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Association between Dental Caries and Body Mass Index (BMI) among Adolescents in Urban Area of Rangpur: A Multivariate Regression Analysis

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ABSTRACT

Obesity and dental caries are two multifaceted problems that have a significant impact on health risks. Various findings about the link between dental caries and obesity have been published in studies conducted around the world. This dissertation's objective was to assess the connection between body mass index (BMI) and dental caries (DMFT) in teenagers (12 to 16 years old) in Rangpur, Bangladesh. There were 300 students in this cross-sectional survey, who ranged in age from 12 to 16 years. Dental caries (DMFT > 0) was present in 7-8% of the population. Around 16% of the students in the schools were obese or overweight. Dental caries (DMFT) and BMI were shown to be statistically significantly correlated (P = 0.008). Multivariate logistic regression indicated that, compared to those with a normal BMI, obese participants were 1.79 times more likely to exhibit healthy teeth (DMFT = 0) (P = 0.02). Additionally, it was discovered that students with greater socioeconomic position are 1.26 times more likely to belong to the group of those with healthy teeth (P = 0.005). Similar to this, when all other factors are taken into account, pupils who reported using fluoride toothpaste were 1.63 times more likely to belong to the group with healthy teeth (DMFT = 0). The amount of physical exercise has a substantial impact on schoolchildren's BMI (P < 0.001). For this study sample, the investigation found a statistically significant correlation between dental caries and BMI. Schoolchildren who were obese had better-looking teeth than their peers. Use of fluoridated toothpaste and socioeconomic status was found to be strongly related to dental caries

INTRODUCTION

In the industrialized world, obesity is currently one of the most prevalent public health issues that is becoming more and more important. Over the past 20 years, obesity rates have risen in several countries. Adolescent obesity predicts adult obesity later in life (Macek &

Mitola, 2006), and obese adults have a higher risk of illness and death later in life (Freire et al., 2019). Children and teenagers worldwide are becoming more and more overweight. Typically, the body mass index (BMI) is used to calculate an individual's weight. Obesity and overweight are significant public health issues that raise the chance of developing later-life conditions like diabetes, cancer, and cardiovascular illnesses.
Given the paradigm shift towards increased indulgence in sugary beverages and fast food, the prevalence of overweight and obesity has significantly increased in developing nations like Bangladesh. Therefore, investigating the localized, multifactorial relationship between BMI and dental caries in Rangpur adolescents is critical for developing targeted public health strategies. In recent years, obesity has reached pandemic proportions. The prevalence of overweight children was reported at 30% in 2006 (Sanyaolu et al., 2019), which is much more concerning than the European Union's average obesity rate of 15.5% (Keyes & Platt, 2024). According to CDC criteria, data on the prevalence of overweight and obesity among Portuguese children and adolescents (10–18 years old, Madeira region; 7–14 years old, Mafra) show that the prevalence of overweight ranged from 8.3% to 16% for males and 18.9% to 35% for females, while the prevalence of obesity ranged from 15% to 26% for males and 12.2% to 20% for females (Frias-Bulhosa et al., 2015).

According to some research, the prevalence of childhood obesity and overweight increased from two to five times in wealthy nations and by as much as four times in underdeveloped nations. Theoretically, dental caries can be brought on by overweight and obesity due to a higher availability of cariogenic substances that can be controlled by oral hygiene practices (Theoretically, dental caries may be caused by overweight and obesity due to higher availability of cariogenic substances that can be controlled by oral hygiene practices). Given the link between dental caries and refined carbohydrates, it is reasonable to assume that being overweight in kids and teenagers may be a symptom of dental caries. The side effects of obesity will indirectly affect oral health, but this alone does not justify this condition. Both dental caries and obesity are multifactorial diseases with complex aetiologias that are linked to things like dietary practices, food availability, oral hygiene, and saliva. Drinks and foods high in sugar are linked to a number of health issues, including obesity and dental caries. Although one comprehensive study found inconsistent results, in most pediatric populations, dietary habits of overweight and obese children may indicate risk of dental caries. Two studies found that obese and overweight teenagers had higher rates of dental caries than those of normal weight, a third found that dental caries was only connected with an increase in BMI in 12-year-old children, and a fourth found that dental caries was only associated with primary dentition. In a recent study, it was discovered for the first timethat there is a correlation between the prevalence of dental caries and body fat percentage as determined by dual energy X-ray absorptiometry (DXA) (Swaminathan et al., 2019). This correlation was attributed to the pediatric population's misclassified adiposity status as determined by BMI as opposed to DXA.

In the past decade, there has been a notable shift in global consumption patterns, with more people opting for soft drinks and fast food. This change in dietary habits has had a significant impact on the diets of individuals. It has been observed that a higher intake of sugar is more prevalent among overweight and obese adolescents compared to those who maintain a normal weight. However, it's important to note that frequent sugar intake is also acknowledged as a risk element for the development of dental cavities, as stated in Macek and Mitola's research from 2006. When it comes to children and teenagers aged 2-20 years, their levels of body fat change as they grow, and these changes vary between boys and girls. Unlike the body mass index (BMI) assessments designed for adults, assessments for children and teenagers consider these growth-related and gender-specific differences. These age-and gender-specific BMI values are referred to as “BMI-for-age”. The

classifications used to describe the levels of body fat in children and teenagers differ from those used for adults. BMI categories for children and teenagers (in common with adult classifications) include underweight, normal weight, being at risk of overweight, and being overweight (Chen et al., 2018). Notably, there is no specific "obese" category designated for children and teenagers (De Onis & Lobstein, 2010; André Kramer et al., 2019; Kumar et al., 2017). In adults, there have been suggestions of a link between weight and oral health, but the available evidence for this connection in children is scarce and, in some cases, contentious (Pinto, 2007). While the quality of oral health is influenced by the daily consumption of appropriate foods, it's important to note that oral health can also have a significant impact on an individual's nutritional intake and overall health status. Both dental caries and obesity are tied to dietary patterns (Reddy et al., 2019). It is a well-established fact that there is a strong correlation between dental caries and the frequent consumption of refined carbohydrates. The World Health Organization (WHO) emphasizes the need to prioritize nutrition in public health policies and programs. This is because foods that are high in sugar contribute to both obesity and dental diseases (Mallik, 2025)). Interestingly, certain studies have reached a conflicting conclusion, stating that there is no substantial correlation between dental caries and obesity (Macek & Mitola, 2006).

However, considering the established cause-and-effect relationship between the consumption of refined carbohydrates and the development of dental caries (Jamelli et al., 2010), it is reasonable to propose that an escalating BMI-for-age could potentially serve as an indicator for dental caries in adolescents. While studies elsewhere are inconclusive, a significant research gap exists regarding the statistically controlled association between BMI and dental caries among adolescents in Rangpur, Bangladesh. This study addresses this gap by utilizing multivariate logistic regression to provide the first such localized evidence in this population. Hence, the primary objective of this study was to investigate the connection between dental caries and BMI-for-age in adolescents residing in the urban area of Rangpur, and to assess the roles of co-factors such as age, gender, socioeconomic status, and sugar consumption in this relationship using a multivariate approach.

METHODS

Data Collection and Hypothesis

This study aimed to explore the connection between Body Mass Index (BMI) and dental cavities in 12 to 16-year-old students from Rangpur, Bangladesh. It also looked at how age, gender, socioeconomic status (SES), dietary habits, and sugar exposure play a role in this connection. To collect data, a questionnaire was used, based on the WHO's oral health survey method, covering demographics, oral hygiene habits, parents' education, sugar intake, and physical activity. The students themselves filled out the questionnaire on the same day before getting dental check-ups and measurements. During the dental check-ups, we used disposable mouth mirrors, dental probes, and protective gear to maintain hygiene. After each examination, we safely discarded these tools to prevent infections. The students sat in a tall chair while the examiner stood in front of them. We noted information about teeth with decay, missing teeth due to cavities, or filled teeth because of cavities, which we referred to as DMFT. A tooth was considered decayed if it met any of these criteria.

1. A lesion found in a groove, crevice, or on a flat tooth surface that clearly exhibits a cavity, weakened enamel, or a noticeably softened wall or base.
2. When the crown has been destroyed by caries and only the root is left.
3. Tooth with temporary or permanent restorations but decayed.

A tooth was categorized as "filled" when it had one or more permanent restorations but showed no signs of caries anywhere on the crown. If a permanent tooth had to be extracted

due to caries, it was labeled as "missed" (Alswat et al., 2015). Any tooth lost for reasons other than caries, such as trauma, was not included in the documentation.

List of variables

Dependent variables

1. Dental caries status
2. Body mass index

Independent variables

1. Age
2. Gender
3. Religion
4. Educational status
5. Monthly family income
6. Family type
7. Smoking habit
8. Tooth brushing habit

Study design

This study utilized a cross-sectional, observational study design. The research was conducted in an urban area of Rangpur Metropolitan City, Bangladesh. The specific study site was the Shishu Niketon High School, a government-run high school chosen for convenience and accessibility in the metropolitan area. A total of 300 students participated in the study.

Sampling Method

A purposive sampling approach was employed to select the study participants. This non-probability sampling method involved intentionally selecting students based on predefined selection criteria and the cooperation of the school administration, as the study was geographically focused on a specific urban cohort.

Study area

The study was carried out in a school at the Rangpur metropolitan city. For this study a government high school is selected. The name of the school was Shishu Niketon High School. The school was select purposively.

Study population

To ensure a focused and relevant sample, the following inclusion and exclusion criteria were applied:

Inclusion Criteria:

1. Students enrolled in Classes VII, VIII, and IX at Shishu Niketon High School.
2. Students within the age range of 12 to 16 years.
3. Provided written informed consent from their parent or guardian and written assent from the student themselves to participate in the study.

Exclusion Criteria:

1. Students with any known systemic diseases (e.g., diabetes mellitus, diagnosed hormonal disorders) that could directly affect BMI or dental health.

2. Students currently undergoing fixed or removable orthodontic treatment.

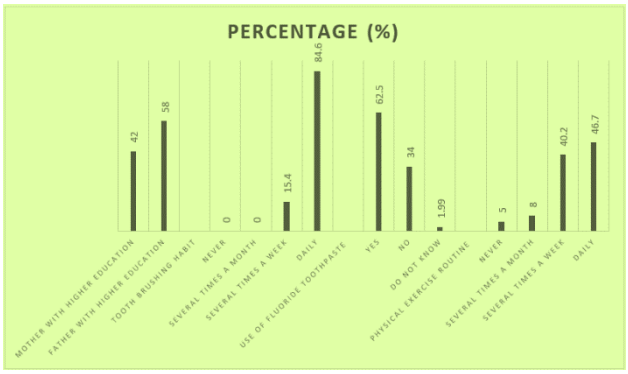


Figure 1. Result from the questionnaire (n = 300)

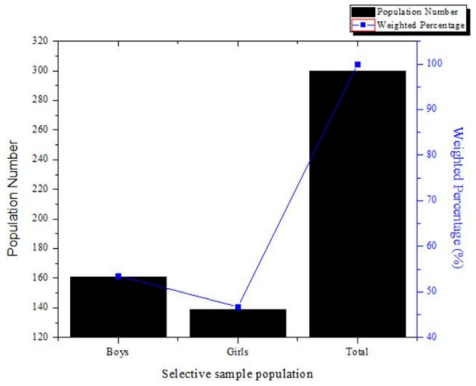
Methodology

Date was analyzed using MATLAB and Origin Pro software. Principal component analysis (PCA) was utilized to estimate composite scores for socio-economic made from parental education and suburban location of residence. Standardized sugar consumption score was made from eight food items, which the school children were asked about. To better grasp the connection between dental caries, BMI, and various other factors, we created a binary variable (DMFT = 0 compared to DMFT >0) and then conducted a multivariate logistic regression analysis. In addition, multivariate logistic regression model was used to explain the relationship between the DMFT and the rest of the predictors. Moreover, multivariate linear regression was conducted to model the relationship between BMI and socio-economic score, sugar consumption and the other relevant predictors. The results were expressed as odds ratios (ORs) with 95% confidence intervals (CIs) and alpha levels were set to 0.05 for all the tests throughout the analysis.

The plan of this study was to assess health literacy status among school students. Sample size was calculated from study population by using the formula:

$$n = \frac{z^2 pq}{d^2} \quad (1)$$

Where, n = desired sample size, success rate, p = 0.5 (as there is no reasonable estimate of any prevalence rate, we use 50%), failure rate, q = 1, p = 1, 0.5 = 0.5 or 50%, d = degree of error (absolute precision of the study assumed 0.05), z = the reliability coefficient at the 95% Confidence Interval = 1.96. Hence the sample size was as follows, 1.96^2 x 0.5 x $0.5/0.5^2$



= 384.16 ~ 384 Thus, the required sample size is 384. Finally, the sample size was taken 300.

Figure 2. Sample selection criterion

Table 1. Algorithm of data acquisition

Personal BMI and dental issues on selected samples		
Boys	**Girls**	**Total**
Age- 11-15 yrs. (Adolescent)		
Influencing factors		
Body-Mass-Index	**Dental Issues**	
1. Weight of individual Samples 2. Underweight (<45 kg) 3. Normal (45-47.9 kg) 4. Overweight (48-55 kg) 5. Obese (>55 kg) 6. Height of individual Samples 7. Short (<1.5 m) 8. Normal (1.51-1.58 m) 9. Tall (≥1.58 m)	1. Decayed (Caries) 2. Missing 3. Filled	

Data collection technique

Data were collected through both a structured questionnaire and clinical dental examinations. Anthropometric measurements (height and weight) were taken to calculate Body Mass Index (BMI). Dental caries status was assessed by a trained and calibrated examiner using the DMFT (Decayed, Missing, Filled Teeth) index, following the standard criteria set by the WHO.

Data Quality Assurance

To ensure the quality and rigor of the collected data, the following steps were implemented:

1. Questionnaire Validity: The questionnaire used to collect socio-demographic factors, dietary habits, and oral hygiene practices was adapted from the globally recognized WHO Oral Health Surveys: Basic Methods (5th Edition, 2013). This established strong content validity, ensuring the instruments measured the intended variables.
2. Intra-Examiner Reliability: Before the main survey, the principal investigator was calibrated for dental examination procedures. Intra-examiner reliability for the assessment of dental caries (DMFT) was calculated using the Kappa statistic on a sub-sample of 10 students. This procedure yielded a substantial agreement of Kappa = 0.89$ (or 89.2% agreement), confirming the consistency and dependability of the clinical data.

Statistical Analysis

Hypothesis

The primary hypothesis was that a statistically significant association exists between Body Mass Index (BMI) and the prevalence of dental caries (DMFT > 0) among adolescents in Rangpur.

Justification for Statistical Methods

The analysis was performed in two stages to address the study's complex objectives:

1. Multivariate Logistic Regression (Primary Analysis): This model was employed to investigate the primary objective: determining the odds of having healthy teeth (DMFT=0) or experiencing dental caries (DMFT>0). As the outcome variable (caries status) is dichotomous (Yes/No), logistic regression is the appropriate method. It allowed us to control for potential confounding factors (e.g., age, gender, socioeconomic status, sugar consumption) while isolating the true effect of BMI.
2. Multivariate Linear Regression (Secondary Analysis): This model was used as a secondary analysis to assess the roles of co-factors. Specifically, it was employed to determine the independent effect of socio-demographic and behavioral factors (e.g., physical exercise, sugar consumption) on the continuous outcome variable, Body Mass Index (BMI). This provided a more comprehensive understanding of the determinants of weight status within the study population.

The level of statistical significance for all tests was set at $P < 0.05$. Data analysis was performed using [Origin Pro 9x].

RESULT AND DISCUSSIONS

Overall, 300 students were included in the study. All of them were males and they came from the selected school in Rangpur. The school children were from the same age group with minor variations in age. The youngest child was 12 years and the eldest was 15 years old. The results from the questionnaire are summarized in Table 1. The frequency of sugar-containing food consumption for the selected eight food items is shown in (Figure 2a) . In this sample, the prevalence of dental caries (DMFT > 0) was 54.1% (Fig. 2b). Most of the school children (43.2%) had a BMI falling within the normal expected range for this age group. Around 32% of the school children were either overweight or obese. The rest of the school children were underweight (24.8%) (Fig. 2c). Intra examiner validity was calculated, and it was 89.2%. The results of the multivariate logistic regression model indicated a statistically significant link between dental caries (DMFT) and BMI ($P = 0.008$). As the BMI increases, the probability of having healthy teeth was increased (Fig. 2). It was found that obese school children are 1.79 times higher to be with healthy teeth (DMFT = 0) when compared to those who had BMI within normal range ($P = 0.02$). In addition, it was found that school children with higher socio-economic status are 1.26 times higher to be with healthy teeth group (DMFT = 0) than those who are less ($P = 0.005$) (Table 2).

Similarly, school children who reported that they are using the fluoridated toothpaste were 1.63 times higher to be within the healthy teeth group (DMFT = 0) when everything else is controlled (Table 2). Conversely, when considering all other factors (Table 2), it was projected that children who had a higher consumption of sugary products like candies, biscuits, and soft drinks would tend to have poorer dental health (DMFT > 0). Notably, the level of physical activity did not show a significant connection to the condition of their teeth. A multivariate linear regression model was conducted to understand how predictors like socio-economic score, standardized sugar consumption and the physical activity level affect the school children's BMI. The latter predictor demonstrated a significant negative association ($P < 0.001$) with the BMI of the schoolchildren when all variables were taken into consideration. It's important to note that neither the socio- economic score nor the standardized sugar consumption had a significant correlation with the BMI of these school children.

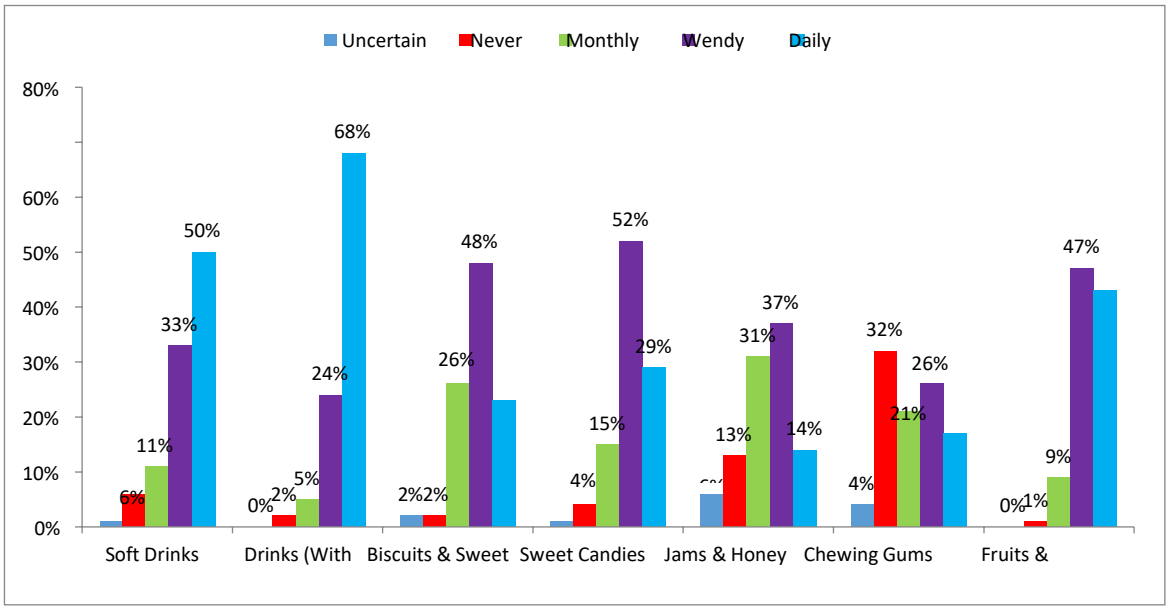


Figure 2 (a): Sugar consumption

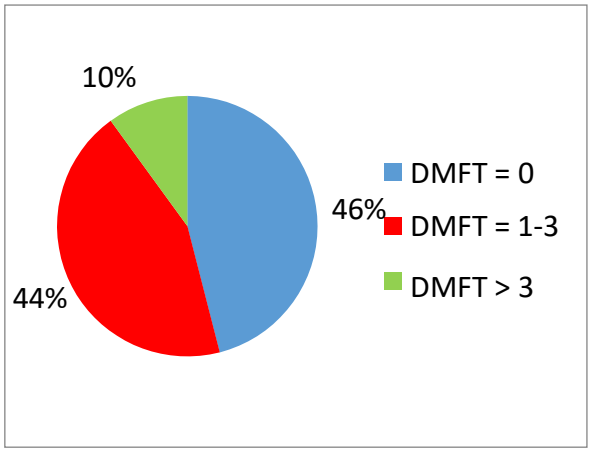


Figure 2 (b): DFMT Scores

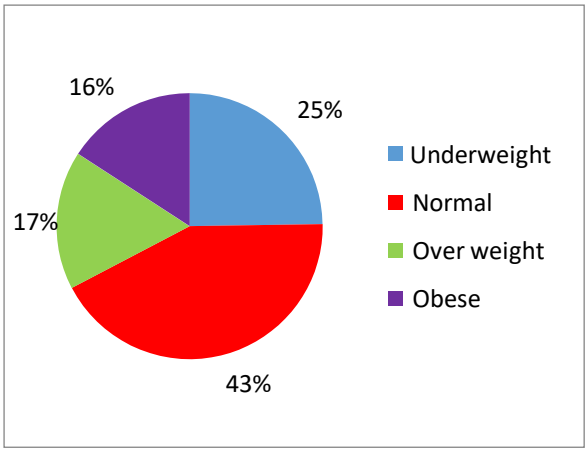


Figure 2 (c): BMI

Table 2. BMI factors analysis on selected samples

Variants	Height factor	Limits (m)	Constituents (B, G, T.A.)	Weight factor	Limits (kg)	Constituents (B, G, T.A.)	Avg. factor (B', G', T.A.')
Boys	Short	<1.63	(17,42,30)	Underweigh t	38-44.99	(27,16, 22)	(1.23, 0.72,1)
Girls	Normal	1.63-1.65	(112,90, 101)	Normal	45-47.99	(118,91, 105)	(1.12, 0.93,1)
Avg. Total	Tall	>1.65	(32,7,20)	Overweight	48-54.99	(14,27,21)	(0.52, 1.29,1)
				Obese	>55	(2,5,4)	(0.5,1.25 , 1)

By applying De-Morgan's set theory, the dental issues can be converted into some sets of numbersfrom which on drawing a Ven-diagram the independent and dependent the dental issues can be filtered out. After the data sorting, the set networking and von diagram was carried out factoring DMFT issues which includes separately D – issues, M – issues, F – issues and ∅ (Null) – issues (Figure 3). Let us consider,

Total Sampled Students, U = $D^c \cup M^c \cup F^c = \{D, M, F, \emptyset\}$ = 300

Sample having only D – issues = $U \cap D^c = \{D\}$ = 23 (B-13, G-10, T.A.-12)Sample having only M – issues = $U \cap M^c = \{M\}$ = 2 (B-1, G-1, T.A.-1) Sample having only F – issues = $U \cap F^c = \{F\}$ = 24 (B-13, G-11, T.A.-12) Sample having DM – issues = $D^c \cap M^c = \{D, M\}$ = 6 (B-2, G-4, T.A.-3) Sample having DF – issues = $D^c \cap F^c = \{D\}$ = 6 (B-1, G-5, T.A.-3) Sample having MF – issues = $M^c \cap F^c = \{M, F\}$ = 4 (B-2, G-2, T.A.-2)

Sample having DMF – issues = $D^c \cap M^c \cap F^c = \{D, M, F\}$ = 4 (B-3, G-1, T.A.-4)

Sample having no – issues, $\emptyset = U/(D^c \cup M^c \cup F^c) = \{\emptyset\}$ = 232 (B-126, G-106, T.A.-116)

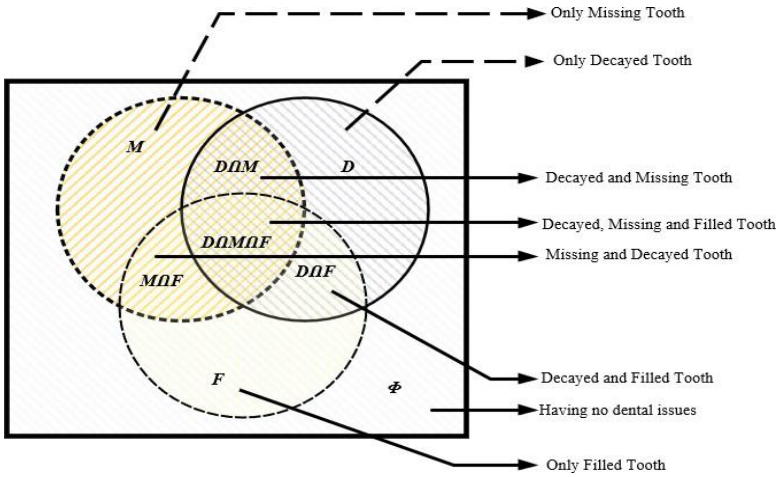


Figure 3. Ven-diagram of dental issues among the sampled students with respect to possibleentities of bad issues focused on DMFT (Decayed, Missing, and Filled Tooth) analysis.

Here, the total possible dental causes can be easily determined by applying the simple theories ofpermutation and combination. As the root causes are mainly 3 variants thus it is possible to have a total permuted combination (${}^nP_r$ + ${}^nC_r$) which is summed to $2! + \frac{2!}{1!(2-1)!}$ or 8 possible ways. Those eight fuzzy ways determines the selection criterion for dental issues based on sampled data(Table 4).

Table 4. Dental issues analysis on selected samples

Dental Issues / Variants	D	M	F	DM	MF	DF	DM F	φ	Cumulative Index, (per capita)	Mean Cumulative Avg
Boys	13	1	13	2	2	1	3	126	126/161 = 0.7826	0.7728
Girls	10	1	11	4	2	5	1	106	106/139 = 0.7626	
Avg. Total inper capita (Avg./2)	12	1	12	3	2	3	2	116	116/150 = 0.7733	

Table 5. shows that DMFT distribution based on multiple sequential variables (Babu, 2019; Folayan et al., 2019; Hamasha et al., 2019; Hallett et al., 1995; Ashi et al., 2019; Petersen et al., 2005).

Table 5. DMFT Distribution based on multiple sequential variables

All	n	Mean (Std. Deviation)	Median	Min-Max	P
	181	4.0 (2.8)	4 (2-6)	0-12	
Gender					0.213
Female	91	4.3 (2.5)	4 (2-6)	0-12	
Male	90	3.8 (2.7)	3 (1.8-5.3)	0-11	
Schools					0.764
Sobrado (Portugal)	132	4.1 (2.8)	3.5 (2-6)	0-12	
Rangpur (Bangladesh)	300	2.73 (1.68)	3.11 (2.9-5.9)	0-11	
Tehran (Iran)	49	3.9 (2.7)	4 (1.5-6.5)	0-9	
Oral hygiene frequency					0.065
<Once/day	0	5.1 (2.65)	4 (3-8)	2-9	
Once/day	231	4.42 (2.88)	4 (2-7)	0-11	
Twice/day	60	3.4 (2.71)	5 (2-8)	0-12	
>Twice/day	9	2.13 (2.9)	2 (3-5)	0-5	
Oral hygiene timings	**Morning**				0.625
Yes	289	4.1 (2.6)	4 (2-6)	0-10	
No	11	4 (2.87)	4 (2-6)	0-12	
Oral hygiene	**Afternoon**				

timings					0.225
Yes	16	4.1 (2.6)	4 (2-6)	0-10	
No	260	4 (2.87)	4 (2-6)	0-12	
Oral hygiene timings	**Night**				0.273
Yes	87	4.1 (2.6)	4 (2-6)	0-10	
No	213	4 (2.87)	4 (2-6)	0-12	
Age selective BMI					0.321
Underweight	44	6.3 (3.2)	6.5 (3-8)	3-11	
Normal	210	4 (2.6)	4 (2-6)	0-12	
Overweight	42	3.9 (2.7)	3 (3-7)	0-8	
Obese	8	3.72 (3.05)	3.4 (1-4)	0-5	

Based on the resulting data, as the logics had been fuzzified earlier thus the solution should be de-fuzzified to fulfill the analysis consisting both BMI and Dental issues. Figure 4 to 7 shows the influencing factor analysis based on selected parameters of evaluation. Table 6 below depicts the de-fuzzified logical solutions based on the previous association of BMI and Dental Caries.

Table 6. De-fuzzified logical solutions based on association between BMI and dental caries on adolescent samples

Fuzzy variants	**Possible logical solutions**			
Body-Mass-Index (Weight in kg / (Height in m^2)	18.5-24.99, t	18.5-24.99, t	<18.5 or >25, ↓	<18.5 or >25, ↓
Dental Caries (D-Issues)	7-8%, ↓	>8%, t	>8%, t	7-8%, ↓
	Normal	Poor	Very Poor	Transitional

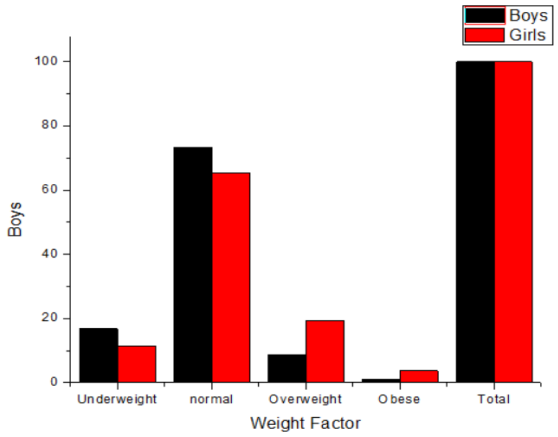


Figure 4. Influencing factor analysis on 'weight factor'

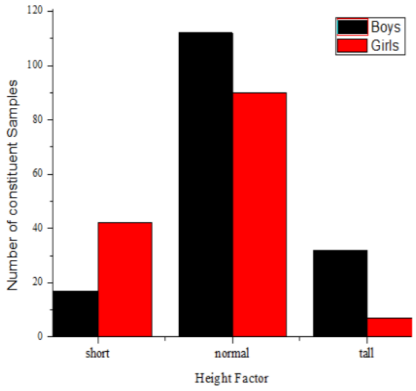


Figure 5. Influencing factor analysis on 'height factor'

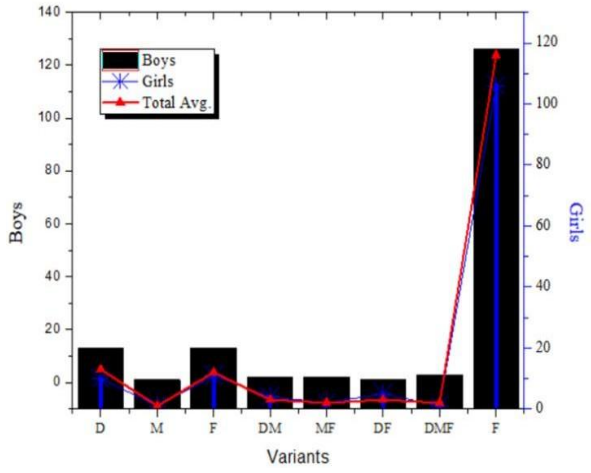


Figure 6. Influencing factor analysis on 'dental issues'

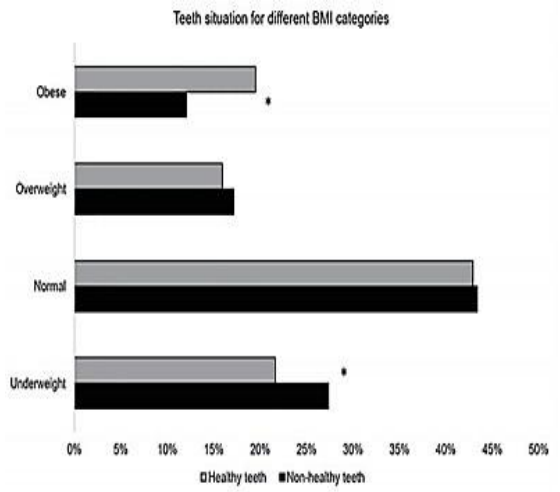


Figure 7. Influencing factor analysis on 'percentage of having either a healthy tooth (DMFT = 0) or non-healthy tooth (DMFT>0) for the different BMI categories'

The connection between adolescent obesity and dental caries did not show a statistically significant link, which aligns with findings from other studies (Petersen et al., 2005; Chen et al., 2018; Cinar & Murtomaa, 2011; Granville-Garcia, 2008). However, in this relationship between BMI-for-age and DMFT, the oral hygiene habits held greater statistical significance. This suggests that the varying results reported over time may, to some extent, be influenced by how frequently and consistently daily oral hygiene practices are carried out.

The DMFT values did not show significant differences between schools ($p = 0.764$, Table 5), suggesting a similar nutritional profile among teenagers in the region. When examining the distribution of DMFT severity across BMI-for-age categories, the limited number of cases in the extreme quartiles made it challenging to identify any correlation, and this also applies to individual components of the DMFT index. These findings align with previous research conducted in various populations (Yen et al., 2021; Suresh et al., 2023; Gunay et al., 2023;

Kor et al., 2021; Sasikala et al., 2021), which did not find any association between obesity and dental caries in permanent teeth. Our analyses provide no indication that 13-year-old overweight children are at an elevated risk for dental caries.

CONCLUSIONS AND SUGGESTIONS

While the initial findings don't show a direct connection between dental cavities and obesity, it's important to recognize that both conditions have common factors and require a comprehensive approach involving different healthcare experts. So, it's recommended for pediatric dentists to be part of the team caring for obese children. From the survey and numerical data analysis, it was found that around 70-80% of the students sampled, both boys and girls, were in good health without dental cavities. Even though dental cavity rates were relatively low at about 8% for boys and 7.2% for girls, it's vital to be cautious because cavities can have a significant impact on the future well-being of both genders, affecting their dental health and appearance. Likewise, concerns about Body Mass Index (BMI) are important since weight and growth-related issues can lead to malnutrition, obesity, and serious health problems like diabetes and high blood pressure.

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