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Original Research Article

Overweight and obesity screening indicator using neck circumference

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ABSTRACT

Background: Overweight and obesity can be assessed through anthropometric measurements using the body mass index (BMI). Some studies suggest that neck fat is positively correlated with visceral fat, insulin resistance, and metabolic syndrome. Neck circumference has been shown to be closely correlated with BMI and can be used as a practical screening tool for identifying overweight or obese individuals in both men and women. However, the correlation of neck circumference with measurements of body fat percentage in obesity has not been studied.
Methods: This study is an analytical study that conducted sensitivity and specificity analyses of neck circumference to describe indicators of overweight and obesity in children. Data collected included neck circumference, weight, height (converted into BMI), and other characteristics of the children. Neck circumference measurements were taken using neck circumference tape.
Results: The results showed that the body weight of school-age children had an average of 28.3 kg. Height had an average of 133.2 cm. Neck circumference measurements had an average of 30.3 cm. The correlation analysis using the Pearson product moment test showed a significant value of r=0.483 and p=0.00.
Conclusions: There is a significant relationship between neck circumference and BMI. The greater the neck circumference, the greater the BMI, and the area under the curve (AUC) of the ROC curve indicates that neck circumference is a better diagnostic tool for identifying BMI. The results of the ROC curve showed a UAC value of 0.783, indicating that neck circumference can diagnose obesity with an accuracy of 78.3%.

Keywords: Overweight, Obesity, Neck circumference

INTRODUCTION

Obesity is a public health problem worldwide, affecting both developed as well as the developing countries. In Asia, the prevalence of overweight school-age children is more than 60 percentages, making it the highest among developing countries.[1] In Indonesia, the national prevalence of obesity among 13-15-year-olds is 2.5 percentages. Obesity occurs due to an imbalance between the amount of incoming energy and what is required for various biological functions, such as physical growth, development, activity, as well as the maintenance of health.[2]

According to the 2013 basic health research data, the prevalence of obesity among children aged 5-12 years in Indonesia is still high, at 18.8 percentages, consisting of 10.8 percentages fat and 8 percentages very fat (obese).[3] The prevalence of childhood obesity has increased in various countries, including Indonesia. The prevalence of childhood obesity has increased in various countries, including Indonesia, due to the growth of urbanization and changes in lifestyle, including energy intake. The World Health Organization (WHO) reports that one in ten children worldwide is overweight, and the increase in obesity in children and adolescent's parallels that of adults.[1]

Childhood obesity is a significant concern, as excess weight can lead to health problems usually experienced by adults, such as diabetes, high blood pressure, and high cholesterol. Obesity can also cause chronic diseases, including impaired glucose metabolism, insulin resistance, type 2 diabetes in adolescents, hypertension, diabetes mellitus, hepatic steatosis, gastrointestinal disorders, and respiratory obstruction during sleep.[4]

Anthropometric methods such as measuring BMI, waist circumference, hip circumference, arm circumference, and neck circumference can be used to determine the occurrence of obesity. BMI is widely used to estimate fat composition, but it has limitations, such as not being accurate in certain conditions, such as an athletic body posture being included in the obesity category or neglecting fat in the elderly.

Neck circumference, on the other hand, is an index of upper body obesity and a simple screening measure to identify overweight or obese children. Neck circumference is correlated with body circumference, waist to hip ratio, BMI, total cholesterol, triglycerides, LDL-cholesterol, uric acid, and glucose levels in both men and women.[5] To measure neck circumference, use a non-elastic measuring tape, hold your head upright with your eyes facing the gauge, measure the most protruding part of the thyroid cartilage (Adam's apple), and measure carefully on the surface of the skin. The explanation above identifies neck circumference as a useful indicator of overweight and obesity screening, and therefore its development is important.

METHODS

This type of research is analytical research because it analyzes the sensitivity and specificity of neck circumference as an indicator of obesity and overweight in children. Based on time, this research is cross-sectional because the independent and dependent variables are measured at the same time. The research was conducted in June 2020 for 1 month.

The population in this study was all elementary school children in Kramat Pela Kebayoran Baru, South Jakarta, while the sample comprised a portion of elementary school children from Kramat Pela Kebayoran Baru elementary school. However, due to pandemic conditions, anthropometric measurements were conducted in Wonogiri Regency, which included SD Wonokerto, Wonokarto, and Wonoharjo.

Sampling in this study was carried out by systematic random sampling. The inclusion criteria were elementary school children who were in good health and registered as students at Kramat Pela elementary school, while the exclusion criteria were elementary school children with physical abnormalities on the neck or gland infections. The determination of the number of samples was carried out using the formula of Lemeshow (1991):

$$n = \frac{Zc^2 \times P \times Q}{E^2}$$

Information:

n: Sample size

Zc^2: Confidence level (95%) →(z: 1.96)

P: Proportion of obesity in school children (34.5%)

Q: 1-P = 1– 0.345= 0.655

E: Acceptable sample error (5%)

N: 685 people

The study involved 182 school children, comprising 37 from Wonokerto, 106 from Wonokarto, and 39 from Wonoharjo.

Data analysis was conducted on characteristic variables, including age and gender, which were processed and analyzed descriptively and presented in tables or graphs. The nutritional status variable was processed by comparing the Z score with the classification of nutritional status. The neck circumference variable was processed as continuous data to develop its boundaries. To answer the research objective, a sensitivity and specificity analysis will be conducted between neck circumference and obesity.

RESULTS

Characteristics of school children and respondent's parents

The analysis of the research results showed that 50.5% of the school children were male, while 49.5% were female. In terms of class distribution, the majority of the respondents were in class 2, accounting for 20.3% of the total. Furthermore, the majority of the mothers (54.9%) and fathers (63.7%) had completed high school or had no formal education. The table below presents the data on the characteristics of the school children and their parents (Table 1).

Anthropometric data of school children

The study's results showed that the minimum weight of the school children was 13.0 kg, the maximum was 70.0 kg, and the average weight was 28.3 kg with a SD of 9.5 kg. The minimum height was 106.0 cm, the maximum was 165.0 cm, and the average height was 133.2 cm with a SD of 11.5 cm. The neck circumference data showed an average of 30.3 cm, minimum of 24.0 cm and the maximum of 40.5 cm with a SD of 3.3 cm. Table 2 presents the anthropometric data of the elementary school children.

Table 1: Distribution of characteristics of children and parents in Jakarta 2020, (n=182).

Characteristics	N	Percent (%)
Gender		
Man	92	50.5
Woman	90	49.5
Grade of children in elementary school		
1st grade	33	18.1
2nd grade	37	20.3
3rd grade	27	14.8
4th grade	24	13.2
5th grade	30	16.5
6th grade	31	17.0
Mother's education		
Elementary school graduated/not	20	11.0
Junior high school graduated/not	44	24.2
Senior high school graduated/not	100	54.9
College	18	9.9
Father's education		
Elementary school graduated/not	24	13.2
Junior high school graduated/not	27	14.8
Senior high school graduated/not	116	63.7
College	15	8.2

Table 2: Anthropometric statistical data for children in 2020, (n=182).

Anthropometry	Min	Max	SD	Average
Weight (kg)	13	70	9.5	28.3
Height (cm)	106	165	11.5	133.2
Neck circumference (cm)	24	40.5	3.3	30.3

When the body weight data is explored for its distribution, the following results are obtained.

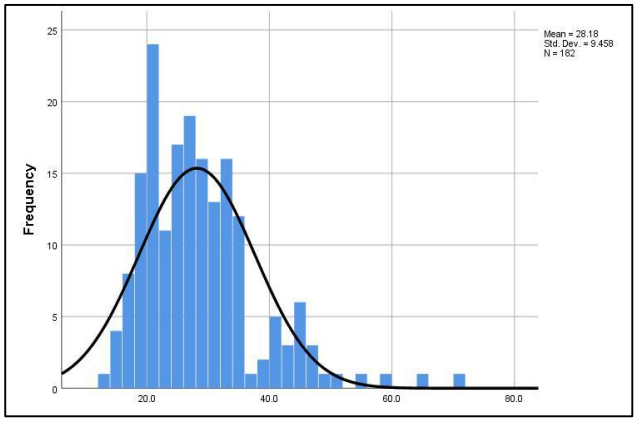

Figure 1: Histogram of weight in children (n=182).

Figure 1 shows the histogram of the toddler's weight. The results of statistical tests using the Kolmogorov Smirnov test showed that the p=0.187, which indicates that Ho is accepted and that the body weight is normally distributed. Similarly, for height, a p=0.200 was obtained, indicating that Ho was accepted. This suggests that the distribution of height is symmetrical, and the median indicates a normal distribution. Figure 2 presents a histogram of the toddler's height.

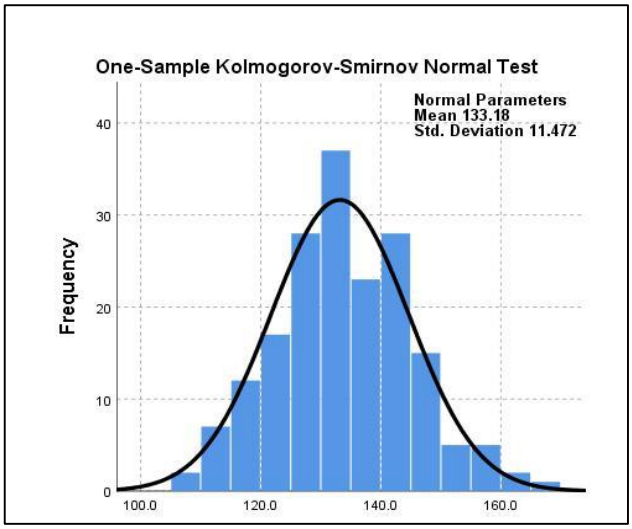

Figure 2: Histogram of height in the children, (n=182).

Nutritional status of school children

Nutritional status of 182 school children showed in Figure 3.

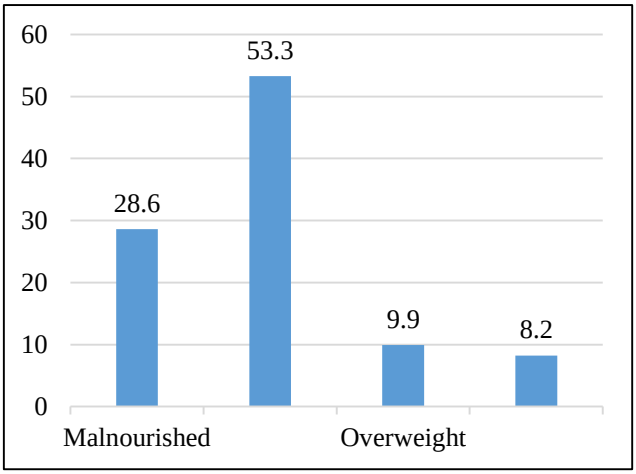

Figure 3: Distribution of nutritional status of school children in 2020 (n=182).

The picture above shows weight and height measurements have been taken for 182 school children. The data has been presented using the TB/A and BMI/A indices. According to the BMI/U index, 8.2% of the children are classified as obese and 9.9% are in a state of overnutrition, resulting in a total percentage of 19.1% of

children being overweight or obese. Figure 4 below presents the results of a composite analysis between the TB/A index and BMI/A.

The Figure 4 indicates 2.8% of school children have the potential to be overweight and obese. Nutritional status data was obtained from 182 school children, which was then screened for malnourished, well-nourished, and overweight/obese children. Out of these, 27 children were malnourished, 45 were well-nourished, and 20 were overweight/obese. Further analysis revealed that there was no significant difference in the proportion of overweight/obese and undernourished children based on gender, mother's education level, and father's education level. Table 3 presents the distribution of parent's characteristics among the groups of malnourished, well-nourished, and overweight/obese children.

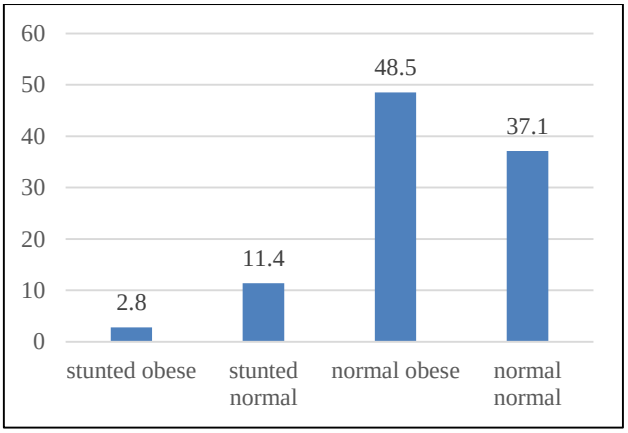

Figure 4: Composite nutritional status based on height/age and BMI/age (n=182).

Table 3: Distribution of nutritional status based on characteristics of school children (n= 92).

Nutritional status	Malnourished		Well-nourished		Overweight/ obese		P value
	N	%	N	%	N	%	
Gender							
Man	27	29.3	45	48.9	20	21.7	0.360
Woman	25	27.8	52	57.8	13	14.4	
Mother's education level							
Low	15	23.4	39	60.9	10	15.6	0.311
High	37	31.4	58	49.2	23	19.5	
Father's education level							
Low	16	31.4	23	45.1	12	23.5	0.328
High	36	27.5	74	56.5	21	16.0	

Neck circumference

The results of the study indicate that the minimum neck circumference of male school children is 24 cm, the maximum is 40 cm, and the average is 30.5 cm with a SD of 3.4 cm. On the other hand, for female school children, the minimum neck circumference is 24 cm, the maximum is 40.5 cm, and the average is 30.2 cm with a SD of 3.3 cm. Table 4 presents the neck circumference values for school children.

Table 4: Neck circumference based on the characteristics of school children, (n=182).

Gender	Min	Max	SD	Average
Man	24	40.0	3.4	30.5
Woman	24	40.5	3.3	30.2

The data above shows that there is little difference in the neck circumference between male and female school children, as can be seen in the similar mean values and SD. The Kolmogorov Smirnov test indicates that the neck circumference of school children follows a normal distribution, with a p=0.173.

Figure 5 displays a histogram of neck circumference in school children.

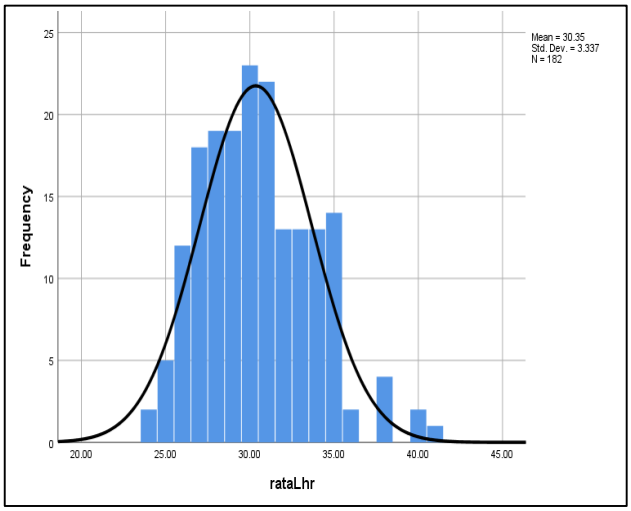

Figure 5: Histogram of height in children (n=182).

Correlation of neck circumference and BMI

The correlation results using the Pearson product moment test indicate that the value of r=0.483 and p=0.000, which is significant. The following table presents the correlation results between neck circumference and mass index in school children.

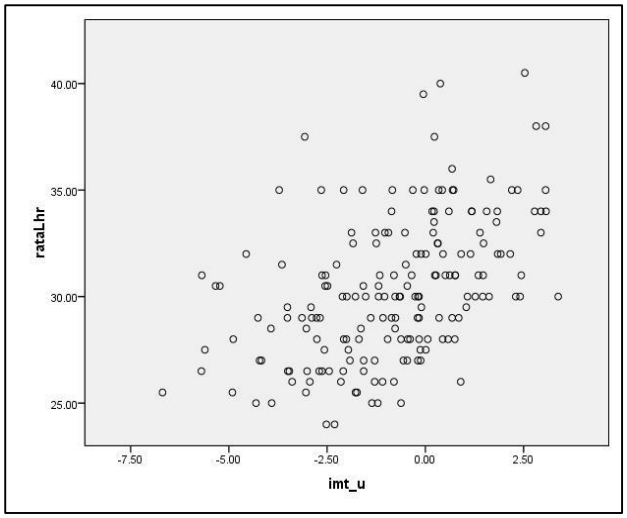

Figure 6: Correlation of neck circumference and BMI (n=182).

Sensitivity and specificity

Based on the graph results, it can be seen that a neck circumference of 32.0 cm corresponds to a sensitivity of 66.7% and a specificity of 75.2%. This indicates that a neck circumference of 32.0 cm can identify 66.7% of overweight/obese children and 75.2% of those who are not overweight/obese. The following table presents the sensitivity and specificity results for school children.

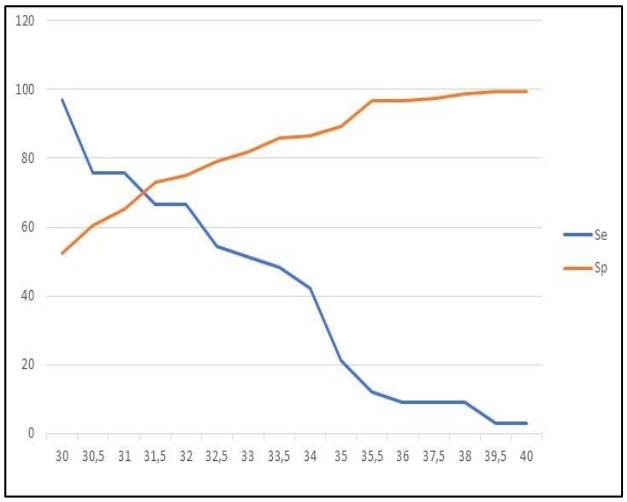

Figure 7: Sensitivity and specificity of neck circumference (n=182).

The ROC (Receiver operating characteristic) curve is a plot of sensitivity to (1-specificity) values within a certain range of cut-off point values. A larger area under the curve indicates a better diagnostic performance, indicating that neck circumference is a better predictor of BMI. The results of the ROC curve for neck circumference in school children show an AUC (Area under the curve) value of 0.783, indicating that neck circumference can diagnose obesity with 78.3% accuracy.

The following shows the ROC curve results for school children.

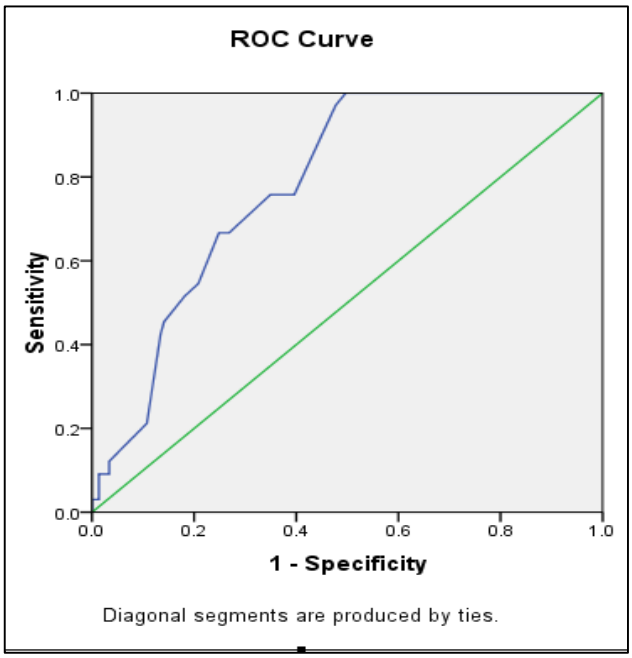

Figure 8: Sensitivity and specificity of neck circumference (n=182).

DISCUSSION

Table 1 indicates that 50.5% of school children are male and 49.5% are female. Although the distribution of the sex of children under five is slightly different from the results of monitoring nutritional status in the DKI Jakarta area, where males account for 50.5% and females account for 49.5%. According to Table 1, education is a crucial factor in the child development process. Parents with higher knowledge and education levels are better equipped to select appropriate food processing methods and provide healthy and nutritious food for their children. Additionally, mothers with a higher level of education are more likely to receive messages and information on nutrition and child health, which influences their understanding of healthcare, hygiene, and awareness of child and family health.

Based on Figure 3, which uses the BMI/A index, 8.2% of school children are obese, and 9.9% are overweight. Therefore, the percentage of overweight and obese children is 19.1%. This proportion is lower than that reported in the 2018 basic health research results for overweight and obese children.[6] However, the proportion of obese/fat children is relatively the same as that observed by bachelor of applied nutrition and dietetics students at the same location in 2018. In simple terms, obesity occurs when food intake exceeds normal requirements. If food intake surpasses the body's energy needs, this excess will be stored in adipose tissue in the form of fat. The body has a regulatory mechanism to

maintain balance between energy input and output to regulate the size of this reserve.

Neck circumference is a relatively new anthropometric measurement that serves as a marker for subcutaneous fat accumulation in the upper body.[7] The neck circumference of obese individuals is typically larger than that of individuals with normal BMI.[8] Figure 6 demonstrates the correlation results using the Pearson product moment test, indicating a significant relationship between neck circumference and BMI with r=0.483 and p=0.000. The greater the neck circumference, the greater the BMI value. Comparable results were observed in other studies with similar r values, r=0.561 and p=0.000 for men and r=0.824 and p=0.000 for women.[5] Other studies also show similarities in r values, namely for men r=0.587 and women r=0.688; p=0.000.[9] Moreover, previous research also supports a significant relationship between neck circumference and BMI (r=0.66).[8]

Neck circumference is also associated with body fat. In obese samples, the results of the Pearson parametric test showed a significant relationship and correlation between total body fat and neck circumference (r=0.310, p=0.002). Meanwhile, the Spearman test was not significant for normoweight samples. Correlation test between visceral fat and neck circumference in obese and normoweight samples showed a positive and significant correlation. Spearman's correlation test on subcutaneous fat showed a positive and significant correlation in both obese and normoweight subjects. The study confirms that an increase in the percentage of total body fat is related to a large value of neck circumference in obese individuals.[10]

Previous studies have demonstrated a significant relationship between neck circumference and overweight and obesity. Neck circumference is also considered a potential indicator for visceral obesity and cardiovascular disease in adults. However, previous studies had limitations in that they only compared neck circumference scores with BMI, rather than using more precise criteria/ gold standard, and they had small sample sizes. Furthermore, various studies report different cut-off values for age and gender categories. Thus, before neck circumference values can be used in clinical practice, it is crucial to systematically validate them and determine optimal cut-off value. It is also important to note that cut-off values for these anthropometric indices may vary between populations. Neck circumference showed a strong positive correlation with BMI, waist circumference, and height and weight in both sexes, but the correlation coefficient was higher in men. Optimal cut-off values for neck circumference for overweight/obesity in men and women are 38.75 and 34.2 cm, respectively. According to Iranian obesity committee, optimal cut-off value for neck circumference for central obesity is 39.25 cm for men and 34.5 cm for women.[7]

From the results of the equation above, we can infer the size of neck circumference in men if the BMI is known. This indicates a linear relationship between neck circumference and BMI in men. The regression coefficient of 0.345 indicates that the neck circumference will increase by 0.356 cm if the BMI value increases by 1 kg/m². The regression line equation obtained can explain 34.5% of the variation in BMI with neck circumference. The correlation coefficient (r) of 0.561 indicates a strong relationship, and the p=0.000 suggests that the compatibility with the existing data and the regression line equation or the regression coefficient is worth 0.345. Therefore, the equation is as follows: neck circumference=29.215±0.345 BMI, and the correlation coefficient (r)=0.561.[5]

The graph results show that there is a positive correlation between neck circumference and BMI, with a correlation coefficient of 0.561. The graph also shows regression line equation, which is neck circumference=29.215±0.345 BMI. This equation can explain 34.5% of the variation in BMI with neck circumference. Additionally, p=0.000 indicates that the compatibility between the data and the regression line equation is significant at alpha, and the regression coefficient of 0.345 shows a strong relationship between neck circumference and BMI.[9] The results of the ROC curve show a UAC value of 0.783. This shows that neck circumference can diagnose obesity by 78.3%. Based on the ROC analysis of the results of previous studies, it can be concluded that neck circumference is a fair test for evaluating obesity in adults. The neck circumference cut-off values of 36.50 cm for men and 32.50 cm for women will help filter populations of Asian Indian origin. The sensitivity of the screening test for cut-off in the previous study was 84.85% and 73.68%.[11]

CONCLUSION

The analysis results indicate a significant correlation between neck circumference and BMI. As neck circumference increases, so does BMI. Measuring neck circumference can provide a sensitive and specific method for detecting overweight and obesity in school-aged children. The analysis revealed a neck circumference threshold of 32.0 cm for both men and women. The larger the area under the curve, the more accurate the diagnosis, indicating that neck circumference is a more effective diagnostic tool for BMI. The ROC curve results yielded a UAC value of 0.783, indicating that neck circumference can accurately diagnose obesity in 78.3% of cases. The study provides valuable insights into the relationship between education, nutrition, and child development. Parents who have higher levels of education are more likely to provide healthy and nutritious food for their children. The study also highlights the prevalence of overweight and obesity among school children and its relationship with neck circumference and BMI. The study confirms that neck circumference is a useful anthropometric method for assessing body fat and is a potential indicator for overweight/obesity and cardiovascular disease. However,

it is important to determine the optimal cut-off values for neck circumference in different populations and to validate these values systematically before they can be used in clinical practice.

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