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ORIGINAL ARTICLE

# ASSOCIATION OF SWEET TASTE PERCEPTION AND DIETARY HABITS WITH BODY MASS INDEX AMONG PUBLIC SCHOOL CHILDREN OF BELAGAVI DISTRICT, SOUTH INDIA

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## ABSTRACT

**Background.** Healthy diet is significant for growth, development, and prevention from dietary related diseases in children and adults. Dietary imbalance can lead to many general and oral diseases and sugar rich diet can affect the teeth at an early age and continues towards adolescence causing several oral problems such as dental caries. Frequent consumption of a certain food causes changes in taste perception and leads to preference for that food. Taste perception may also be affected by several environmental, cultural, and genetic factors and has been found to be linked to oral health and body mass index (BMI).

**Objective.** This study evaluated the association between sweet taste perception, dietary habits, and body mass index among 13-15-year-old public school children in the Belagavi district.

**Material and Methods.** A descriptive cross-sectional study was conducted among 1300 school children aged 13-15 years. Data were collected using a self-designed and validated questionnaire to assess dietary habits. Sweet taste perception was evaluated using sweet taste threshold (TT) and sweet taste preference (TP). Based on the sweet taste perception scores, participants were categorized into low, medium, and high groups. Body mass index was calculated using standard criteria. Descriptive statistics, Spearman's correlation test and ANOVA were performed. Statistical significance was considered for p-value $\leq 0.05$.

**Results.** Of the 1300 participants, 625 (48.1%) were males and 675 (51.9%) were females. A majority of the students demonstrated a low sweet taste threshold (78.7%), while 66% exhibited a medium level of sweet taste preference. More than half of the participants (57.8%) were underweight. A statistically significant association was observed between BMI and sweet taste preference ($p < 0.05$).

**Conclusions.** Sweet taste preference and dietary habits were significantly associated with BMI among adolescents (sugar preference and sugar exposure were positively correlated with BMI, while nutrient score was negatively correlated). These findings suggest that taste perception and dietary behaviours may play an important role in the nutritional status of school-going children.

**Keywords:** *school children, dietary habits, BMI, sweet taste perception, India*

## INTRODUCTION

A healthy diet is significant for growth, development, and prevention of dietary related diseases both in children and adults. Among the five different basic taste perceptions like sweet, sour, bitter, salty and savory/umami, sweet taste is often linked with impacts on health and more so on oral health. Sugar, vital source of energy, is also delicious and enjoyable, making it easy to satiate hunger. Its sweet taste encourages people, especially children, to consume more of it. Flavor is the primary dimension by which young children determine food acceptance [1]. It is assumed that children's preferences for sweets influence the choice of high-calorie foods. Frequent consumption of a certain food causes changes in taste perception and leads to preference for that food. Taste perception, in turn, may also be affected by several environmental, cultural, and genetic factors and has been found to be linked to oral health and body mass index (BMI). Sweet taste perception is a genetically driven feature that can influence a person's preference for sweet foods, which in turn can affect their body mass index and overall dietary intake [2].

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A balanced meal is necessary for the proper growth and development of children and helps to tackle nutritional problems in this age group. However, studies reveal that many children do not eat enough fruits, vegetables, seafood, fiber, and other essential nutrients, leading to potential nutritional deficiencies [3-5]. Nutritional inequalities in India are already well characterized across caste, economic position, gender and place of residence by a single axis [6]. This can be attributed to poor living standards, food insecurity, and inadequate dietary practices among individuals living in poverty. Poverty exacerbates the risk of malnutrition, making those affected more vulnerable due to inadequate living conditions, food insecurity, and poor dietary practices.

Today's children are exposed to social media in wide various ways and become easily fascinated by the advertisements of colorful, unhealthy and cariogenic foods. There is an increasing concern that the intake of free sugar, particularly in the form of sugar-sweetened beverages, contributes to overall energy intake and may reduce the consumption of foods that provide more nutritionally adequate calories [7]. This can lead to an unhealthy diet, weight gain, and an increased risk of developing non communicable diseases (NCD). The World Health Organization (WHO) recommends a reduced intake of free sugars throughout the lifetime. For both adults and children, WHO strongly recommends reducing free sugar intake to less than 10% of total energy intake [7]. A recent Lancet EATS commission recommends that daily intake of food from all the seven good groups is essential for appropriate growth and development of children [8].

There is a scarcity of literature about the association of sweet taste perception, its impact on daily nutrient intake and BMI, especially among school children and hence, the present study has been attempted with an aim to fill this lacuna.

The aim of this study is to investigate the relationship between sweet taste perception, dietary habits, and BMI among children attending public schools.

## MATERIAL AND METHODS

### Design and method

This cross-sectional study was conducted among children studying in public schools across Belagavi district from November 2023 to March 2024. Belagavi is the largest district in Karnataka which has 15 subdivisions and approximately 1.3 million children belong to the age group of 12-15 years.

### Ethical considerations

Ethical approval was obtained from the Institutional Research and Ethics Committee (Ref. No: 165). Prior to the commencement of the study, required permissions from school authorities and parental consent were obtained.

### Data collection

Participants were selected based on specific inclusion and exclusion criteria. The study included children aged 13-15 years who were willing to provide informed consent when studying at public schools. Children with special healthcare needs or underlying medical conditions were excluded. The sample size was calculated based on a similar cross-sectional study [9] on school children aged 13-15 years, which found a prevalence rate of 25.9% for taste preference (TP) at a concentration of 12.84 g/L. Taking these findings into account and considering a 10% attrition rate, the sample size was calculated using the formula: $n = z^2 \cdot p \cdot q/d^2$, (where p = prevalence of taste perception (25.9% in this case) [11], q = 74.1 (1-p), d = allowable error (2.5) and z = 1.96. Required sample size was 1228 which was rounded off to 1300 with a 10% allowable error.

A two-stage random sampling technique was employed in this study. Five subdivisions were randomly chosen from the 15 subdivisions in Belagavi district, followed by the random selection of four schools from each chosen subdivision using the lottery method. From each subdivision, 260 children meeting the inclusion criteria were chosen, resulting in a total sample size of 1300 students.

Study questionnaire consisted of four sections: socio-demographic details, BMI recording, sweet taste perception and 3 days diet diary. Students were instructed to write the details of their dietary intake for 3 days including one weekend. They were reinforced to write the details of all the foods and beverages consumed by them, including in-between meal sweets/snacks. They were advised to mention the approximate portion size of the food consumed.

Pilot study: A pilot study was conducted on 130 participants belonging to a similar age group, after the questionnaire was finalized, to test its comprehensibility and feasibility. Subtle changes were made in the questionnaire to reduce any ambiguity.

BMI was calculated as per Quetelets formula [10], using a portable digital weighing machine and a measuring tape. Repeated checks were conducted to ensure the accuracy and reliability of the measurements obtained. BMI-for-age Z-scores were obtained using the WHO Anthro software, with the World Health Organization (2020) standards applied to categorize BMI.

For children over five years old, underweight was defined as a Z-score below -2, overweight was classified as a Z-score above +1 but less than or equal to +2, and obesity was defined as a Z-score above +2 as per WHO recommendation [11].

Analytical-grade sucrose (Sigma Aldrich) and sterile distilled water were used to prepare sugar solutions under sterile conditions. Fresh solutions were prepared for each visit.

The sugar exposure score was calculated based on the intake of liquid, solid, sticky, and slowly dissolving foods, as recorded in a three-day dietary record. It was categorized as excellent if the score was 5 or less, good if it was 10, and in the watch-out zone if it was 15 or more.

The nutrient score was assessed based on data extracted from 3 days dietary records. All the food items consumed were divided into four food groups:

- bread/cereals,
- milk/milk products,
- meat/poultry products,
- vegetables and fruits.

From the dietary records, the food or mixed food dishes were classified into one or more of the appropriate food groups. For each serving of these foods listed in the food intake record, a check was placed in the appropriate food group block.

The number of checks were added and multiplied by the number shown:

- milk group – multiplied by 8, highest possible score – 24,
- meat/poultry group – multiplied by 8, highest possible score – 24,
- vegetables and fruits group: vitamin A – multiplied by 6, highest possible score – 6, vitamin C – multiplied by 6 and highest possible score – 6, others – multiplied by 6 highest possible score – 12,
- bread and cereal group – multiplied by 6 highest possible score – 24.

All the points were added and the total was the score for four food group scores. Average of three days score was calculated and food score was interpreted as follows:

- 72 to 96 – excellent,
- 64 to 72 – adequate,
- 56 to 64 – barely adequate,
- 56 or less – not adequate.

The examiners were standardized and calibrated by a panel of experts before the start of the study to ensure consistent examination and uniform interpretation of the data recorded.

**Procedure**

The purpose of the study was explained in detail to the participants, and their informed consent and assent forms were obtained. A team of three examiners collected demographic details from the participants, and then proceeded to assess sweet taste threshold (STT), sweet taste preference (STP), and dietary intake using a dietary record. Sucorse solution which was used to assess STT, STP were prepared as per the modified technique prescribed by Furquim et al. [12]. The children were presented with ten sucrose solutions ranging in concentration from 1.63 g/L (0.0047 M/L) to 834.56 g/L (2.40 M/L), with each step doubling the concentration in grams per litre. A dropper was used to administer the 5 mL of solutions, and between tastings, the children rinsed their mouths with filtered water. The assessment of STT involved identifying the lowest concentration at which the participants could detect the presence of sucrose and differentiate it from water. STP which is the solution chosen by participants based on the level of sweetness they preferred in a drink. Based on their STT and STP levels, the children were categorized as "low" if their preferred solution was within the range of 1.63-12.84 g/L, "medium" if within 25.67-102.69 g/L, and "high" if within 205.38-834.56 g/L. Dietary information was collected using a three-day diet record to estimate sugar intake and food group scores.

Anthropometric measurements: Height of participants was recorded using digital measuring scale (model: Seca 213 portable Stadiometer height-rod). The weight was noted using an electronic calibrated scale, and rounded off to the nearest kilograms.

**Statistical analysis**

Obtained data was entered into Microsoft Excel and subjected to statistical analysis using software package IBM SPSS Statistics Version 21. Descriptive statistics, Spearman's correlation test and ANOVA were performed to determine association between the BMI Z-score, as the dependent variable, and various predictors. Statistical significance was considered for p-value of $\leq 0.05$.

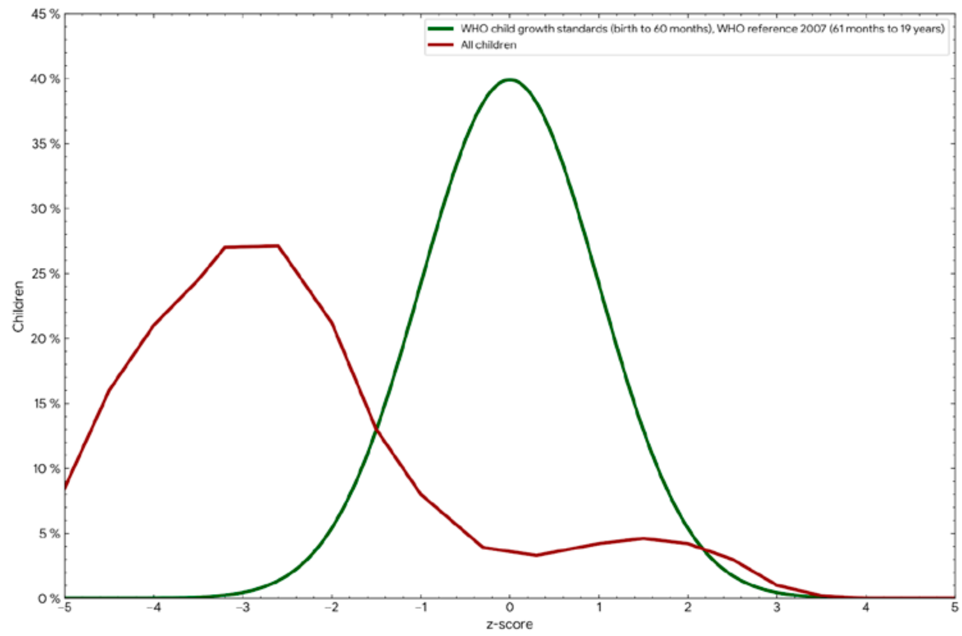
## RESULTS

**Socio-demographic characteristics of the participants**

Of the total 1300 school children, 48.1% were males with mean age of the participants being 14.53 ± 0.67 years. Majority (58%) of children belonged to the upper-lower socio-economic class as per Kuppuswamy's Classification [13]. In terms of BMI, majority (58.8%) of participants were underweight, whereas 8.1% were overweight (Table 1). School children exhibited lower BMI Z-scores (skewed left) compared to the WHO standard reference (Figure 1).

**Sugar exposure, nutrient score, sugar threshold and sugar preference**

Majority of participants had an excellent sugar exposure score (54.5%) and low sugar threshold (78.6%). When sugar preference was recorded, approximately (66.1%) had medium sugar preference. However, nutrient scores recorded among the a)




b)

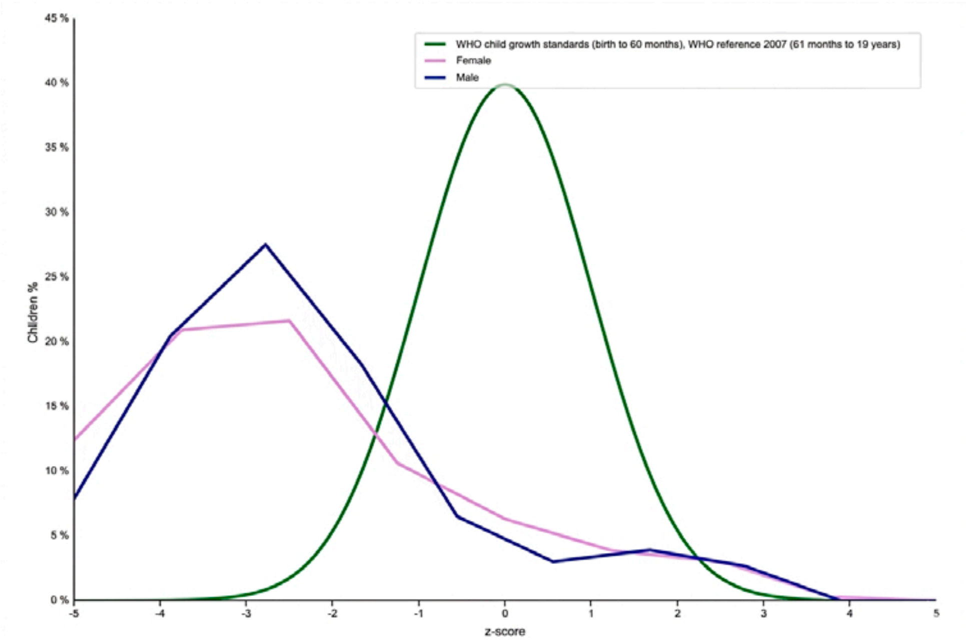



Figure 1. Kernel density plots of BMI-for-age Z-scores versus WHO 2007 reference (61 months-19 years): a) all children (n = 1300); b) males (n = 625) and females (n = 675)

participants revealed that majority had inadequate nutrition (Table 1).

When sugar exposure was analyzed, it was found to be higher among females, obese participants BMI Z-score > +2·SD and those from lower socio-economic status. Similar findings were obtained for both the sugar threshold and preference scores. However, both the scores were higher among males unlike sugar exposure scores. Nutrient scores on the other hand were higher among males, healthy individuals, and those from upper socio-economic status (Table 2).

Among the study parameters, only BMI showed a statistically significant difference with all the variables such as nutrient score, sugar exposure, threshold, and preference scores, whereas gender showed statistically significant difference only in nutrient score ($p \leq 0.05$) (Table 2).

**Relationship between BMI and various study variables**

Table 3 depicts the correlation between BMI and study variables such as sugar exposure, nutrient score, sugar threshold, and sugar preference. Sugar threshold, sugar preference and sugar exposure showed positive linear correlations with BMI ($p \leq 0.05$). However, there was a negative correlation observed between nutrient score and BMI ($p \leq 0.05$).

Table 1. Distribution of study variables among participants

| Characteristics | N (%) |
|---|---|
| Age | |
| Mean ± SD | 14.53 ± 0.67 |
| 13 years | 132 (10.2%) |
| 14 years | 349 (26.8%) |
| 15 years | 819 (63.0%) |
| Gender | |
| Male | 625 (48.1%) |
| Female | 675 (51.9%) |
| Socio-economic status | |
| Upper class | 3 (0.2%) |
| Upper middle class | 67 (5.2%) |
| Lower middle class | 426 (32.8%) |
| Upper lower class | 754 (58.0%) |
| Lower class | 49 (3.8%) |
| Body mass index | |
| Underweight | 764 (58.8%) |
| Healthy | 249 (19.2%) |
| Overweight | 105 (8.1%) |
| Obese | 181 (13.9%) |

| Characteristics | N (%) |
|---|---|
| Sugar exposure | |
| Excellent | 709 (54.5%) |
| Good | 568 (43.7%) |
| Watch out zone | 23 (1.8%) |
| Sugar threshold | |
| Low threshold | 1022 (78.6%) |
| Medium threshold | 277 (21.3%) |
| High Threshold | 0 (0.0%) |
| Sugar preference | |
| Low threshold | 102 (7.8%) |
| Medium threshold | 859 (66.1%) |
| High threshold | 338 (26.0%) |
| Nutrient score | |
| Not adequate | 1175 (90.4%) |
| Barely adequate | 79 (6.1%) |
| Adequate | 16 (1.2%) |
| Excellent | 30 (2.3%) |

SD – standard deviation

Table 2. Distribution of sugar exposure, nutrient score, sugar threshold and sugar preference among various demographics and BMI

| Parameters | Sugar exposure Mean ± SD | Nutrient score Mean ± SD | Sugar threshold Mean ± SD | Sugar preference Mean ± SD |
|---|---|---|---|---|
| Gender | | | | |
| Male | 5.31 ± 3.46 | 41.81 ± 14.76 | 3.66 ± 1.11 | 6.74 ± 1.52 |
| Female | 5.76 ± 3.81 | 37.25 ± 12.29 | 3.63 ± 1.06 | 6.30 ± 1.55 |
| t value[a] | -2.25 | 6.05 | 0.52 | 5.19 |
| p-value | 0.082 | < 0.001* | 0.365 | 0.992 |
| Socio-economic status | | | | |
| Upper | 3.30 ± 2.21 | 47.10 ± 13.71 | 3.33 ± 1.15 | 5.00 ± 1.73 |
| Upper middle | 5.53 ± 3.38 | 41.91 ± 15.19 | 3.29 ± 1.21 | 6.46 ± 1.51 |
| Lower middle | 5.63 ± 3.69 | 39.52 ± 13.78 | 3.66 ± 1.07 | 6.47 ± 1.53 |
| Upper lower | 5.47 ± 3.63 | 39.43 ± 13.47 | 3.68 ± 1.07 | 6.54 ± 1.57 |
| Lower | 6.04 ± 4.02 | 35.24 ± 14.51 | 3.51 ± 1.08 | 6.53 ± 1.45 |
| F value[b] | 0.65 | 1.93 | 2.23 | 0.87 |
| p-value | 0.627 | 0.103 | 0.064 | 0.483 |
| Body mass index | | | | |
| Underweight | 5.29 ± 3.44 | 40.23 ± 13.83 | 3.55 ± 1.08 | 6.42 ± 1.56 |
| Healthy | 5.69 ± 3.97 | 40.39 ± 13.86 | 3.79 ± 0.96 | 6.37 ± 1.44 |
| Overweight | 6.03 ± 3.78 | 39.01 ± 12.76 | 3.53 ± 1.19 | 6.65 ± 1.73 |
| Obese | 6.11 ± 3.89 | 34.61 ± 12.64 | 3.93 ± 1.13 | 7.01 ± 1.46 |
| F value[b] | 3.48 | 9.20 | 8.38 | 7.99 |
| p-value | 0.015* | < 0.001* | < 0.001* | < 0.001* |

[a]Unpaired t test; [b]ANOVA test; * $p \leq 0.05$ is considered statistically significant.

Table 3. Correlation of BMI with various study variables

| Parameters | Body mass index (BMI) | |
|---|---|---|
| | r | p-value |
| Sugar exposure[a] | 0.072 | 0.010* |
| Nutrient score[a] | -0.141 | < 0.001* |
| Sugar threshold[b] | 0.187 | < 0.001* |
| Sugar preference[b] | 0.109 | < 0.001* |

[a]Pearson's correlation coefficient; [b]Spearman correlation coefficient; *p-value ≤ 0.05 is considered as statistically significant.

Table 4 summarizes the multiple regression analysis models performed using BMI as the dependent variable and the predictors: age, gender, socio-economic status, sugar threshold, sugar preference, sugar exposure, and nutrient score. This analysis revealed that, except for gender, all other predictors significantly influenced BMI ($p \leq 0.05$), and the dependence on these predictors is found to be 13.1%.

## DISCUSSION

Educating children in adopting healthy food choices can pave a way in developing individuals who are health conscious and would preferably adopt a healthy life style.

Taste is an important factor that significantly influences food choices, preferences, and intake in young children. It has been proven in previous studies that children aged 11 to 13 years possess varied basic taste perceptions which could influence their eating behaviour [14]. Among the different tastes, sweetness plays a major role in the selection of food [15]. However, there is an individual difference in this taste preference which could be a result of genetics or by early exposures [1]. Children's preference for sweets and related sugar consumption might be due to exposure to sugary foods, and their growth maturity in addition to parental influence [16]

WHO stated that an unhealthy diet can pave way for various non-communicable diseases such as dental caries, obesity and overweight [17]. Children are at a higher risk for unhealthy dietary behaviours with their preferences for food selection based on high-calorie intake, especially sweets. Recently Central Board of Secondary Education in India has taken up the issue of 'sugar consumption' seriously and has come up with 'Sugar Boards' in schools to educate students about the risks of excessive sugar intake.

Body mass index is an important parameter to monitor growth of a child and has been reported equivocally in the literature. In a study by Ashi et al. authors noticed that most of their study participants in Saudi Arabia belonged to 'normal' category [11], contrary to this, in the present study, 58% of the students were in the underweight category. This prevalence rate is higher compared to 28% reported for Karnataka as per Comprehensive National Nutritional Survey (CNSS) 2019 [18]. The type of diet, religion, area of residences, purchasing power of the family, food adequacy, maternal literacy rate may be some of the factors which could have an indirect impact on the BMI of the children. However as per CNSS report, it was interesting to note, that, as the demands of the growth spurt decreased, boys started to gain weight and the prevalence of low BMI slowly declined to ~15% by age 19 [18].

In the current study, 90.4% of participant's nutrient score was 'not adequate'. This was very high compared to the result of the CNSS report, which stated that, 28% of the adolescents had inadequate nutrient score. The disparity could be explained on the basis of calculation of food group score. In the current study we have employed the food group score calculation as prescribed by Nizel and Pappas [19], whereas CNSS has employed an ingenious method – children were assessed for consumption of seven food groups during the previous day; grains, roots and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin A-rich

Table 4. Multiple linear regression analysis of BMI with other variables

| Parameters | Coefficient r | SE | t | 95% CI | p-value | Adjusted $R^2$ |
|---|---|---|---|---|---|---|
| Dependent variable: BMI | | | | | | |
| Constant | - | 4.189 | -4.563 | -27.333 – -10.898 | 0.001* | 0.131 |
| Age | 0.195 | 0.259 | 7.440 | 1.421 – 2.439 | 0.001* | |
| Gender | 0.005 | 0.411 | -0.178 | -0.880 – 0.734 | 0.859 | |
| Socio-economic status | 0.213 | 0.303 | 8.197 | 1.890 – 3.080 | 0.001* | |
| Sugar threshold | 0.067 | 0.192 | 2.462 | 0.096 – 0.848 | 0.014* | |
| Sugar preference | 0.080 | 0.136 | 2.921 | 0.130 – 0.662 | 0.004* | |
| Sugar exposure | 0.070 | 0.055 | 2.677 | 0.039 – 0.256 | 0.008* | |
| Nutrient score | 0.118 | 0.015 | -4.411 | -0.095 – -0.037 | 0.001* | |

SE – standard error; CI – confidence interval; *p ≤ 0.05 is considered as statistically significant.

fruits and vegetables; and other fruits and vegetables [18]. Only frequency was assessed in CNSS, unlike the current study, which calculated food score for each child. Majority of the participants in the current study did not consume eggs/meat, milk and milk products or fruits; unfortunately, they had easy access to junk foods which had zero nutritional value.

Several studies have tried assessing sweet taste perception and obesity with contrasting results suggesting diversity in the relationship between them [20, 21]. Previous studies have reported that taste perception is more distinct in normal weight than in obese children stating that a higher sweet threshold was noted among obese children [22]. A study conducted on representational sample from Europe concluded that taste threshold is related to the weight of an individual and the taste sensitivity increases with increasing age [23].

The influence of sweet taste perception on dietary intake in the context of dental caries and BMI was assessed among the Saudi Arabian population [11]. There was an absence of any significant relationship between dietary patterns and BMI in their study which was in contrast to the study by Washi and Ageib which concluded that being overweight and the number of meals intake in children have a significant relation [24]. In the present study, sugar reference scores were directly related to the BMI status of the children with the highest score for overweight children and vice versa, thereby revealing a positive correlation between BMI and sugar preference.

Gender differences in sweet taste perception have been documented by studies that stated that poor dietary habits are linked to food choice, with taste being an aspect considered by females more than males [25]. It was interesting to note that in the current study boys had more preference for sugar than girls and this was statistically significant. Though exact scientific cause responsible for this finding is obscure it may be related to physiological reasons. Children may be less sensitive to certain tastes, and may require higher concentration of sweetness to get the same sensation as adults. Increased preference for sugar may also be due to increased calorific requirements or hormonal changes that take place during puberty, particularly with secretion of leptin and insulin which are known to decrease sweet taste preference [16].

**Limitations of the study**

The present study has a few limitations that need to be addressed for implication in a public health perspective. Sweet taste perception and dietary habits with BMI were assessed in this present study.

Most children followed the instructions for entering dietary records, but personal variations in presentation and reporting along with individual variability in taste threshold can possibly cause a bias which was inherent to the study. Social desirability bias cannot be completely ruled out.

**Strengths of the study**

The current study was conducted on a wide representational sample. The study provided an uncommon opportunity to sensitize and create awareness towards sugar intake and general health.

## CONCLUSION

This study reveals there was a significant association observed between sweet threshold, sweet preference, and gender with BMI. A high prevalence of underweight participants was observed, with sugar exposure and preferences positively correlating with BMI, especially among those from lower socio-economic backgrounds. Nutrient scores were generally low, particularly among those with lower BMI, emphasizing the need for targeted nutritional interventions to support healthier growth in underprivileged groups.

**Future recommendations**

Children and teachers need to be aware of the association between sweet taste and general health. Educating young minds on making healthy choices can be a key component in fostering "healthier individuals" of tomorrow. Longterm follow-up studies assessing sugar intake and its impact on growth and development of general health could be taken up on a representative sample.

**Public health significance**

It was shocking to note that 90.3% of student's nutritional score was "not adequate," whereas 57.8% were underweight. This is an alarming number given the fact that there are many flagship nutritional programs ongoing in Karnataka state, like mid-day meal scheme and Kshera Bhagy program to name a few. The prevalence of undernutrition in school age children remains a considerable public health problem in South Indian part of the country. Long term follow-up studies can give more insight into effect of diet on overall growth and development of the children as well as its impact on the development or progression of oral diseases.

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