparison at national and international levels (Al Shammary et al., 2021) and guide the allocation of dental health resources. Moreover, targeted oral health screening and awareness programs for children with abnormal BMIs and those living in rural areas are recommended. In addition, the effectiveness of such programs should be monitored regularly using universal oral health indicators (Al Shammary et al., 2021; WHO, 2023). Therefore, expanding the access to oral health services in rural areas through mobile and virtual dental health clinics is recommended. Moreover, health policies mandating regular dental checkups for children at an early age are warranted (Alhabdan et al., 2018) to detect and manage dental decay before it starts affecting weight status and nutrition.

Our analysis was based on one of the largest samples of children from all regions of Saudi Arabia. However, our study has some limitations that are worth addressing. First, dental decay was assessed using direct visual oral examination, and DMFT data were only available for less than 1 % of the sample, which may have limited our ability to detect the actual prevalence of dental decay and its statistical significance. Second, comparing our findings with those of previous reports is challenging because of the differences in the assessment and reporting of dental decay and obesity in children (Al-Shehri et al., 2019; Lembert et al., 2014; Paisi et al., 2019). Third, the DMFT and dental decay were collected only for permanent teeth. Including deciduous teeth in the assessment provides a comprehensive assessment of oral health during childhood (Abu El Qomsan et al., 2017). Fourth, the cross-sectional design limits our ability to examine the relationship between dental decay and BMI. Longitudinal approaches may offer better opportunities to track the progression and impact of demographic, economic, and behavioral risk factors on dental decay and BMI (Paisi et al., 2019).

5. Conclusions

Dental decay is highly prevalent among underweight students, female students, and students living in rural areas and the eastern regions of Saudi Arabia. To reduce the prevalence of dental decay and related health disparities, dental health awareness and screening programs should be designed to detect dental decay early among children at high risk due to abnormal BMIs and sociodemographic factors. In addition, dental health screening and management programs should utilize standardized dental decay assessment methods and ethnically representative growth charts.

CRediT authorship contribution statement

Arwa Alhamed: Conceptualization, Methodology, Data curation, Software, Validation, Writing – original draft. **Abdullah Al-Zeer:** Conceptualization, Methodology. **Fahad Alsaawi:** Supervision. **Abdulrahman Alshaikh:** Software, Validation. **Abrar Alzaher:** Visualization, Investigation. **Abdullah Alkattan:** Visualization, Investigation. **Noura Alrasheed:** Visualization, Investigation. **Khlood Sagor:** Visualization, Investigation. **Elham Alsalem:** Visualization, Investigation. **Mona Ibrahim:** Visualization, Investigation. **Amjad Alfaleh:** Visualization, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The General Authority of School Health at the Saudi Ministry of Health and The Research and Development department at Lean Business Services for facilitating data acquisition.

We would like to thank Editage (www.editage.com) for English language editing.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2024.01.008.

References

Abobakr, R., Elkwatehy, W., 2021. The pattern of dental care utilization among Saudi school children. Al-Azhar Dent. J. Girls 8 (3), 507–515.

Abu El Qomsan, M.A., Alasqah, M.N., Alqahtani, F.A., Alobaydaa, M.A., Alharbi, M.M., Kola, Z., 2017. Intricate evaluation of association between dental caries and obesity among the children in Al-Kharj city (Saudi Arabia). J. Contemp. Dent. Pract. 18, 29–33. https://doi.org/10.5005/jp-journals-10024-1983.

Akpata, E. S., al-Shammery, A. R., & Saeed, H. I. (1992). Dental caries, sugar consumption and restorative dental care in 12-13-year-old children in Riyadh, Saudi Arabia. *Community Dentistry and Oral Epidemiology*, *20*(6), 343–346. 10.1111/j.1600-0528.1992.tb00695.

Al Agili, D.E., & Alaki, S.M. (2014). Can socioeconomic status indicators predict caries risk in schoolchildren in Saudi Arabia? A cross-sectional study. Oral Health Prev Dent. 12(3):277–88. 10.3290/j.ohpd.a31669.

Al Agili, D.E., Farsi, N.J., 2020. Need for dental care drives utilization of dental services among children in Saudi Arabia. Int. Dent. J. 70 (3), 183–192. https://doi.org/10.1111/idj.12539.

Al Ansari, A., 2014. Prevalence, severity, and secular trends of dental caries among various Saudi populations: A literature review. Saudi J. Med. Med. Sci. 2 (3), 142–150. https://doi.org/10.4103/1658-631X.142496.

Al Dosari, A.M., Wyne, A.H., Akpata, E.S., Khan, N.B., 2004. Caries prevalence and its relation to water fluoride levels among schoolchildren in Central Province of Saudi Arabia. Int. Dent. J. 54 (6), 424–428. https://doi.org/10.1111/j.1875-595x.2004.tb00299.x.

Al-Dossary, S.S., Sarkis, P.E., Hassan, A., Ezz El Regal, M., Fouda, A.E., 2010. Obesity in Saudi children: a dangerous reality. East. Mediterr. Health J. 16 (9), 1003–1008. PMID: 21218729.

Alesia, K., Khalil, H.S., 2013. Reasons for and patterns relating to the extraction of permanent teeth in a subset of the Saudi population. Clin. Cosmet. Investig. Dent. 5, 51–56. https://doi.org/10.2147/CCIDE.S49403.

Alghamdi, A., Almahdy, A., 2017. Association between dental caries and body mass index in schoolchildren aged between 14 and 16 years in Riyadh, Saudi Arabia. J. Clin. Med. Res. 9 (12), 981–986. https://doi.org/10.14740/jocmr2958w.

Alhabdan, Y.A., Albeshr, A.G., Yenugadhati, N., Jradi, H., 2018. Prevalence of dental caries and associated factors among primary school children: a population-based cross-sectional study in Riyadh, Saudi Arabia. Environ. Health Prev. Med. 23 (1), 60. https://doi.org/10.1186/s12199-018-0750-z.

Alkarimi, H. A., Watt, R. G., Pikhart, H., Sheiham, A., & Tsakos, G. (2014). Dental caries and growth in school-age children. *Pediatrics*, *133*(3), e616–e623. 10.1542/peds.2013-0846.

Al-Rafee, M.A., AlShammery, A.R., AlRumikan, A.S., Pani, S.C., 2019. A comparison of dental caries in urban and rural children of the Riyadh Region of Saudi Arabia. Front. Public Health 7, 195. https://doi.org/10.3389/fpubh.2019.00195.

Al-Sadhan, S.A., 2006. Dental caries prevalence among 12–14-year-old schoolchildren in Riyadh: a 14-year follow-up study of the Oral Health Survey of Saudi Arabia Phase 1. Saudi Dent. J. 18, 2–7. https://doi.org/10.1016/j.sdentj.2012.10.002.

Alshammari, F.R., Alamri, H., Aljohani, M., Sabbah, W., O'Malley, L., Glenny, A.M., 2021. Dental caries in Saudi Arabia: A systematic review. J. Taibah Univ. Med. Sci. 16 (5), 643–656. https://doi.org/10.1016/j.jtumed.2021.06.008.

Al-Shammery, A.R., 1999. Caries experience of urban and rural children in Saudi Arabia. J. Public Health Dent. 59 (1), 60–64. https://doi.org/10.1111/j.1752-7325.1999.tb03236.x.

AlShammery, A.R., Al-Dosari, A., Al-Rusayes, A., Al-Ansari, A., Halawany, H., Sonbul, H., AlOtibi, M., Pani, S., 2017. Consensus statement of the Makkah symposium on the prevention of dental caries: common goals to prevent dental caries in Saudi Arabia. Saudi J. Oral. Sci. 4, 62. https://doi.org/10.4103/sjos.SJOralSci_38_17.

Alshehri, Y. F. A., Park, J. S., Kruger, E., & Tennant, M. (2020). Association between body mass index and dental caries in the Kingdom of Saudi Arabia: Systematic review. The Saudi Dental Journal, 32(4), 171–180. https://doi-org.sdl.idm.oclc.org/10.1016/j.sdentj.2019.11.002.

Alswat, K., Mohamed, W.S., Wahab, M.A., Aboelil, A.A., 2016. The association between body mass index and dental caries: Cross-sectional study. J. Clin. Med. Res. 8 (2), 147–152. https://doi.org/10.14740/jocmr2433w.

Al-Wazzan, K.A., 2004. Dental caries prevalence in 6–7-year-old schoolchildren in Riyadh region: a comparative study with the 1987 Oral Health Survey of Saudi Arabia Phase I. Saudi Dent. J. 16, 54–60.

Amin, T.T., Al-Abad, B.M., 2008. Oral hygiene practices, dental knowledge, dietary habits, and their relation to caries among male primary school children in Al Hassa, Saudi Arabia. Int. J. Dent. Hyg. 6 (4), 361–370. https://doi.org/10.1111/j.1601-5037.2008.00310.x.

Angelopoulou, M.V., Beinlich, M., Crain, A., 2019. Early childhood caries and weight status: A systematic review and meta-analysis. Pediatr. Dent. 41 (4), 261–272. PMID: 31439085.

Ashi, H., Campus, G., Klingberg, G., Forslund, H. B., & Lingström, P. (2019). Childhood obesity in relation to sweet taste perception and dental caries - a cross-sectional multicenter study. *Food & nutrition research*, *63*, 10.29219/fnr.v63.1682. 10.29219/fnr.v63.1682.

Cappelli, D.P., Mobley, C.C., 2008. Prevention in clinical oral health care. Mosby Elsevier Inc.

Cheng, Y.H., Liao, Y., Chen, D.Y., Wang, Y., Wu, Y., 2019. Prevalence of dental caries and its association with body mass index among school-age children in Shenzhen, China. BMC Oral Health 19 (1), 270. https://doi.org/10.1186/s12903-019-0950-y.

El Mouzan, M., Salloum, A.A., Omer, A.A., Alqurashi, M., Herbish, A.A., 2016. Growth reference for Saudi school-age children and adolescents: LMS parameters and percentiles. Ann. Saudi Med. 36 (4), 265–268. https://doi.org/10.5144/0256-4947.2016.265.

Farooqi, F. A., Khabeer, A., Moheet, I. A., Khan, S. Q., Farooq, I., & ArRejaie, A. S. (2015). Prevalence of dental caries in primary and permanent teeth and its relation with tooth brushing habits among schoolchildren in Eastern Saudi Arabia. *Saudi medical journal*, *36*(6), 737–742. 10.15537/smj.2015.6.10888.

FDI World Dental Federation. (2015). The challenge of Oral disease-a call for global action. Geneva: FDI World Dental Federation; Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (2020). Seattle: Institute of Health Metrics and Evaluation (IHME);. Available from http://ghdx.healthdata.org/gbd-results-tool.

Hayden, C., Bowler, J.O., Chambers, S., Freeman, R., Humphris, G., Richards, D., Cecil, J. E., 2013. Obesity and dental caries in children: a systematic review and meta-analysis. Commun. Dent. Oral Epidemiol. 41 (4), 289–308. https://doi.org/10.1111/cdoe.12014.

Hooley, M., Skouteris, H., Boganin, C., Satur, J., Kilpatrick, N., 2012. Body mass index and dental caries in children and adolescents: a systematic review of literature published 2004 to 2011. Syst. Rev. 1, 57. https://doi.org/10.1186/2046-4053-1-57.

Kassebaum, N.J., Bernabé, E., Dahiya, M., Bhandari, B., Murray, C.J., Marcenes, W., 2015. Global burden of untreated caries: a systematic review and metaregression. J. Dent. Res. 94 (5), 650–658. https://doi.org/10.1177/0022034515573272.

Khan, S.Q., Khan, N.B., Arrejaie, A.S., 2013. Dental caries. A meta-analysis on a Saudi population. Saudi Med. J. 34 (7), 744–749.

Klein, H., Palmer, C.E., 1970. Studies on dental caries: VII. Sex differences in dental caries experience of elementary school children. Public Health Rep. 1896–1970, 1685–1690.

Lempert, S.M., Froberg, K., Christensen, L.B., Kristensen, P.L., Heitmann, B.L., 2014. Association between body mass index and caries among children and adolescents. Commun. Dent. Oral Epidemiol. 42 (1), 53–60. https://doi.org/10.1111/cdoe.12055.

Martinez-Mier, E.A., Zandona, A.F., 2013. The impact of gender on caries prevalence and risk assessment. Dent. Clin. N. Am. 57 (2), 301–315. https://doi.org/10.1016/j.cden.2013.01.001.

Ministry of Health (2019). MOH: 2nd Phase of School-Based Screening Program Launched. Retrieved from https://www.moh.gov.sa/en/Ministry/MediaCenter/News/Pages/News-2019-10-13-002.aspx.

Modéer, T., Blomberg, C., Wondimu, B., Lindberg, T. Y., & Marcus, C. (2011). Association between obesity and periodontal risk indicators in adolescents. *International journal of pediatric obesity: IJPO : an official journal of the International Association for the Study of Obesity*, *6*(2-2), e264–e270. 10.3109/17477166.2010.495779.

Paisi, M., Kay, E., Bennett, C., Kaimi, I., Witton, R., Nelder, R., Lapthorne, D., 2019. Body mass index and dental caries in young people: a systematic review. BMC Pediatr. 19 (1), 122. https://doi.org/10.1186/s12887-019-1511-x.

Qadri, G., Alkilzy, M., Feng, Y.S., Splieth, C., 2015. Overweight and dental caries: the association among German children. Int. J. Paediatr. Dent. 25 (3), 174–182. https://doi.org/10.1111/ipd.12110.

Reyes-Perez, E., et al., 2014. Effect of early childhood protein-energy malnutrition on permanent dentition dental caries. J Public Health Dent. 74 (3), 181–187.

Shaffer, J.R., Leslie, E.J., Feingold, E., Govil, M., McNeil, D.W., Crout, R.J., Weyant, R.J., Marazita, M.L., 2015. Caries experience differs between females and males across age groups in Northern Appalachia. Int. J. Dent. 2015, 938213 https://doi.org/10.1155/2015/938213.

WHO (2013). Global Strategy on Oral Health by The World Health Assembly 75. https://www.who.int/news-room/feature-stories/detail/landmark-global-strategy-on-oral-health-adopted-at-world-health-assembly 75#:~:text=The%20global%20strategy%20sets%20the,individuals%20and%20communities%20by%202030.

Wyne, A.H., 2004. The bilateral occurrence of dental caries among 12–13 and 15–19-year-old school children. J. Contemp. Dent. Pract. https://doi.org/10.5005/jcdp-5-1-42.

Wyne, A.H., Al-Ghorabi, B.M., Al-Asiri, Y.A., Khan, N.B., 2002. Caries prevalence in Saudi primary schoolchildren of Riyadh and their teachers' oral health knowledge, attitude and practices. Saudi Med. J. 23 (1), 77–81.