

parents of the participants. The results showed that a number of children consuming sea food, cod liver oil, and vitamin-D-fortified milk less than once a week were at significantly higher risk for dental caries compared with those without caries. Highlighting that being female, overweight/obese and having a household income over US\$2,747 ($\geq 10,000$ QAR) per month was an independent risk factor for dental caries [25].

In the summary, most aforementioned studies were cross-sectional studies, which makes establishing the relationship between BMI and dental caries slight challenging. However, conducting several small studies like a cross-sectional study can help in providing a good future base for big studies. For instance, establishing the prevalence of the disease and exploring risk factors. In addition, to observe the changes over time, a longitudinal study is also required.

The relationship between BMI and Dental caries

All the studies that are available in the literature evaluated the association between dental caries and BMI though the results were contrasting.

Positive association between BMI and dental caries

Some studies have shown a positive association such as, Willerhausen [26] mentioned a statistically significant association between BMI and dental caries after adjustment of age. The author noticed that 44.7% of underweight and 40.7% of normal-weight children had healthy natural teeth compared to overweight and obese children 30.5% and 31.7%, respectively [26].

Severe Early Childhood Caries (S-ECC) was linked to BMI in a case-control study. Two groups of children were matched on age and gender; 100 children with caries S-ECC subjects (50 boys and 50 girls) and 100 caries-free subjects (50 boys and 50 girls). The study showed a positive association between BMI and S-ECC, 51% caries-free and 45% S-ECC low weight children [27].

Yao [28] reported a positive relationship between BMI and dental caries in a cross-sectional study, which was conducted on primary school children ($N=67,956$) of 5-14 years of age in the Wannan area, China. Dental caries data were collected from routine health screenings conducted between 2009 and 2013 and trained staff supervised by school nurses recorded BMI. Statistical analysis was performed by multivariate logistic regression, potential confounders, including age and gender, were adjusted.

The study findings showed that obese children have 1.908 times (OR =1.908; CI 95% = 1.750, 2.079) more caries development compared to low or normal-weight children. Overweight children were 1.547 times (OR = 1.547; CI 95% = 1.479, 1.618) more likely to experience caries when compared to underweight children or of a healthy weight. In addition, a statistically significant association was detected between year, grade, BMI categories and caries after

adjusting for gender and age [28]. The study result is relevant and precise because the odds ratio is more than one and the confidence interval is narrow and did not include zero. Nevertheless, using routine screening in the detection of dental caries may lead to underestimating the prevalence of dental caries, as the examination of dental caries needs good lighting and cleaning and drying of the tooth surface, particularly in the early stages of dental caries.

Caries experience could be a future marker of being overweight in children. Lampert S.M (2014) evaluated the relationship between dental caries, BMI and subsequent change over a 6-year period of time and aimed to assess whether social classes altered these correlations. Data were collected from the European Youth Heart study and combined with data on caries from the Danish National Board of Health. Twenty-six percent of children/adolescents were caries-free at the beginning of the study and 39% at follow-up. Linear regression analysis was performed, showing that there was no association between caries and BMI or subsequent changes in BMI over 6 years of follow-up. Although, there was an inverse relationship between caries and BMI at the beginning of the study and subsequent changes over that period among children whose mothers were highly educated. The study reported that caries level might be a future marker for being overweight/obese to advantaged children while it may not be important among non-advantaged children. However, the author pointed out that the number of participants was low, which may overestimate the result. Thus, more studies need to be conducted to provide further evidence [29].

A longitudinal relationship between dental caries and obesity was assessed in a large cohort study in Hong Kong. The study recruited 668 participants aged 12 years old. The study extended 3 years with 2 rounds follow up. They reported that participants with high caries index have high BMI [30].

A descriptive study also found a positive association between BMI and dental caries. They noted that people with high weight and obesity tend to have advanced dental caries lesions, this was more associated with elderly women [31]. This might give a message that dental caries and BMI share same common risk factors.

Lack of the association between BMI and dental caries

On the other hand, a lack of association has been shown in other studies. Macek and Mitola [32] reported that there was no association between dental caries and BMI. All covariates were controlled in this case-control study, including age, race/ethnicity, gender, and poverty. Data were collected from the National Health and Nutrition Examination Survey (NHNES) 1999-2002 in the USA, and the analysis was limited to children aged 2 to 17 years old. Despite the study hypothesis expected to find an association between age-specific BMI and prevalence and severity of dental caries, this relationship was not found [32].

Furthermore, Kopycka-Kedzierawski [33] in another study in the US identified the lack of this association. The National Health and (NHNES) 1999-2002 (the same source used in the aforementioned study) and the National Health and Nutrition Examination Survey (stage III) 1988-1994 (NHNES III) were used in this study. Potential confounders were controlled and logistic regression was carried out for 10,180 children aged 2-18 years from NHNESIII 1988-1994 and 7,568 children aged 2-18 years from NHNES 1999-2002 [33]. The two surveys provide no association. Even though these two previous studies conducted two different types of study designs, the results of both studies were consistent.

Additionally, Mojarad and Maybodi [34] had pointed out the lack of any association between obesity and dental caries in a cross-sectional study. A cluster random sample of 1,000 pupils was recruited, including 500 boys and 500 girls aged 6-11 years. After collecting and analyzing the data, the prevalence of dental caries was found to be higher in normal-weight children than in overweight children. Furthermore, 11.8% of underweight, 66.7% of normal weight and 9.8% of overweight children were caries-free but at risk of obesity [34].

Furthermore, a cross-sectional study was carried out in the Netherlands. This study aimed to assess the relationship between BMI and dental caries in children aged 5 to 8 years attending dental pediatric referral practice [35]. Two hundred and thirty children were recruited with a response rate of 98%, and a mean age of 7.0; 56.5% were girls. Dental caries experience was collected from a routine clinical examination supported with x-rays and using dmft and dmfs as indicators. Trained dentists using weight divided by height squared recorded BMIs. Additionally, sociodemographic information was gathered, including child's age, sex, ethnicity and mother's level of education. In the result, there was no statistically significant association between BMI and dental caries, despite the fact that the study was hypothesized to find a positive correlation. Although this study had some strength such as a high response rate (98%) and high prevalence of dental caries (80.4%), there were weaknesses as well. One of these limitations was that the result cannot be generalized to that population because the study subjects were selected only from a pediatric referral center and children with emotional and behavior issues were excluded. Another weakness was in the referral process; some parents were asked to refer their children instead of general dental practitioner (GDP) choices, this might increase the number of caries-free children. Furthermore, not all participants were examined by x-ray. The last two factors might have underestimated dmft and dmfs prevalence [35]. The result of this study was consistent with a cohort study that aimed to assess if dental caries can be a predictive for adolescent obesity or not. The study reported that there was no correlation between BMI and dental caries [36].

Inverse association between BMI and dental caries

The severity of obesity can also the oral health status. These relationships were investigated in some studies. The severity of obesity has a huge impact on caries level among obese individuals. This has been shown in a case-control study, aimed to assess caries experience in an adolescent population who were treated for severe obesity. Two groups were compared in this study: severely obese adolescents (n=41) and non-obese adolescents (n=41). Two groups were matched on age, gender, and socio-occupational categories. A Non-parametric test was used to evaluate the relationship; BMI and DMFT correlation were significant (p-value <0.001) in the obese group. In conclusion, severely obese children were found to be experiencing a high level of dental caries [37].

The level and severity of dental caries can be an indicator of BMI. The severity of dental caries may affect the weight of children, especially if associated with odontogenic infections. This relationship was presented in a representative cross-sectional study in a Filipino population [38]. This study was based on population classifications of the Philippines, using modified and stratified cluster sampling. The sample consisted of 1,951 schoolchildren aged 11-12 years from all 17 regions of the country. Caries was measured according to WHO criteria (WHO, 1997) and trained nurses measured BMI while socioeconomic status was taken into account as a potential confounder. In addition, the pulp, ulceration of soft tissue, fistula, and abscess (PUFA) index was used to determine infectious status.

In the result, the overall prevalence of caries (DMFT, dmft) was found to be 80.6% and prevalence of odontogenic infection (PUFA) was 55.7%. The BMI of 27.1% of the children was underweight and only 1% was overweight. The research concluded that children with an odontogenic infection had a high risk of reduced weight under normal conditions compared to those who did not have an odontogenic infection (odds ratio 1.47, CI 95% 1.19-1.80) [38].

Additionally, caries development among low weight children was stated in a population-based cross-sectional study [39]. The study was carried out in Southern Sweden and assessed 920 children at age 5 years. It emphasized that low weight children might be linked with eating habits that put them at risk of caries development. Although the result of the study was representative of the target population, such a study design cannot establish the cause-and-effect relationship, and the author recommended that a longitudinal study design would provide a piece adequate evidence.

In addition, reverse correlation was reported in a longitudinal study. The participants were followed up at three points; at birth, 18 months, and six years of age. It was a part of twin cohort study in Australia. The study concluded

that children with low BMI were associated with high caries index [40]. This is consistent with a Chinese study that assessed the bidirectional relationships, found that low weight children were exposed to more dental caries [41]. In contrast, Pérez [42] reported that people with high BMI experienced less dental caries in a cross-sectional study that included 522 school children selected from public schools. Thus, the relationship between dental caries and BMI might occur in different ways.

Effects of obesity on oral health

Obesity has an impact on oral health, such as reduced saliva flow, which is a contributing factor to the development of dental caries. In a cross-sectional study, the effect of childhood obesity on reducing saliva flow was investigated. Two groups were recruited: obese adolescents (n=65) and normal weight (n=65) at mean age 14.5 and 14.2 years, respectively. A well-designed questionnaire was used to collect potential factors, including food intake, education, oral hygiene, sociodemographic situation and medical status. Clinical examination included dental caries (DMFT), dental plaque using the visible plaque index (VPI), bleeding on probing for gingival inflammation and saliva flow. Saliva was collected 2 times in the morning and afternoon, paraffin wax was given to participants to stimulate saliva and then collected in a test tube and calculated ml/min. After analyzing the data, an association was found between Obesity and saliva flow. The saliva flow rate was 2.0 ml/min for normal weight compared to 1.2 ml/min for the obese group. However, this study had a limitation in that saliva samples were taken at two different times which may have an effect on saliva flow rhythm [43].

Furthermore, obesity may have an effect on the nature and characteristics of saliva that reflect negatively on oral health and dentition. This relationship was highlighted in a case-control study in India. The study aimed to assess the antioxidant level of saliva, dental development and oral health in childhood obesity. The sample consisted of 120 participants aged 6 to 12 years selected randomly from several private schools. The subjects were divided into two groups and based on age and sex: 60 overweight/obese and 60 control or normal-weight participants. Phosphomolybdc acid and the spectrophotometric method were used to determine the total antioxidant capacity level (TAC). For oral health status, oral hygiene index-simplified, modified gingival index and dentition index was used, while dental development was examined clinically [44].

After the analysis, the study group (obese/overweight) was found to have very high levels of TAC compared to the control group. There was no difference in terms of oral health status in both groups. Dental development was relatively less in the obese group, which was not statistically significant. In conclusion, it was identified that salivary TAC and prevalence of dental caries were higher among the overweight/obese group than the normal weight group [44].

Despite the significance of the study findings, this research has some weaknesses. Firstly, the study population was selected from private schools only, which might introduce selection bias and not be representative of the other populations. Another point is that although the study groups were matched on age and gender, other potential cofounders include sweat intake, brushing habit and use of fluoride, which were not considered in the study design or at the analysis stage. This could have affected the result, especially the prevalence of dental caries.

CONCLUSION

In summary, several studies were conducted in different countries to investigate the relationship between BMI and dental caries, and explore the risk factors for both conditions. Most of the aforementioned studies had shown that overweight/obesity and dental caries were sharing common risk factors such as diet (particularly sugar), socioeconomic status, and lifestyle. Some of these studies revealed that there was no relationship between BMI and dental caries. The WHO guidelines have shown that free sugar contributes energy density of the diet and leads to a positive energy balance. Sugar is an important component of the diet in terms of balancing healthy body weight and ensuring ideal nutrient intake. However, there is concern raised towards the rise of free sugar consumption, specifically sugar-sweetened forms of beverages, which may lead to an increase the overall energy and decrease the other food components, thus leading to an unhealthy diet. In addition, consuming free sugar in large amount promotes weight gain and creates dental caries lesion. In recommendation, more longitudinal studies need to be conducted to understand the common risk factors between dental caries and obesity.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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