



Physical Activity, Sensory Threshold of Sweetness, and Waist-to-Height Ratio (WHtR) in Adolescents

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ABSTRACT

Purpose: The research objective is to reveal the correlation between physical activity and sensory threshold sweetness with a waist to height ratio in adolescents (WHtR).

Methodology: This research was observational analytic using a cross-sectional approach. The study was conducted at State High Schools in the Districts of Jebres, Banjarsari, and Serengan in Surakarta City, which involved 140 adolescents aged 15-17 years. The physical activity data were obtained from interviews with the subjects using the Physical Activity Questionnaire for Adolescents (PAQ-A) questionnaire, and the sensory threshold of sweetness data was obtained from the identification of the subject in a sucrose solution with different concentrations. The data of the waist to height ratio were obtained by dividing the measurement value of waist circumference by a height value.

Results: The study showed that there was a significant link between the physical activity with a waist to height ratio ($r = -0.602$; $p < 0.001$), and the sensory threshold sweetness with a waist to height ratio ($r = 0.393$; $p < 0.001$).

Applications/Originality/Value: From the results of this research, it can be concluded that there is a significant relationship between physical activity and sensory threshold of sweetness with a waist to height ratio (WHtR). Adolescents with abnormal waist to height ratio (WHtR) measurements (≥ 0.50) can carry out physical activity in sufficient quantities, and regulate food habits according to the needs of physical growth and development, especially limiting sugar consumption.

Keywords: abdominal obesity, adolescent, physical activity, sensory threshold of sweetness, WHtR

INTRODUCTION

Adolescents are age groups that are vulnerable to nutritional problems, so balanced nutrition is needed to accelerate growth and development of physical, psychological, neurological, and intellectual (1,2). Nutrition problems that are often found in adolescents are unwanted changes in body weight, one of which is obesity due to increased muscle mass, body fat tissue, and hormonal changes (3,4). The waist to height ratio (WHtR) is an anthropometric index that is more sensitive than BMI to illustrate the distribution of excess fat in the upper body and reflect the presence of harmful fat in the abdomen (abdominal obesity) (5). The use of WHtR is highly recommended for obesity screening in adolescents as the cut-off point. WHtR of ≥ 0.50 cm can be applied to adolescent age groups with various ethnic and gender, both male and female (6).

Obesity is one of the rapidly growing health problems among teenagers. The highest incidence rate of overweight and obesity occurs in low-and middle-income countries, with a global prevalence of overweight and obesity at the age of 5-19 years by 18% (7). The prevalence of overweight in Indonesia in

adolescents aged 13-15 years increased from 2.5% (2010) to 10.8% (2013) and 16% (2018), while the prevalence of excess weight in teenagers aged 16-18 years also increased from 1.4% (2010) to 7.3% (2013) and 13.5% (2018) (8-10). While in the city of Surakarta, the prevalence of overweight in adolescents aged 13-15 years was 10.9% consisting of 10.1% fat and 0.8% obesity and at the age of 16-18 years was 12.3% consisting of 6.4% fat and 5.9% obesity (11).

Obesity in adolescents is at high risk of becoming obese in adulthood (12), potentially becoming a cause of cardiovascular and metabolic diseases (1,13), and increasing mortality (14). Obesity is caused by the interaction of genetic, physiological, environmental, social, and economic factors (15), such as lifestyle changes, especially diet and physical activity (16). Dietary habits with unbalanced nutrient intake can trigger weight gain to become obese in adolescents (17,18). Adolescents, with a tendency to consume food specifically, have a positive relationship with more nutritional status. Fast food consumption can increase risk by 1.23 times to become obese in adolescents aged 13-15 years with a higher percentage of body fat and an increase in body mass index by 0.08 kg/m^2 (19). Sugar-sweetened and soft-drink consumption

in adolescence can also increase body mass index by 0.07-0.1 kg/m² and the fat percentage by 4.45% (20,21).

Physical activity is the body's movements produced by skeletal muscles that require energy expenditure (22). Lack of physical activity is one of the main factors that cause overweight and obesity (23). Individuals who are less active in moving have a 2.55 times chance to become obese due to excess energy reserves in the body (24-26). Recommendations that are suggested for the prevention of being overweight become obese require more physical activity at least 45-60 minutes/day and prevention of weight gain increases again in individuals who are overweight are an encouragement to do physical activity 60-90 minutes/day (27,28).

The diversity of Indonesian society ranging from ethnicity, culture, age, and occupation has an influence on the sensitivity of sweet taste and daily sugar intake, such as, Javanese ethnic tastes tend to prefer sweet foods and drinks (29), as the Riskesdas (Basic Health Research) data (2013) which shows that the prevalence of the behavior of consuming sweet foods/drinks ≥ 1 time a day in Central Java is 62.9%; this figure is much higher than the national figure of 53.1% (11). It is undoubtedly influenced by habits that affect the sensitivity of specific tastes (30). Someone who likes and often consumes sweet foods tends to have a high threshold of sweet taste (31,32), besides the condition of obesity can also affect the sensitivity of taste because there is a direct relationship between the expression of genetic variations in the taste sense and changes in the sense of taste to the sharpness in detecting taste (33-35). Given the prevalence of obesity continues to increase, especially among adolescents, this research needs to be done to determine the relationship of physical activity and sensory threshold of sweetness with the ratio of waist to height in adolescents.

SUBJECT AND METHOD

Research Types and Design

The type of this research was observational analytic with a cross-sectional approach. The study was conducted in seven senior high schools in the Banjarsari, Jebres, and Serengan Sub-districts of Surakarta. Data were collected from August till October 2019.

Population and Sample

The population in this study is adolescents aged 15-17 years who are state high school students in the Surakarta City area. The sample of this study was state high school students in the Surakarta City area. The sample size in this study was calculated using the formula (36), and based on the calculation results, it can be obtained a total sample of 140. Sampling was done by a multi-stage random sampling method. The determination of sub-districts and schools was based on the location of state high schools located in three sub-districts (Banjarsari, Serengan, and Jebres), then the sample of adolescents in each school was selected by proportional random sampling.

The inclusion criteria in this study were teenage boys and girls attending high school in the Surakarta City area, aged 15-17 years, physically and mentally healthy, not smoking, and not consuming alcohol while the exclusion criteria in this study

were adolescents who were not present during the study and were menstruating.

Data Collection

Physical activity

Physical activity data collection was using the PAQ-A (Physical Activity Questionnaire for Adolescence) form with research-based categories (37). There were nine items of questions in the questionnaire related to activities carried out daily with an intensity of time was seven days before.

Sweet sensory threshold

Sensory threshold sweetness data collection was using five sucrose solutions with different concentrations based on the American Society of Testing and Materials (ASTM) (38), Sucrose solution was presented in the order of concentration from the lowest to the highest. The subjects tasted five sucrose solutions in sequence and were asked to identify samples that gave the impression of sweetness.

The ratio of waist to height (WHtR)

Data collection of the ratio of waist to height (WHtR) adolescents was through direct measurement of waist circumference and height, then divided the measurement value of waist circumference with the height value. Classification of data on the ratio of waist to height (WHtR) was based on (39) and research (6). Height measurements were carried out in an upright position as close as possible to the wall and straight ahead, and the measurement results were expressed in centimeters (cm). Whereas, waist circumference measurements were made on the top of the iliac crest horizontally around the abdomen. The measuring tape had to stick to the skin but not to the point of pressure, and the measurement results were also expressed in centimeters (cm).

Data Analysis

The data obtained were analyzed by using SPSS software version 22. The normality test used Kolmogorov-Smirnov, a test between physical activity and the ratio of waist to height with Pearson Product Moment correlation, while the test between the sweet taste sensory threshold and the ratio of waist to height was performed with the Spearman Rank. Pearson Product Moment Test and Spearman Rank used to determine the strength and direction of the relationship between variables.

Research Ethics

Research ethics with informed consent, anonymity, confidentiality, and ethical clearance were from the Research Ethics Commission of Sebelas Maret University, Surakarta, with numbers 142/UN27.06/KEPK/2019.

RESULTS

The research subjects were 140 adolescents aged 15-17 years, and most of them were female. Physical activity of the subjects in this study included in low physical activity with an average of 2.17. The average concentration value of the sensory threshold sweetness of 0.53 g/ml was included in the high category. Most subjects had a normal waist to height ratio of 0.48. The distribution of subject characteristics can be seen in **Table 1**.

Table 1. Characteristics of research subjects

Characteristics	n	%	Min Value	Max Value	Mean±SD
Sex					
Male	68	48.6			
Female	72	51.4			
Age (years)			15	17	15.56 ± 0.54
15	64	45.7			
16	73	52.1			
17	3	2.1			
Physical Activity			1.191	3.429	2.17 ± 0.62
Sensory Threshold Sweetness			0.06	0.96	0.53 ± 0.32
Waist-to-Height Ratio			0.32	0.64	0.48 ± 0.07

Table 2. Relationship between physical activity, sensory threshold sweetness, and waist-to-height ratio

Variables	Waist-to-Height Ratio	
	r	p
Physical Activity	-0.602	<0.001 ^a
Sensory Threshold Sweetness	0.393	<0.001 ^b

^aProduct Moment Correlation test^bRank Spearman test**Table 3.** Regression analysis of physical activity, sensory threshold sweetness and waist-to-height ratio

Variables	B	t	p	95%CI
Physical Activity	-0.064	-8.126	<0.001	2.064 - 2.271
Sensory Threshold Sweetness	0.059	3.947	<0.001	0.477 - 0.585
Constant	0.583	27.774		
F		51.128		
F (sig)		<0.001		
R square		0.427		

The results of data analysis showed that there was a significant correlation between physical activity with the waist to height ratio (WHtR) ($p < 0.001$) with the correlation coefficient number which showed a negative relationship. Sensory threshold sweetness was also significantly related to the waist to height ratio ($p < 0.001$). The correlation coefficient showed a positive relationship between the sensory threshold sweetness and the waist to height ratio. The relationship between physical activity, sensory threshold sweetness, and waist-to-height ratio can be seen in **Table 2**.

After conducting linearity analysis, normality, and classic assumptions, it is known that there is a linear relationship between the independent variable and the dependent variable, residual value is normally distributed ($p > 0.05$), and the model is free from multicollinearity symptoms (VIF value > 10) and heteroscedasticity problem so that it can be continued to be analyzed by using multiple linear regression tests. Based on the result of the multiple linear regression test in **Table 3**, it is obtained the probability value of F (sig) < 0.05 , so that it can be concluded that the regression model is feasible to use. The determinant coefficient (R square) is obtained by 42.7%. This is showed that the variation of waist to height ratio of 42.7% is influenced by physical activity and sensory of sweetness, while 57.3% is explained by other variables not examined. Based on the calculation of effective contributions, physical activity contributes by 32.51% affecting the waist to height ratio and sensory threshold sweetness contributes by 10.19% affecting waist to height ratio.

DISCUSSION

The taste is an important parameter that determines the acceptance of food product. Eating habit is one of the factor that affect sensory threshold related to the intensity of certain flavor found in food. The difference in eating habits is an interesting thing to study further in relation to the sensory threshold of sweetness in the Javanese tribe in Indonesia. This study was the first to be conducted to find out the relationship between sweet taste threshold and nutritional status based on the ratio of waist-height ratio (WHtR) in 15-17 years old Javanese adolescents. Indonesian especially Javanese have had a high sensory threshold for sweetness as they are accustomed to consuming sweet foods and drinks. Javanese eating habit cannot be separated from sweet taste like the use of sugar in dishes that are a source of calories. Then, it is one of the factors associated with high energy intake. The increase in energy sourced from sweet foods is considered as one that contributes to an excess nutritional status and obesity.

The Relationship Between Physical Activity and Waist to Height Ratio

Statistical analysis showed a significant correlation between physical activity and the ratio of waist to height ($r = -0.602$, $p < 0.001$). It is relevant to previous studies, which also reported that there was a significant inverse correlation between physical activity and the ratio of waist to height (p -value < 0.001) (40). Physically active individuals can reduce body fat, especially in the abdominal area, thus affecting the size of the ratio of waist circumference to lower body height (41). It supports the inverse relationship between physical activity and obesity, which is explained by the low ratio of waist to height.

Physical activity plays a significant role in increasing the regulation of energy and macronutrient balance and general bodily functions (homeostasis) (42). In addition, physical activity plays an important role in preventing overweight and obesity in children and adolescents, as well as reducing the risk of obesity in adulthood (43). Puberty and adolescence are vulnerable to the development of obesity due to sexual maturation and decreased physical activity (44). Adolescents who are more physically active usually have lower body fat levels than those who are less active in moving (45). However, most adolescents in some countries are reported not to do physical activity according to recommended guidelines. Adolescents spend more time on sedentary activities such as watching television and using other electronic media (46).

Physical activity is very beneficial for adolescents. The physical activity carried out regularly in sufficient quantities can control and maintain ideal body weight and improve

fitness and health (22). Physical activity also has psychological benefits for adolescents by providing mental health effects and better happiness so that adolescents could avoid anxiety and depression (44,47). Increasing knowledge, intelligence, creativity, productivity, ability, skills, and academic achievement are long-term positive impacts that can be obtained by adolescents from regular physical activity (48).

Relationship between Sensory Threshold Sweetness and Waist to Height Ratio

The sense of taste is one of the five senses that are active when nutrients or chemical compounds stimulated the taste receptor cells in the oral cavity (49). Taste is an important aspect that is used to determine the acceptance of food, so it plays a role in influencing one's eating behavior. The difference in the ability to detect and recognize taste is influenced by a person's daily eating habits (30,40). Individuals with the habit of consuming foods with high levels of sweet taste will tend to need a high concentration of sweet taste to obtain the desired taste sensation, or the threshold of detection of sweet taste is increased (31).

The results showed that there were a significant relationship between the sensory threshold of sweetness and the waist to height ratio ($r = 0.393$, $p < 0.001$). Relevant to the previous studies, which reported that the threshold of sweetness detection affects the size of the ratio of waist to height in children aged 7-14 years (52). Other studies have also shown that obese individuals have a higher sweet taste threshold at a concentration of 0.7 g/ml, whereas normal individuals have a sweet taste threshold at a concentration of 0.33 g/ml (33). Significant differences in sweet taste detection threshold with Body Mass Index ($p < 0.001$) were also found in children aged 13-15 years in Saudi Arabia (52). A favor for sweetness and sugar-sprinkling habits also have a positive influence on increasing body mass index (31).

Individuals are born with a taste for sweetness. The sweet taste is a sign that food has calories (52). Sugary foods are consumed to provide the energy needed to increase growth and development, but an increase in energy intake, especially those sourced from sweet foods, is considered to be one that contributes to obesity (51). It is relevant to the research conducted by (53), which showed that food intake with high carbohydrate and sugar has a positive effect on obesity, which is characterized by an increase in the ratio of waist to height (WHtR).

The difference in the sweet taste threshold in children and adolescents is influenced by genetic factors that play a role in regulating the gustatory system (sense of taste). Diversity of sweet taste receptors TAS1R2, TAS1R3, and GNAT3 have been shown to affect sweet taste sensitivity (55,56). Changes in leptin can also cause an increase in sweetness. Leptin is a hormone released by adipocytes (lipocytes and fat cells) which functions to regulate food intake, energy expenditure, and body weight. The sense of taste is one of the targets of leptin. Leptin selectively suppresses the response of nerves and behavior to sweet compounds without affecting other taste stimuli. Previous studies conducted on mice identified that leptin receptors in the taste buds of obese mice showed an increase of nerve response and higher behavioral preferences for sweet arousal stimuli (57). In addition, studies conducted on obese individuals undergoing a weight-loss diet program experience changes in leptin levels and lower detection rates for sweetness. It is related to the leptin receptor polymorphism

(Lys109Arg) associated with insulin and glucose metabolism (58).

Several factors caused obese individuals to have a higher taste detection threshold compared to normal individuals. First, obese individuals have lower sensory signal of sensitivity. Decreased sensitivity of this sensory signal can affect the psychology of obese individuals to increase food consumption resulting in excess energy intake, which has an impact on obesity (59). Second, there are differences in activity in the brain tissue of obese and normal individuals. The brain tissue of obese individuals shows a variety of higher activity in reaction to responses to taste stimuli. Third, the differences in CD36 expression found in the sense of taste (tongue), which are receptors related to taste sensitivity. Decreased expression of taste sensory CD36 (tongue) in obese individuals can reduce sensitivity to taste stimulation, so obese individuals must consume more food to get the desired taste sensation (60).

CONCLUSION

This study concluded that there was a significant negative correlation between physical activity and waist to height ratio. The more physically active, it will affect the size of the waist to lower height ratio. In addition, there was a significant correlation between sensory threshold sweetness and waist to height ratio.

The research result provided some recommendations for adolescents such as performing physical activities as suggested by WHO (World Health Organization), doing a moderate level of physical activity every day for 60 minutes or at least a high level of physical activity with a frequency of 3 times a week (22). It is also necessary to limit the intake of food groups with high sugar, according to recommendations (61), which suggests a decrease in sugar usage to below 5% or 25 grams, and the addition of sugar should not exceed 10% of the total daily energy intake.

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