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RESEARCH

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Association between taste sensitivity, taste preference, and obesity: study of healthy snacks in children aged 9–14 years

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Abstract

Healthy eating habits are essential to prevent childhood obesity. Children's eating habits are influenced by many factors, such as taste sensitivity and taste preferences. This study aimed to analyze the correlation between taste sensitivity, taste preference, and obesity in children. This cross-sectional study enrolled 101 healthy children aged 9–14(34 boys and 67 girls). Nutritional status was assessed based on age- and sex-specific BMI z-scores, following CDC Growth Charts. Taste sensitivity was measured using graded sucralose (sweet)/ saline (salty) solution of 0.1709, 0.3418, and 0.6837 mol/L with distilled water (blanks). Taste preferences were assessed using a self-reported questionnaire, the gradation of sugar and salt, and four healthy snacks (two sweet snacks and two salty snacks). Statistical analysis was performed using correlation test. A quarter of the subjects were overweight and obese (25.8%). Most subjects had good taste sensitivity, and it was easier to recognize salty than sweet taste (89.1% vs. 58.4%). Moreover, the sweet taste and sweet food were preferred by almost all subjects. Correlation test showed a correlation between sweet taste sensitivity ($r = 0.213$; $p = 0.032$) and sweet preference ($r = 0.374$; $p = 0.029$) especially in boys to nutritional status, but not for salty taste. Obesity in children was associated with taste sensitivity and taste preferences especially for sweetness. Presenting healthy foods that consider the daily limit of sugar intake is very important to support optimal nutritional status for children.

Keywords Children, Good health, Obesity, Taste preference, Taste sensitivity, Well being

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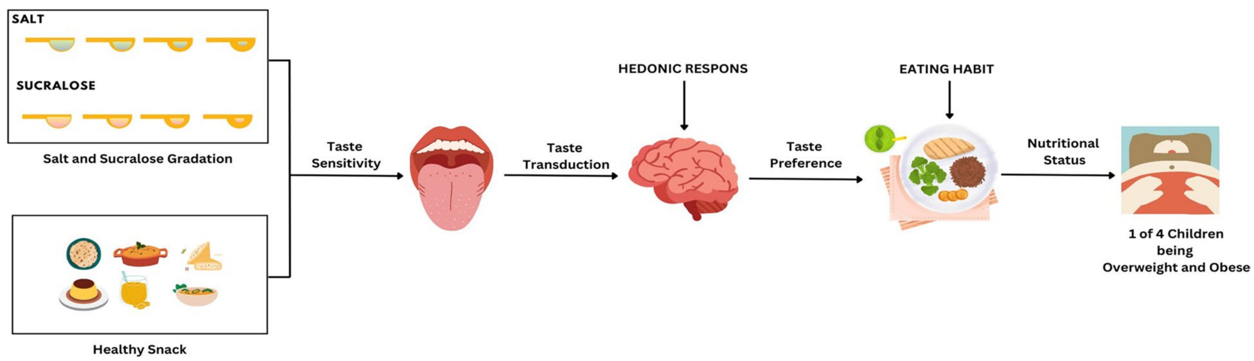
Graphical Abstract



Background

Obesity is a global health problem that affects all ages, even children.The World Health Organization (WHO) recorded a threefold increase in the prevalence of obesity in 2016 compared to 1975 (World Health Organization 2016). Updating data based on a survey conducted in 2020, around 175 million children between the ages of 5 and 9 were classified as obese, and it is anticipated that this will increase by 10% in 2023 (Lobstein et al. 2023). Indonesia is also experiencing the same situation, with around 29.2% of children being overweight and obese (Sulistiadi et al. 2023). The occurrence of obesity in children will have physical and psychological consequences in both the short and long term (Di Cesare et al. 2019). Obese children often struggle with social problems such as bullying, low self-esteem, anxiety, depression, and poor academic performance (Central for Disease Control and Prevention 2022b; Di Cesare et al. 2019; Sahoo et al. 2015). It is also known to be associated with the incidence of disability and premature death in the long term (World Health Organization 2016).

The World Health Organization (WHO) stated that childhood obesity increases the risk of non-communicable diseases (NCDs) in adulthood (World Health Organization 2016). Similarly, the study by Simmonds et al. (2016) conducted on 1,000 participants aged 7 to 18 showed that obese children and adolescents had a five times higher risk of adult obesity than those who were not obese. Childhood obesity can lead to insulin resistance, adiposity rebound, and putting obese children at a 3.98-fold increased risk of developing type 2 diabetes mellitus (Raditya et al. 2022). In addition, obesity in children negatively affects the cardiovascular system. If this problem is not treated properly, it will encourage the occurrence of other health problems in the future.

Childhood obesity is influenced by several risk factors, including genetics, maternal Body Mass Index (BMI), socioeconomic and demographic conditions, physical activity, and unhealthy diet (Banjarnahor et al. 2021; Japutra et al. 2015; Rini et al. 2018). Consuming high-calorie but low-nutrient foods such as fast food, sweet drinks, and snacks play an important role in obesity status (Sahoo et al. 2015). Research in Australia, China, Mexico, and the United Stated also found that children consumed snacks at least four times a day, accounting for a quarter of total energy intake (Wang et al. 2018). Unfortunately, the largest contribution to caloric intake comes from added sugar and saturated fats but small in the fruit groups. The high consumption of unhealthy snacks compared to healthy snacks is related to children's preferences, among other multifactorial causes (Cox et al. 2016). Schoolchildren in Mexico show that the food most preferred by children is sweet food, followed by high-calorie foods with low nutritional value, such as french fries and pizza (Sánchez-García et al. 2014). On the other hand, the most rejected foods come from vegetables, whole-grain cereals, and fish. In fact, foods that are more favored by children have a positive relationship with BMI.

Taste preferences are a strong predictor of food acceptance in children. Taste preferences are influenced by multiple factors, such as environmental factors, social factors, and biological factors such as sensory function (Scaglioni et al. 2018). Results of a comprehensive review found an association between sweet and salty taste preferences to food intake (Cox et al. 2016). Results of a study by Dora et al. (2021) also showed that taste bud sensitivity can affect taste preferences and food intake in children of different ethnicities in Malaysia. Since consumption of high-calorie foods is widespread among children, taste sensitivity and taste preference play a pivotal role in children's food consumption. Hence, there is an urgent need to provide healthy snacks for children and to analyze the correlation of taste sensitivity and preference with childhood obesity.

Materials and methods

Subjects and study design

This was a cross-sectional study conducted at the end year 2020 to 2022 in Surabaya, Indonesia. The study enrolled healthy school-aged children, between 9 and 14 years of both sexes. We conducted a screening test and all subjects who had flu, taste disorders and food allergies during this study were excluded. A total of 101 participants from 155 population were recruited from 5 randomly selected evening -Islamic schools in Surabaya, the capital city of East Java, Indonesia. The sample size for this study was determined using Lemeshow et al. (1990) formula, which has been proven to provide an adequate sample size for health studies (Lemeshow et al. 1990). The prevalence of overweight and obesity among children used in this calculation was 24.2% (Sulistiadi et al. 2023), with a desired precision level of 5%. The study was performed using direct information to the headmaster, teacher, students, and their parents. We explained clearly study protocol and asked for their signature in the informed consent. The study protocol adhered to the ethical standard of the Helsinki Declaration, and the Institutional Review Board (IRB) of Universitas Airlangga. In the first years, we focused on arrenging the formulation of healthy snack, do food market survey and, apply test food in limitted and traned sample until got the appropriate food formulation. The study got delayed for several months in 2021 because of COVID pandemic peak, and we continue to recruit subject directly by giving study information at the participant and measured all variables in study in early 2022. So this study we used two ethical clearances that approved by Universitas Airlangga with certificate number 409/HRECC.FODM/IX/2020 that approved by Faculty if Dentsitry and 143/EA/KEPK/2022 by the committee of Ethics Faculty Health Public University.

Anthropometric measurement

Height was measured using a SECA 213 GEA portable stadiometer (SECA GmbH & Co. KG, Hamburg, Germany) and subject was asked to standupright and remove footwear. Body weight was measured using Bioelectrical Impedance Analysis (BIA) using the Karada Scan HBF-375 (OMRON Healthcare Co., Kyoto, Japan),. The BMI was calculated from the weight in kilograms divided by the square of the height in meters. BMI was categories based on age- and gender-specific BMI z-scores using Center for Disease Control and Prevention (CDC) Growth Charts. Underweight was defined as < 5th percentile, normal weight as 5th to < 85th percentile, overweight as 85th to < 95th percentile, and obese as ≥ 95th percentile (Central for Disease Control and Prevention 2022a).

Sweet and salty sensitivity test

Sweet and salty taste sensitivity was assessed using the detection threshold (DT) method, which has been used in several studies (Dora et al. 2021; Ervina et al. 2020; Petty et al. 2020) and has proven to be better than taste identification (Fry Vennerød et al. 2018). The method used is a taste solution that does not require lengthy procedures, is suitable for children, and can be easily applied in clinical practice (Van Den Brink et al. 2021). Sweet taste sensitivity was achieved using sucralose solution (Sanghiang Perkasa Co. Ltd., Jakarta, Indonesia), while salty taste was achieved using salt solution/ sodium chloride (Daesang Agung Co., Gresik, Indonesia). Sucralose was chosen because it exhibits a taste perception profile similar to that of sucrose, but about 600 times sweeter, so it is suitable for the sweet test (Van Den Brink et al. 2021). Whereas NaCl was chosen because it provides an almost pure salt flavor and is primarily responsible for the salty taste (Henney et al. 2010) Each solution of sucralose and saline was administ at a concentration of 0.1709, 0.3418, and 0.6837 mol/L, and stored at room temperature. Each subject will be given three solutions in each set sample (one sample solution and two distilled water as blanks) with three-digit different label numbers. Each level of solution was applied to the tongue (the tip of the tongue for sweet taste and the anterior tongue for salty taste), ranging from the lowest to the highest concentration. Each subject was given a few minutes to identify each set of samples. The neutralization between the solutions was carried out by rinsing the mouth with water. The subject's answer is marked with (+) if correct and (0) if wrong. Subjects were rated as having good sweet and salty taste sensitivity when they could answer three correct answers, and less sensitive when they answered fewer than three correct answers.

Taste and food preference test

Preferences test were measured in two way tests, through questions and formulation of the foods, to support the validity of subject's taste preferences (Matsuzuki et al. 2008; Sijtsema et al. 2012). In food preference test, we have assembled and cooked healthy snacks based on foods that are easy to find around children. Each menu was prepared by adding four different sugar and salt into four samples. Each cooked sample subjected to be done organoleptic tests with a limited panellists to obtain the most suitable healthy snack for children. Three measures were used to determine taste preferences for salty and sweet tastes. The first, self-reported preferences divided into three categories—very like, like, or less like with the question " Do you like the sweet taste?“ and " Do you like the salty taste?“. Before completing the questionnaire, we explain the preference standard to reduce perceptual bias in the study.

We formulated mango smoothies and meatball soup for taste preference test. The selected mango was a ripe characterized by a yellowish-green rind, a smooth skin, and a fragrant aroma. Mango smoothies was processed in one operation so they produce the same flavor. The highest gradation of mango smoothies and meatball soup has been adjusted to the tastes commonly sold and decreased gradually. mango smoothies contain four levels of sugar (0, 5, 10, 15 g) and four levels of salt in meatball soup (0.5, 0.75, 1, 1.25 g). All food served is tested blinded by giving the same cup size and portion on each food gradation.

Healthy snack formulation

We cooked and served healthy snack like mango puding, banana klappertart, tofu schotel, and stuffed tofu with meatball. The The mango pudding and banana klappertart all of which contained 10 g of sugar, and tofu schotel and stuffed tofu with meatballs, both of which contained 1 gram of salt, adapted to the daily needs of children. The perception of sugar and salt in healthy foods is divided into three categories: less sweet/salty, enough, and too sweet/salty. Sugar and salt preferences in healthy foods are divided into three categories as very like, like, and less like. The composition of each healthy snack formulation is shown in Table 1.

Table 1 The recipe formulation of healthy snack

Menus	Weight (g)
Mango pudding	
Jelly	1.3
Milk	50.0
Sugar	10.0
Mango	25.0
Water	60.0
Banana klappertaart	
Bananas	25.0
Young coconut	40.0
Wheat flour	5.0
Cornstarch	5.0
Skim milk	10.0
Jackfruit	5.0
Sugar	10.0
Whole egg	15.0
Egg white	15.0
Cinnamon	0.5
Raisins	5.0
Vanilla extract	0.25
Water	500.0
Tofu schotel	
Tofu	100.0
Carrot	10.0
Oyster mushroom	10.0
Peas	10.0
Potato	20.0
Chicken egg	15.0
Non dairy creamer	6.0
Skim milk	4.0
Onion	3.0
Garlic	3.0
Palm oil	3.0
Sugar	0.75
Salt	1.0
Pepper	0.25
Stuffed tofu with meatball	
Tofu	50.0
Ground chicken	27.0
Starch	15.0
Sugar	4.0
Salt	1.0
Water	100.0

Statistical analysis

The collected data was statistically analyzed using the Statistics Package for the Social Sciences (SPSS), version 24.0. Categorical variables were described in the form of numbers and percent, and continuous variables were described as averages and standard deviations. Correlation test is used to find the correlation between taste sensitivity and taste preferences related to nutritional status. All data for the correction test are presented in the form of ratio data with an evaluation of taste sensitivity 0.1709 mol/L = 1, 0.3418 mol/L = 2 and 0.6837 mol/L = 3, and taste preference categorized very like = 1, like = 2 and less like = 3. A p-value less than 5% is considered significant to test the correlation between the two variables.

Results

Most subjects were girls aged 11.83 ± 1.86 years and had two siblings. According to age- and gender-specific charts, 25.8% of the subject were overweight and obese and about 10% suffered from wasting. A total of 36.6% were included in the hypertension category with a mean of systolic blood pressure (SBP) of 106.96 ± 12.89 mm Hg and a diastolic blood pressure (DBP) is 76.51 ± 10.79 mm Hg (Table 2).

Table 2 Characteristics of subjects

Variable	Mean / n (%)
Age (years)	11.83 ± 1.86
Number of siblings	1.99 ± 1.55
Gender	
Girls	67 (66.3%)
Boys	34 (33.7%)
Nutritional status (z score)	-0.15 ± 1.50
Underweight	10 (9.9%)
Normal weight	65 (64.4%)
Overweight	14 (13.9%)
Obese	12 (11.9%)
Blood pressure (BP) status	
Systolic BP (mmHg)	106.96 ±12.89
Diastolic BP (mmHg)	76.51±10.79
Hypertension status	
No	64 (63.4%)
Yes	37 (36.6%)

Sensitivity test

In term of taste sensitivity, more than half of the subjects can correctly distinguish all solutions. The results of the taste sensitivity categorization showed that the salty taste sensitivity (89.1%) was much better discriminated than the sweet (58.4%). The results also demonstrated that the proportion of all incorrect responses was higher for sweet taste (3.0%) than salty taste. As a result, it is easier for the subjects to identify/describe salty taste over sweet taste (Table 3).

Perception and preference test

Following of taste sensitivity test, it's important to consider the subjects' perception and preference for different tastes. The results showed that the sweet taste was preferred by subjects. It can be seen that only 2.0% of the subjects who less like the sweet taste and even 35.6% of subjects very like the sweet taste. A different result was shown by the salty taste, which indicates that almost 40.0% of subjects less like the salty taste (Table 3).

Table 3 Taste sensitivity and taste preference

Variable	Sweet taste sensitivity *n*=101 (%)	Salty taste sensitivity *n*=100 (%)
Taste Sensitivity		
Number of correct responses		
All correct	59 (58.4)	90 (89.1)
Two correct	31 (30.7)	8 (7.9)
One correct	8 (7.9)	3 (3.0)
All wrong	3 (3.0)	0 (0.0)
Category of sensitivity		
Good sensitivity	59 (58.4)	90 (89.1)
Less sensitivity	42 (41.6)	11 (10.9)
Taste Preferences		
Very like	36 (35.6%)	1 (1.0%)
Like	63 (62.4%)	60 (59.4%)
Less like	2 (2.0%)	40 (39.6%)

Food preferences with different sugar and salt gradations are presented in Table 4. The results showed that most subjects prefer foods with the highest level of salt and sugar. In addition, we also formulate healthy snacks with adjustments for the addition of sugar and salt in snacks commonly consumed by children. Healthy snacks were arranged into two sweet foods, mango pudding and banana klappertaart, and two salty foods, namely tofu schotel and stuffed tofu with meatballs. Both sweet snacks are added as much as 10 g of sugar and 1 gram of salt in salty snacks. The children's daily sugar and salt requirements have been factored into all compiled menus. All snacks given to subjects underwent organoleptic testing by limited panelists, and all agreed that the healthy snack model was the best for children's dietary needs and preferences. The composition and nutritional content of the healthy snack are described in Table 5.

The average subjects agreed that the healthy food offered enough sweetness and saltiness. About 11.3% complained that the food was too sweet and only 5.4% admitted that the food provided tasted too salty. In addition, the majority of subjects liked the food that was served. As many as 8.4% admitted that they less like the sweet food offered, while more than a quarter admitted that they very like it. The same results were found for salty foods, with as many as 36.6% saying they very like the salty food and the least is less like (3.9%) (Table 6).

Correlation test

The correlation was only found for sweet taste sensitivity and self-reported sweet preference, but not for salt taste.

Table 4 Food preference of sweet and salty taste (gradation test)

Variable	n (%)
Sweet taste preference (mango smoothie)	
15 g	58 (57.4)
10 g	15 (14.9)
5 g	22 (21.8)
0 g	6 (5.9)
Salty taste preference (meatball soup)	
1.25 g	33 (32.7)
1.00 g	31 (30.7)
0.75 g	32 (31.7)
0.50 g	5 (5.0)

Table 5 Nutritional content of healthy food

Menu	Energy (kcal)	Protein (g)	Fat (g)	Carb. (g)	Potassium (mg)	Sodium (mg)	Sucrose (g)
Mango pudding	102.5	1.9	2.0	20.6	141.7	21.2	12.2
Banana klappertaart	217.2	8.2	3.4	39.1	411.1	107.1	14.6
Tofu schotel	180.4	12.9	9.7	12.5	401.2	442.4	1.6
Stuffed tofu with meatball	182.8	8.4	11.9	11.0	94.3	405.4	0.6

Table 6 Sweet and salty taste perception and preference in healthy food trial

Category	Sweet Taste			Salty Taste		
	Mango pudding *n*=101 (%)	Banana klappertaart *n*=101 (%)	Total *n*=202 (%)	Tofu schotel *n*=101 (%)	Stuffed tofu with meatball *n*=101 (%)	Total *N*=202 (%)
Taste Perception						
Not sweet/ salty	36 (35.6)	41 (40.6)	77 (38.1)	53 (52.5)	38 (37.6)	91 (45.0)
Enough	61 (60.4)	41 (40.6)	102 (50.4)	40 (39.6)	60 (59.4)	100 (49.5)
Too sweet/ salty	4 (4.0)	19 (18.8)	23 (11.3)	8 (7.9)	3 (3.0)	11 (5.4)
Taste Preference						
Very like	43(42.6)	18 (17.8)	61 (30.1)	26 (25.7)	48 (47.5)	74 (36.6)
Like	58 (57.4)	66 (65.3)	124 (61.3)	70 (69.3)	50 (49.5)	120 (59.4)
Less like	0 (0.0)	17 (16.8)	17 (8.4)	5 (5.0)	3 (3.0)	8 (3.9)

Correlation test showed a correlation between sweet taste sensitivity ($r=0.213$; $p=0.032$) and sweet preference ($r=0.374$; $p=0.029$) especially in boys to nutritional status, but not for salty taste (Table 7).

Table 7 The correlation of taste sensitivity and self-reported taste preferences with nutritional status

Variable	IMT/U	
	r	*p*-value
All gender		
Sweet taste sensitivity	0.213	0.032*
Salt taste sensitivity	-0.093	0.354
Sweet taste preference	-0.198	0.047*
Salt taste preference	-0.147	0.142
Boys		
Sweet taste sensitivity	-0.183	0.299
Salt taste sensitivity	-0.314	0.071
Sweet taste preference	0.374	0.029*
Salt taste preference	-0.003	0.987
Girls		
Sweet taste sensitivity	0.141	0.256
Salt taste sensitivity	-0.148	0.231
Sweet taste preference	-0.223	0.069
Salt taste preference	-0.083	0.507

*p value < 0.05

Discussion

Our results showed that as many as 25.8% of children are overweight and obese. This statistic aligns with study conducted in Indonesia among school children aged 9–12 years, which discovered that a similar 23.87% of children were classified as obese (Farapti et al. 2019). These results emphasize the multifactorial factors associated to obesity in children such as food habit containing high calorie on weekends than weekdays (Kandinasti & Farapti 2019). Nevertheless, in COVID-19 pandemic, it seem not really happen. Online learning due to school closures during the COVID-19 pandemic has also been reported to have contributed to weight gain in children. Storage of ultra-processed foods, consumption of high-calorie foods, reduced physical activity, and longer screen time for both for study or play contribute to an increased risk of childhood obesity (Herliani 2021).

Children's nutritional status is often linked to food intake, which is closely related to taste sensitivity. Our study found that more than half of the children have a good sensitivity to sweet and salty tastes. Similar results were found in Pennsylvanian school children aged 7 to 14, that the majority of students were able to provide accurate responses with a sweet detecting threshold of 12.0 Mm (Joseph et al. 2016). The results may have been similar because both studies used healthy children with no medical conditions, similar age ranges, and had the same sucralose concentration. A good taste sensitivity in children is often associated with an optimal children's physiology and the entire body still functions properly. In addition, decreased taste sensitivity can also be caused by age, illness, smoking, and use of certain medications, which increase with age (Sari et al. 2022).

In addition, the results also showed a significant difference in the number of children who had good sweet and salty taste sensitivity, with salty taste sensitivity showing a greater value. The same results were carried out by Ervina et al. (2020)in their study on 11 – year – old children in Norway, who showed that children were more sensitive to the taste of salt than sucrose (both detection and recognition threshold). This study gave five concentrations of sucrose solution ranging from 3.0 g/L to 16.0 g/L and saline from 0.2 g/L to 1.6 g/L, while we gave sugar and salt solutions with the same amount or equivalent of 1 g/L to 4 g/L. Based on how the brain represents the intensity of sweet and salty tastes, an increase in salt concentration leads to a greater increase in anterior insula activation than an increase in sugar concentration (Spetter et al. 2010). As a result, the perception of saltiness is easier to recognize than sweetness when given the same concentration.

Our study shows that taste preferences determined by sugar and salt grading tests on foods are consistent with self-reported preferences. Gage et al. (2021) discovered similar results, showing that children prefer dairy products with a content of >10 g/100 ml compared to <10 g/100 ml of sugar. Similar results were also found for salty taste preferences. The study conducted by Mennella et al. (2014) showed that children preferred higher salt concentration by giving 0.92–6.14% wt/vol NaCl to vegetable broth. Additionally, research on school food contributions in Indonesia highlighted that the estimated sodium intake among school children aged 9–12 still exceeds 40% (Farapti et al. 2019). These insights underscore the importance of understanding taste preferences, which tend to develop during early exposure to sweet or salty foods and will increase between the ages of 6 and 11 years. At this age, children often eat what they like without considering whether it is considered to be healthy or not. A lack of understanding and little awareness of the value of maintaining good health exists until children adopt of a healthy lifestyle. Serving and preparing nutritious food for children becomes critically important.

Eating preferences in children is influenced by eating habits, and that eating habits are influenced by community, family, and individual (Paglia 2019). The process of taste learning take place in the early stages of life. The results of a systematic review by Paroche et al. (2017) showed that infants who received repeated sugar water at three months of age experienced an increase in sugar consumption at age 2 years and infants who received repeated vegetable exposure experienced an increase in vegetable preference. In addition, family and friend also gives a big role to the selection of its main food for children. Children tend to have an imitative nature and want the same foods that are being consumed by their peers and family.

In the results of formulating healthy food, the majority of subjects admitted that they have enough sweet and salty taste. Given the foregoing, shows that healthy snacks with an ideal sugar and salt can still be well received by the taste buds even though about a quarter of them claim to be less sweet or salty. Positive results were also found in the preferences provided for healthy snacks. The results showed that more than half of the subjects said they liked the taste of the snack provided, followed by very like, and less like with the least number of subjects. Based on the findings above, it can be seen that in addition to being well received by the tongue, snacks with ideal sugar and salt settings are still preferred by children.

The results showed that there was a correlation between sweet taste sensitivity and obesity, but not salty taste. Differences in results may be caused by using too high a saline solution, leaving 89.1% in the good sensitivity group or by the results that are too homogeneous. Similar results were found by Overberg et al. (2012) who found a difference in taste sensitivity between obese and non – obese children and adolescents. Overberg et al. (2012) mentioned that normal-weight children can answer more precisely than obese ones. The correlation between taste sensitivity with obesity is often related to eating habits. Food exposure can also be linked to taste sensitivity. According to a study by Fry Vennerød et al. (2018), preschoolers children aged 4–5 years who were more sensitive to sweet were also less frequently exposed to sweet meals. Meanwhile, in children aged 12–13 years showed that children at this age consume fast food more often, have a low sensitivity of salty taste and, as consequently, their preference for the saltier bean sprout soup.

The results also showed that there was a correlation between sweet taste preferences with nutritional status in children. Research conducted by Morenga et al. (2013) mentioned that children who consume sugar-sweet beverages as much more than 1 times the risk of 1.55 times the incidence of overweight/obesity compared to children who do not consume sugar-sweet beverages. In general, an individual's preference for a particular taste has implications for energy intake. Some studies suggest that sucrose consumption may activate opioid (e.g., nucleus accumbens) and dopaminergic (e.g., ventral tegmental area and right amygdala) reward centers in the brain (Green & Murphy 2012). This suggests that sugar is "addictive" and leads to excessive food intake and weight gain (Tan & Tucker 2019). Together, these mechanistic investigations appear to show that sweetness stimulates both food intake and behavior.

The advantage of this study is to present a comprehensive method for assessing taste sensitivity and taste preference to conduct applications on foods commonly consumed by children. In addition, the presented healthy snack menu also refers to the provision of sugar and salt settings. The weakness of this study is that it did not examine the factors underlying eating habit, such as knowledge, awareness of healthy food consumption, diet in the family, and peer environmental factors that may play a role in shaping children's eating preference.

Conclusion

The results showed that the prevalence of overweight and obesity in this study is still relatively high. Although the results of the study show that sensitivity to sweet and salty is quite high, it was found that a child's taste preference for sweet and salty tastes was always the same in both the sucralose and saline tests and the food-form test is still pretty dominant. In addition, taste sensitivity and taste preferences, especially for sweetness, showed significant results in overweight and obesity. For this reason, the selection and presentation of healthy foods must be considered according to the daily limit of sugar and salt intake in children to support optimal nutritional status.

This study has several strengths. First, it thoroughly examined taste sensitivity and preference using multiple methods, including perceptual observation, gustatory testing, and taste implementation through commonly consumed food. This allows for a deeper understanding of how taste affects children's eating habits, not only from a scientific point of view but also from a cultural and food acceptance perspective. Additionally, the study was conducted on a relatively large sample of healthy children aged 9–14 years. Consequently, this investigation provides a more thorough understanding of the correlation between taste and food preference in children.

However, it is important to note the limitations of this study. This study used only three saline concentrations during testing. As a result, there were limitations in analyzing the upper and lower thresholds of subjects' taste sensitivity. This study did not include cognitive testing before conducting the experiment to ensure that subjects comprehended the study procedures and instructions. Although the subjects followed the study cooperatively, there is a likelihood that their interpretation of the directions varied, which could have an impact on the testing outcomes. In addition, there may be a concern regarding the restriction of subjects from eating for an hour before the study and not assessing their hunger levels. These factors could potentially influence the subjects' perceptions and taste preferences. Thus, identifying their impact could reduce the bias in this study, especially when involving children.

Considering the identified limitations, various recommendations can be proposed for future research. First, future studies should consider testing taste sensitivity using a wider range of saline concentrations. This would allow for a better understanding of subtle or blunted levels of sensitivity within the child population. Second, administering a baseline cognitive test before conducting the study would help ensure that the subjects understood the instructions adequately and reduced variability in their responses. Furthermore, it is important to examine the hunger levels of the subjects before the study to understand how they affect taste perception and preference. Longitudinal studies that monitor children's taste sensitivity and preferences over time may provide more comprehensive insights. Finally, incorporating the dietary intake data of the subjects in the study can aid in examining the correlation between children's taste preferences, diet, and how it affects their health. Investigating family eating habits, knowledge of a healthy diet, and influence of peers is necessary to determine the impact of the environment on children's eating preferences.

The results of this study have various practical applications such as improving nutrition programs in schools by aligning food offerings with children's taste preferences. This could include more attractive and nutritious options, such as fruits and vegetables with interesting tastes and textures. Schools and community organizations can implement educational programs that teach children the importance of a balanced diet and the impact of excessive sugar and salt intake on their health. Parents can also benefit from this research by becoming more aware of their children's taste preferences and their potential impact on eating habits, which will ultimately affect their health and well-being in the future.

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Authors' contributions
Farapti Farapti designed and conceived the research, performed the analytical calculation, interpreted the result, and reviewed the manuscript; Afifah Nurma Sari participated in designed the study, data collection, and wrote the manuscript; Chusnul Fadilla participated in designed the study, data collection, and wrote the manuscript; Zuraini Mat Issa assigned in reviewed and supervised the final manuscript.

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Availability of data and materials
The data supporting the findings in this article are included in the manuscript. More details about the data and materials will be made available on request by the corresponding author.

Declarations

Ethics approval and consent to participate
The research ethics were approved by the Health Research Ethics Committee of the Faculty of Dentistry, Universitas Airlangga, with certificate number 409/HRECC.FODM/IX/2020 and the committee of Ethics Faculty of Public Health, Universitas Airlangga with certifict number 143/EA/KEPK/2022 Informed consent was obtained from the teacher and children's parents prior to the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no conflicts of interest.

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