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ORIGINAL RESEARCH

Dietary habits that affect the caries experience in Mexican adolescents. An odds ratio study

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Abstract

Background: Dental caries was believed to be a sugar-dependent disease caused by acidogenic bacteria in dental plaque that cause hard tissue degeneration. For this reason, this study aimed to determine the association between adolescents' dietary habits and caries experience. **Methods**: 100 adolescents were evaluated for their DMFt levels (decayed, missing and filled teeth), ICDAS (International Caries Detection and Assessment System), pH (hydrogen potential) and salivary volume. According to the National Health and Nutrition Survey in 2022, dietary information was assessed by answering a questionnaire concerning acidic and cariogenic foods. **Results**: Adolescents were primarily males (53%), with an average age of 16.03 ± 0.68 years. DMFt scores showed a low caries rate (36%). The ICDAS averaged 0.58 ± 0.43, with values ranging from 0.05 to 2.17. Most of the adolescents had a basic pH with a mean of 7.5 ± 0.67 and a salivary volume of 1.74 ± 0.70 mL. In the Pearson correlation, salivary volume and pH were not significantly correlated with ICDAS values ($p = 0.815$). Consumption of industrial juice and sweetened drinks was positively associated with caries experience, with p-values of 0.01 and 0.04, respectively. Regarding ICDAS evaluation, 94% of the tested subjects presented caries in enamel and dentin. Of these, 66% exhibited a white spot identified as the first and distinct visual enamel changes, ICDAS code 1 and 2, respectively. **Conclusions**: To prevent further progression of these lesions, we recommend remineralizing therapy. The consumption of industrial juices and sweetened drinks should also be reduced.

Keywords

Caries; Epidemiology; Caries risk factors; Caries in adolescents; Cariogenic diet

1. Introduction

Global Burden Disease (GBD) estimates 265 million dental caries cases, which represent 47% of the world's population in 2017 [1]. Together with periodontitis, dental caries was one of the most common oral diseases and the leading cause of tooth loss [2]. In the rural Mexican population, a DMFt mean of 14.47 was reported among children aged 13–18 [3]. DMFt scores for the middle-income population were 8.36, while children with access to health care had a mean of 10.4 [4].

According to Mexico's Epidemiological Surveillance System for Oral Pathologies, 94% of the population has cavities despite health promotion. It has been attributed to biological, behavioral, and socioeconomic factors on the one hand, and obesity on the other, with overweight increasing significantly among young females on the other [5].

However, untreated dental caries can cause pain, abscesses and severe infections. It has a negative impact not only on the quality of life but also on the economic, social and psychological spheres [6, 7]. Dental caries was considered a diet-modulated disease [8]. This factor (*i.e.*, diet) was one of the most studied in the development and prevention of dental caries, with carbohydrate intake being a major risk factor, in addition to the frequency of sweetened drinks, snacks, or candies. A Mexican cohort study found that children who consumed carbohydrates (candy, cereals and fast food) had a 6-fold greater risk of caries [9]. However, during dental caries, the biofilm microorganisms generate lactic acid as an end product, resulting in a pH drop that partially demineralizes the surface layer of the tooth [10–13].

Although dental caries and sugar consumption were linked [14], a correlation between higher food intake and dental caries remains to be determined [15]. There was little understanding of the relationship between dental caries and diet in Mexico, according to systematic reviews. The main risk factors in rural

and urban Mexican populations, respectively, were limited access to health centers and easy access to foods with high sugar content [5]. Additionally, by examining the association between diet, consumption frequency of industrial juices (fruit concentrate), sweetened drinks, ice cream, salivary pH, and dental caries among school teenagers, our research may serve as a guideline for promoting awareness and reinforcing prevention within the adolescent population.

2. Materials and methods

100 adolescents between 14 and 17 years old were analyzed for their actual caries status in this cross-sectional study. We surveyed all high school students enrolled at the Autonomous University of Mexico State between February and March 2024. We used a convenience and quota sampling method to collect data on DMFt, ICDAS, pH and diet. Each participant voluntarily participated in the review, and their legal guardians signed the informed consent form. Smokers, pregnant women, medically compromised individuals, orthodontically treated individuals, or those with dental pathological symptoms were excluded because they may exhibit pH or salivary volume variations that may contribute to the development and progression of additional dental caries. Adolescents attended the dental examination with prior dental hygiene and without having previously consumed food for 2 hours. Clinical evaluations were conducted in a mobile dental unit equipped with a dental chair and artificial lighting. All protocols have been approved by the bioethical committee of the Autonomous University of the State of Mexico (CEICIEAO-2024-027).

2.1 pH and saliva sample

Examiners collected basal saliva while adolescents were seated in the dental chair, depositing saliva for 1 minute in 15 mL Falcon tubes. At the end of the collection, samples were transported to the Biomedical Laboratory of the Faculty of Dentistry of the UAEMex to evaluate salivary pH. Each sample was inserted with a pH electrode to measure its acidity or alkalinity quantitatively (pH meter, Hanna Instruments, 3222-01, Padua, Italy) [16].

2.2 Caries detection

2.2.1 International caries detection and assessment system (ICDAS)

Dental examination examiners were previously trained and calibrated to diagnose appropriately the specific conditions and criteria established by the ICDAS [16]. The intra-rater reliability of examiners A and B was determined by reviewing 20 subjects in two periods separated by a week. In addition, 30 adolescents were evaluated for inter-rater reliability between reviewers A and B. The intraclass correlation coefficient (ICC) was obtained from intra- and inter-rater tests. Patients were assessed with a probe and air syringe, classifying them according to 7 degrees of severity as indicated by the World Health Organization (WHO) assessment system [16]. Using the number of teeth present in each patient, the average ICDAS was calculated [16, 17].

2.2.2 Decayed, missing and filled teeth index (DMFt)

After performing the examiners' calibration to correctly evaluate the DMFt index, adolescents were reviewed following the WHO guidelines. DMFt index scores were calculated by summing decayed, missing, and filled teeth of each patient and dividing by the total number of their existing teeth. DMFt was determined as follows: (Dt) teeth with a detectable carious cavity, undermined enamel, or secondary caries seen next to the filling or temporary filling; (Mt) extracted teeth due to severe caries complications; and (Ft) when at least one permanent restoration was placed as a consequence of carious lesion treatment.

We classified DMFt scores as described by the WHO into: Very low <1.2, Low 1.2–2.6, Moderate 2.7–4.4, High 4.5–6.5, Very high >6.5 [18, 19]. Similarly to the ICDAS section, intra- and inter-rater reliability tests were conducted according to the same parameters.

2.3 Diet assessment

Adolescents answered a questionnaire in an interview regarding their eating habits, which contained the following sections: (a) Liquids: unsweetened milk, unsweetened coffee, natural juice, industrial juice and sweetened drinks; (b) Spicy condiments: hot sauce, tomato sauce and lemon; (c) Snacks: potato chips, cupcakes, cookies, gelatin and ice cream; (d) Protein: chicken, meat and fish. As described in the National Health and Nutrition Survey (Ensanut, 2022). This survey instrument was applied to adolescents in the native Spanish language and was valid for the Mexican population. Data regarding liquid consumption was classified as daily consumption, with G0 being non-consumption, G1 being 1–2 days, and G2 being 3–5 days, which were reported by the patients. Consumption of spicy condiments was classified as none, little, moderate and a lot. The consumption frequency of the snacks was classified into 4 groups: G0; does not consume, G1; 1–2 days per week, G2; 3–5 days per week, G3; 6–8 days per week, and G4; 9–11 days per week. Concerning the protein group, data was collected as high, balanced and little consumption per week, determining a portion size of 100 g per event (NOM051) [20, 21].

2.4 Statistical analysis

Diagnostic methods (DMFt and ICDAS) and eating habits were analyzed using descriptive statistics. A Pearson correlation was used to evaluate the relationship between pH and ICDAS. The Odds Ratio (OR) was calculated using the contingency table method to identify the association between caries experience and the different foods and beverages that make up adolescents' diets. Data analysis was performed with SPSS 26 (IBM, Chicago, IL, USA).

3. Results

Among the adolescents, 53% were males and 47% were females, and 87% lived in urban areas and 13% lived in suburbs. The parents were 65% tradesmen and 35% professionals. The ICDAS intra-rater reliability showed a mean of 0.61 for

reviewer A during the first week and 0.68 in the second, with an intraclass correlation coefficient (ICC) of 0.97, which according to the Fleiss scale corresponds to an excellent agreement. Reviewer B recorded a mean of 0.71 and 0.70 in the first and second week, respectively, with a reliability of 0.97. Regarding inter-rater reliability, reviewers A and B evaluated 30 subjects, obtaining a mean of 0.66 and 0.68, respectively, with a reliability index of 0.97.

A mean of 2.35 obtained from intra- and inter-rater reliability for reviewer A was obtained with an ICC of 0.93. In regards to the intra- and inter-rater reliability of the DMFt, reviewer A had a mean of 2.15 and 2.25 with a reliability index of 0.89, indicating an almost perfect intra-rater reliability. An inter-rater reliability index of 0.89 was obtained by reviewer A and 2.20 by reviewer B. Mexican adolescents showed a dental caries prevalence rate of 94%, of whom 30% had a very low DMFt index (<1.2), 36% low (1.2–2.6), 23% moderate (2.7–4.4) and 11% high (4.5–6.6). No participant showed a very high index (>6.5). Despite the high prevalence of caries in adolescents, most reported lesions were not cavitated visually. There were 951 caries lesions within the posterior teeth of the 2797 dental organs analyzed (34%). DMFt scores were disclosed as follows: 769 teeth (7.69 $\pm$ 3.2 mean) as decayed, 3 (0.17 $\pm$ 0.17 mean) missing due to caries, 179 (1.82 $\pm$ 1.8 mean) filled as a result of caries infection. Based on the WHO's DMFt classification, the above information was provided. ICDAS results showed a mean of 0.58 $\pm$ 0.43, with values ranging from 0.05 to 2.17 and solely 6 adolescents without evident caries lesions (6%). The pH

assessment showed that most adolescents have a basic pH with a mean of 7.5 $\pm$ 0.67 and the volume was 1.74 $\pm$ 0.70 mL. Pearson correlation showed no significant difference between this measurement and ICDAS values ($p = 0.815$).

3.1 Consumption frequency of Mexican adolescents (eating habits)

Table 1 shows the descriptive values of the variables analyzed for adolescents' diets, considering consumption frequency per week. Adolescents consumed drinks more often, such as unsweetened milk in these analyses, industrial juice in between 1–2 portions, and sweetened drinks in between 3–5 portions per day. Most adolescents consume tomato sauce sporadically to moderately; 91% consume potato chips on a weekly basis with a frequency of 1–9 servings, and 83% consume ice cream on a weekly basis. Meat consumption was the most frequent in the balanced category at 63%, and the highest consumption recorded was 22% per week.

3.2 Analysis of the variables associated with the development of caries experience

Odd ratio test was used to determine the association between adolescents' foods and beverages and caries. A positive association of 9.24 (1.03–82.45) $p = 0.01$ was found between industrial juice consumption. This indicates that adolescents who consume industrial juice have a 9-fold higher risk of developing caries than adolescents who do not consume such drinks (Table 2). As for sweetened drinks, 1.85 (1.79–62.74) p

TABLE 1. Consumption frequency of Mexican adolescents (eating habits).

Frequency of consumption per day	Milk N = 100	Coffee N = 100	Natural juice N = 100	Industrial Juice N = 100	Sweetened drinks N = 100
G0 0[a]*	15	44	51	38	44
G1 1–2	80	55	40	37	25
G2 3–5	5	1	9	25	31
	Hot sauce N = 100		Tomato sauce N = 100		Lemon N = 100
G1 Nothing[b]*	12		20		4
G2 Little	48		47		16
G3 Moderate	40		27		51
G4 A lot	0		6		29
Frequency of consumption per week	Potato chips N = 100	Cupcakes N = 100	Cookies N = 100	Gelatin N = 100	Ice cream N = 100
G0 0[c]*	9	38	20	23	17
G1 1–2	73	48	59	54	68
G2 3–5	17	12	18	21	13
G3 6–8	0	0	0	0	0
G4 9–11	1	2	3	2	2
	Chicken N = 100		Meat N = 100		Fish N = 100
G1 High	34		22		4
G2 Balanced	62		63		19
G3 Little	4		15		77

[a]*G0—Number of times consumed per day; [b]*Added amount; [c]*Number of times consumed per week.

TABLE 2. Analysis of the variables associated with the development of caries experience.

Variables	Categories	DMFt >0 N (%)	DMFt = 0 N (%)	Odds Ratio (95% CI)
Milk				
	Yes	80	5	1.14 (0.12–4.05)
	No	14	1	$p = 0.90$
Coffee				
	Yes	53	3	1.29 (0.24–6.74)
	No	41	3	$p = 0.76$
Industrial juice				
	Yes	61	1	9.24 (1.03–82.45)
	No	33	5	$p = 0.01*$
Natural juice				
	Yes	46	3	0.95 (0.18–4.99)
	No	48	3	$p = 0.96$
Sweetened drinks				
	Yes	55	1	1.85 (1.79–62.74)
	No	39	5	$p = 0.04*$
Hot sauce				
	Yes	84	4	1.68 (0.17–15.85)
	No	10	2	$p = 0.64$
Tomato sauce				
	Yes	74	6	0.74 (0.65–0.83)
	No	20	0	$p = 0.15$
Lemon				
	Yes	90	6	0.97 (0.95–1.00)
	No	4	0	$p = 0.71$
Potato chips				
	Yes	85	6	0.91 (0.86–0.97)
	No	9	0	$p = 0.45$
Cupcakes				
	Yes	58	4	0.80 (0.14–4.62)
	No	36	2	$p = 0.80$
Cookies				
	Yes	75	5	0.78 (0.74–5.72)
	No	19	1	$p = 0.83$
Gelatin				
	Yes	74	3	3.70 (0.69–19.75)
	No	20	3	$p = 0.10$
Ice cream				
	Yes	77	6	0.84 (0.77–0.91)
	No	17	0	$p = 0.28$

*Risk factor $p \leq 0.05$. DMFt: decayed, missing and filled teeth. CI: confidence interval.

= 0.04 a 2-fold higher risk of caries was noted when comparing consumers with non-consumers. In contrast, the other foods and drinks showed no association, $p > 0.05$.

4. Discussions

Caries is a dynamic disease determined by biological and behavioral factors, resulting in the loss of minerals in the tooth's hard tissues [8]. This emphasizes the need to identify the dental health status of Mexican adolescents and its association with dietary habits.

94% of adolescents between 15 and 17 years of age had apparent caries lesions with an ICDAS ranging from 0.05 to 2.07, corresponding to initial caries. Caries experiences were reported by individuals from Poland, Greece, and China to be 55.8%, 19.9% and 36% higher than those reported by other

studies on adolescents [22–24]. Mexico had a high percentage of caries compared to other countries. In 2021, Mexican adolescents had an 88.5% caries prevalence, similar to Moreno *et al*. [4] with an 84% prevalence in permanent dentition. Romo-Sáenz *et al*. [3] evaluated a rural population and found that 98% of the participants had caries lesions. These results might be attributed to a lack of a culture of disease prevention among the Mexican population, so health policies and educational programs must be emphasized. Previous studies have shown that 53% of caries lesions affect the male gender [25]. According to this study, male participants had a prevalence of caries of 53%.

However, they have reported a prevalence of 61.3% for caries among women, with 28.1% presenting a very high DMFt [7]. Such differences can be attributed to the larger sample size of female patients in their population.

The salivary pH of all the analyzed individuals showed an average pH of 7.5, which did not present any association with respect to ICDAS with values between 0.05 and 2.17. In previous studies, salivary pH was reported at 8.03, which also failed to show a significant association with ICDAS results [21]. Studies, however, report a significant relationship between pH values between 5.85–7.69 and ICDAS values between 0.03–2.48. A major reason for this difference was that the majority of their evaluated population had lower than 2 ppm of calcium and phosphate, as well as an acidic pH, suggesting that those two characteristics could result in the demineralization of tooth enamel [16]. According to this study, salivary flow of 1.74 mL was not associated with ICDAS. Similarly, Velásquez *et al*. [26] reported a salivary flow of 1.5 mL, which did not show a positive correlation with the ICDAS. Generally, saliva flow between 1 and 2 mL is considered normal. In another study, adolescents with low salivary flow (0.25 mL) had 39% caries lesions, without significant differences compared to subjects with salivary flow greater than 0.25 mL, indicating adolescents have adequate buffer capacity, favoring dental remineralization [24].

In this study, adolescents consumed a balanced diet of recommended food groups (meat, fish and chicken). Despite fish being consumed infrequently, this study found no significant correlation between these recommended foods and ICDAS (0.50, *p* = 0.624). It is considered a non-cariogenic food group; however, when combined with cariogenic foods, it can indirectly affect oral health.

In contrast, Gaona-Pineda *et al*. [20] reported that 46% of adolescents consumed some type of dairy product. It has been found that the consumption of sweetened milk over 290 mL per day was strongly associated with the development of dental caries (OR of 1.26) [15]. According to Shi *et al*. [27], lactose was fermented into acids that were used by certain bacteria such as *Streptococcus mutans* and *Streptococcus sobrinus*.

This created an acidic oral environment that initiates dental demineralization [26]. Other researchers, however, have found a link between cow's milk and low levels of dental caries [27]. Adolescents consumed mostly sugar-free milk, so there were no significant differences here. Regarding the non-recommended groups, it is important to emphasize that adolescents in Mexico have a particular eating pattern, facilitated by an obesogenic environment. Starch in potato chips can

adhere to the teeth and cause cavities [28]. In this study, daily consumption of potato chips was higher than what was reported nationally [20]. This phenomenon was evidenced as a disadvantage of the COVID-19 pandemic [29]. Individually, 68% consume potato chips, and no significant association between potato chips and dental caries was observed [24]. In this study, 92% of individuals consumed potato chips without evidence of a significant relationship with dental caries. Although this consumption was 1 to 2 times per week, studies have reported a frequency of consumption of potato chips of 2 to 3 times a day without a significant relationship to caries [6].

Sugar should not exceed 5% of a person's total energy requirement [30, 31]. Sugar content in ketchup and gelatin contributes to caries development [32]. In this study, gelatin was consumed by 77% of individuals and ketchup by 80%; however, they did not present a significant relationship with the presence of caries.

Lemon is a favorite food for teenagers that erodes tooth enamel and increases caries susceptibility [33]. In this study, 95% of individuals consumed lemon more frequently in the moderate and high categories, but no significant relationship was observed with caries.

Approximately 80% of the analyzed individuals consumed cookies in the following way: 1–2 (59%), 3–5 (21%), and 9–11 (3%) portions per week. According to Chin-En *et al*. [34], snack consumption was associated with parent education, where higher parent education (Masters and PhD degrees) correlates with fewer snacks consumed by children. This could explain the higher consumption of snacks shown in our study.

A significant correlation was found in this study between the consumption of industrial juice and the presence of caries (*p* = 0.01) with an OR of 9.24 in the non-recommended drinks. It has been reported that industrial juice consumption was significantly associated with caries, mentioning that according to the WHO, these drinks were the main source of free sugars in many countries. The remainder of the unused sugar will contribute significantly to the development of caries if the quantity exceeds what our system requires (10% of the total daily intake) [15, 28]. Clinically, this association will manifest as erosions of the enamel caused by citrus fruit juices. Eventually, the loss of hard tissue will result in the colonization of dental caries-causing microorganisms [28].

Sweetened drinks were not recommended. Among adolescents aged 15 years, sweetened drinks consumption was associated with caries with a 1.15 OR [35]. In this study, similar results were found, identifying a significant association between sweetened drinks and dental caries (*p* = 0.04) with an OR of 1.05. Some studies, however, indicate that sweetened water consumption wasn't associated with dental caries [24, 34]. A significant association was found between industrial juice and sugary drinks and caries in adolescents. This could be explained by the fact that these drinks were consumed for an extended period of time, resulting in constant acidic oral pH and dental demineralization. 94% of these patients suffered from caries, although these lesions were considered to be initial codes 1 and 2 by the ICDAS. A remineralizing therapy should therefore be considered to prevent the progression of these lesions to codes 3–6.

Regarding the diet of adolescents, it was necessary to reduce

the frequency of consumption of industrial juices and sugary waters, raising awareness among the population about the damage these drinks cause to dental tissues, in addition to reinforcing Mexican health policies and curricula to promote prevention programs with health promotion activities. The present findings will likely be regarded as potentially cariogenic dietary guidelines in the Mexican population. The strengths of this study was the great spirit of commitment and discipline was demonstrated throughout the process of collecting samples and conducting interviews. However, the main limitations of the study were lack of funding and insufficient supplies resulted in difficulty collecting several saliva samples at different points.

5. Conclusions

It should be noted that 94% of these patients had an experience of caries, although it should be highlighted that these lesions are considered initial codes 1 and 2 according to the ICDAS criteria. Therefore, a remineralizing therapy should be considered to prevent the progression of these lesions to codes 3–6. Regarding the diet of adolescents, it is necessary to reduce the frequency of consumption of industrial juices and sweetened drinks, raising awareness among the population about the damage these drinks cause to dental tissues, in addition to reinforcing Mexican Health Policies to promote prevention programs with health promotion activities. Therefore, the present findings will be announced at dental conferences to be considered as potentially cariogenic dietary guidelines in the Mexican population.

AVAILABILITY OF DATA AND MATERIALS

The data and materials in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

AAMV, WHHM, JSZM and MJSP—they have participated in the drafting of the manuscript and in its critical review to determine its intellectual content. AAMV and ENSV—made substantial contributions to conception and design; analysis and interpretation of data. WHHM and UVE—completed the experiment and supervised the data collection. ELC and VHTR—acquisition of data. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the ethics committee of the Center for Research and Advanced Studies in Dentistry, Faculty of Dentistry, School of Dentistry, Autonomous University of Mexico (CEICIEAO-2024-027) and conducted in accordance with the Declaration of Helsinki, before the initiation of the research, the study protocol, risks and benefits, and the social impact, were fully explained to each participant and then informed consent to participate in the study was obtained from each participant or their legal guardian individually.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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