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Correlation of Neck Circumference with Body Fat Percentage by Bioelectrical Impedance Analysis

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Resumen

Introducción: La obesidad es un importante problema de salud pública asociado a diversos riesgos para la salud. Los métodos precisos y accesibles para evaluar el porcentaje de grasa corporal son esenciales para la evaluación de la obesidad. Este estudio tuvo como objetivo investigar la relación entre la circunferencia del cuello y el porcentaje de grasa corporal, considerando el análisis de impedancia bioeléctrica como método de referencia. **Métodos:** Se realizó un estudio transversal en 63 estudiantes de medicina y paramédica del sexo masculino con edades entre 18 y 25 años. La circunferencia del cuello, el porcentaje de grasa corporal, el peso, la altura y el índice de masa corporal (IMC) se midieron utilizando técnicas estandarizadas. El análisis estadístico incluyó estadísticas descriptivas, análisis de correlación y pruebas de significación. **Resultados:** La circunferencia media del cuello fue de 37,4 cm (DE = ±1,6) y el porcentaje medio de grasa corporal fue del 22,8% (DE = ±4,5). Se observó una fuerte correlación positiva entre la circunferencia del cuello y el porcentaje de grasa corporal ($r = 0{,}75$, $p \leq 0{,}001$). Los resultados indicaron que la circunferencia del cuello puede servir como una medida práctica y accesible para estimar el porcentaje de grasa corporal. **Conclusión:** la circunferencia del cuello se correlacionó fuertemente con el porcentaje de grasa corporal, lo que sugiere su potencial como herramienta de evaluación de la obesidad. Se necesita más investigación que involucre a poblaciones más grandes y diversas para validar estos hallazgos y explorar las implicaciones clínicas del uso de la circunferencia del cuello en la evaluación de la obesidad.

Palabras Clave: Circunferencia del cuello, porcentaje de grasa corporal, evaluación de la obesidad, análisis de impedancia bioeléctrica.

Abstract

Introduction: Obesity is a significant public health concern associated with various health risks. Accurate and accessible methods for assessing body fat percentage are essential for obesity evaluation. This study aimed to investigate the relationship between neck circumference and body fat percentage, considering bioelectrical impedance analysis as the reference method. **Methods:** A cross-sectional study was conducted among 63 male medical and paramedical students aged 18 to 25 years. Neck circumference, body fat percentage, weight, height, and body mass index (BMI) were measured using standardized techniques. Statistical analysis included descriptive statistics, correlation analysis, and significance testing. **Results:** The mean neck circumference was 37.4 cm (SD = ±1.6), and the mean body fat percentage was 22.8% (SD = ±4.5). A strong positive correlation was observed between neck circumference and body fat percentage ($r = 0.75$, $p \leq 0.001$). The results indicated that neck circumference can serve as a practical and accessible measurement for estimating body fat percentage. **Conclusion:** Neck circumference strongly correlated with body fat percentage, suggesting its potential as an obesity assessment tool. Further research involving larger and more diverse populations is needed to validate these findings and explore the clinical implications of using neck circumference in obesity evaluation.

Keywords: Neck circumference, Body fat percentage, Obesity assessment, Bioelectrical impedance analysis.

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Introduction

The global prevalence of obesity has reached pandemic proportions, posing significant challenges to public health worldwide. Recent data from the National Family Health Survey (NFHS-5 - 2019-2021) revealed a substantial increase in the percentage of individuals with a body mass index (BMI) greater than 25, with rates of 33.2% among women and 29.8% among men. These figures represent a significant rise of 9% and 7%, respectively, compared to the previous NFHS-4 (2015-2016) survey, highlighting the urgent need for targeted interventions aimed at high-risk populations (National Family Health Survey NFHS-5, 2019-21).

Accurate and practical methods for assessing obesity prevalence are essential to guide effective interventions and public health strategies. The measurement should be straightforward, minimize errors, and remain unaffected by factors such as food or water intake and hydration levels. Additionally, it should be applicable in diverse cultural contexts, considering restrictions on garment removal, as observed in countries like India.

While body mass index (BMI) is the most widely used clinical indicator of obesity, it does not fully capture the distribution of body fat or differentiate between muscle mass and body fat. Consequently, the measurement of body fat percentage has gained prominence as a more comprehensive assessment of obesity. Non-invasive methods, such as bioelectrical impedance analysis, have been widely accepted for measuring body fat percentage. However, the requirement for costly equipment limits their practicality in resource-constrained settings (WHO expert consultation, 2004; Gallagher et al., 2000).

In this context, neck circumference (NC) has emerged as a promising alternative for measuring obesity, fulfilling the criteria for a practical and accessible measurement tool. Neck circumference reflects adiposity and has shown associations with overall body fat percentage and its distribution. Moreover, NC measurement can be performed without the need to remove garments, making it culturally appropriate for populations with specific dress codes or preferences. Additionally, NC remains stable throughout the day and is minimally affected by factors such as food intake or hydration status (Margaret & Sigrid, 2016; Nyamdorj et al., 2010).

The objective of the present study is to explore the correlation between NC and body fat percentage, utilizing bioelectrical impedance analysis as the reference method. By establishing the relationship between these variables, we aim to determine the utility of NC as a practical and accessible measurement for estimating body fat percentage. The findings from this study could have significant implications for obesity assessment, intervention strategies, and public health initiatives aimed at combating the obesity epidemic.

Material and Methods

Study design and setting

This is a cross-sectional correlational study done in Department of Physiology, AIIMS Mangalagiri, Andhra Pradesh, India. Ethical approval was obtained for the study (certificate no: AIIMS/MG//IEC/2022-23/245 dated 20-01-2023).

Study population

Apparently healthy male medical and paramedical students studying in AIIMS, Mangalagiri in the age between 18-25 years were considered for the study. Individual on steroid treatment or any known systemic illness were excluded. Study procedure was explained to the participants and written informed consent was obtained from them (n=63). The volunteers were requested to report to the isolated room allotted for anthropometric measurements at least 2 hours after the lunch. Volunteers were asked to refrain from doing any vigorous physical activity, intake large amount of water, drinking alcohol or taking bath immediately before reporting. We are presenting here the part of the data of a larger study and the sample size calculation was based on the other parameter which is not mentioned in this manuscript. All the measurements were made by ISAK certified anthropometrist. The following parameters were measured.

Parameters measured: Body fat percentage was measured by bioelectrical impedance using digital body composition monitor (Omron HBF 702T Digital Body Composition Monitor, Omron, Japan (50 kHz, 500 µA, SEE 3.5%). The NC was measured as per ISAK guidelines (Esparza-Ros et al., 2019). The subject assumes a relaxed seated position, arms by the side and head in the Frankfort plane (Figure 1a). The circumference of the neck was taken immediately superior to the thyroid cartilage and perpendicular to the long axis of the neck using an anthropometric tape with 1 mm accuracy (cescrof, Brazil) (Figure 1b).

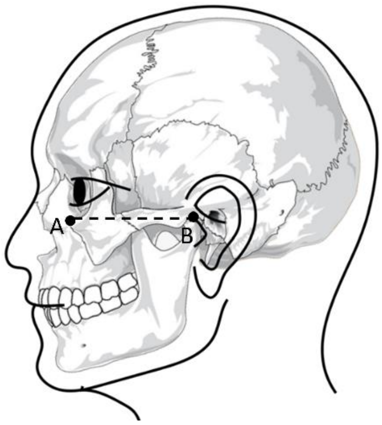

Figure 1a. Frankfurt plane

Figure 1b. Neck circumference measurement technique

Orbitale – the point at the lowest part of the inferior bony margin of the eye socket.

Tragion – The point in the notch superior to the tragus of the ear.

Dashed line – Frankfurt plane – line joining the point A and B and kept horizontal to the ground.

Statistical analysis: Statistical analysis was performed using IBM SPSS statistics (version 25, IBM corp, USA) Both NC and fat percentage data were normally distributed and were expressed in mean ± Standard deviation. The relationship between NC and body fat percentages were analysed using Pearson correlation. Coefficient of determination (R2) was calculated to explain the amount of variability shared by one variable in the other. Simple linear regression was used to test if NC significantly predicted fat percentage. Bias corrected and accelerated bootstrap analysis (BCa) was done to find 95% confidence interval for both correlation and linear regression analysis using 1000 bootstrap samples.

Results

The study included a total of 63 apparently healthy male medical students with mean age of 19.68 ± 1.55 years and mean NC was 35.72 ± 2.25 cm.

Table 1 and figure 3 shows the correlation between NC and various body fat percentages. NC showed significant positive correlation with total body fat, subcutaneous fat, visceral fat, arms fat, trunk fat and leg fat. Correlation was more with body mass index followed by visceral fat; more than 50% of variability in BMI and visceral fat is shared by NC.

On simple linear regression analysis, the fitted regression model was: Visceral fat percentage = -49.508 + 1.567 (NC in cm). The overall regression was statistically significant (R^2 = .542, $F(1, 61)$ = 72.251, p <.001). It was found that NC significantly predicted body fat percentage (β = 1.567, p = .001). For each cm increase in NC visceral fat percentage increases by 1.567 times.

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Table 1. Correlation between neck circumference and body fat percentage at various sections

Parameters	Mean ± SD	r	R^2	p value	Bca 95% confidence interval	
					Lower	Upper
Body mass index	23.20 ± 4.78	.758**	0.57	< .001	0.640	0.873
Total Body fat%	19.46 ± 6.50	.543**	0.29	< .001	0.329	0.684
Subcutaneous fat %	13.56 ± 4.68	.602**	0.36	< .001	0.410	0.728
Visceral fat%	6.47 ± 4.79	.736**	0.54	< .001	0.604	0.870
arms fat %	20.50 ± 6.12	.530**	0.28	< .001	0.328	0.662
trunk fat%	11.98 ± 4.64	.630**	0.40	< .001	0.460	0.745
Leg fat%	19.85 ± 6.65	.535**	0.29	< .001	0.327	0.669

Pearson's correlation was done. Bias corrected and accelerated bootstrap analysis (BCa) was done to find 95% confidence interval using 1000 bootstrap samples. r- Pearson's correlation coefficient; R^2 - Coefficient of determination.

Table 2. Simple linear regression analysis between visceral fat percentage and neck circumference

Model		B	Bootstrap[a]				
			Bias	Std. Error	Sig. (2-tailed)	BCa 95% Confidence Interval	
						Lower	Upper
1	(Constant)	-49.508	.155	7.249	.001	-64.909	-33.881
	neck circumference	1.567	-.005	.210	.001	1.164	1.972

Dependent variable: body fat percentage, predictor variable: neck circumference. Simple linear regression analysis was done. P < .05 is considered statistically significant. Bias corrected and accelerated bootstrap analysis (BCa) was done with 1000 samples

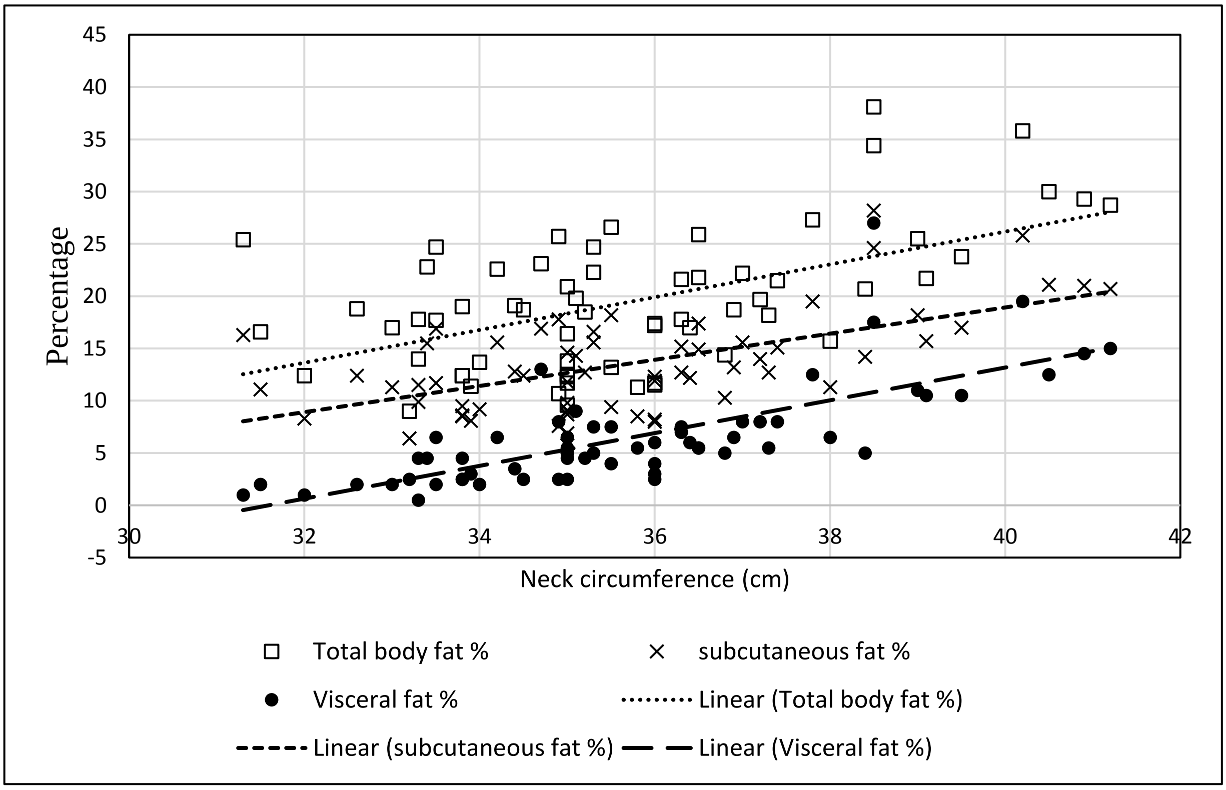

Figure 2. Correlation of neck circumference with fat percentages Pearson's correlation was done.

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Discussion

The present study aimed to evaluate the utility of NC as a reliable indicator of body composition by correlating NC values with body fat percentage as assessed by Bioelectric impedance analysis method. Bioelectric impedance analysis (BIA) is a non-invasive and cost-effective technique widely used for determining body composition (Kyle et al., 2004). It has been validated in various populations in terms of age, gender and body shape, and demonstrated its adequacy compared to dual-energy X-ray absorptiometry (DEXA), a gold standard method (Malavolti et al., 2003; Pietrobelli, Rubiano, St-Onge, & Heymsfield, 2004). Our results demonstrate a significant positive correlation between NC and various measures of body fat, including total body fat, subcutaneous fat, visceral fat, arm fat, trunk fat, and leg fat. These associations suggest that NC can serve as an indicator of overall adiposity and fat distribution. The findings of our study highlight the potential of NC as a practical and accessible measurement tool for assessing obesity and body composition.

The mean NC in our study is 35.72 ± 2.25 cm. Previous research has reported that the cut off values of young male adults is 37-39 cm which were close to the cut-offs found in our study (Limpawattana, Manjavong, & Sopapong, 2016).

Obesity is associated with various risk factors for cardiovascular and metabolic conditions in the future. Obesity, particularly when it occurs in the upper body, poses a serious health risk (Hatipoglu, Mazicioglu, Kurtoglu, & Kendirci, 2010; Kissebah et al., 1982; Peiris, Struve, Mueller, Lee, & Kissebah, 1988). There are numerous assessment methods for overweight and obesity. Various techniques are applicable, including the measurement of weight, height, abdominal and hip circumferences, waist/hip ratio, and body mass index (BMI) (Ben-Noun, Sohar, & Laor, 2001). While the body mass index (BMI) is commonly used to assess obesity, it does not provide a comprehensive evaluation of body fat distribution or differentiate between muscle mass and body fat. In contrast, NC reflects adiposity and has shown associations with body fat percentage and its distribution. Simple, and rapid method. The use of NC as a surrogate measure for body fat percentage has important implications for obesity assessment, intervention strategies, and public health initiatives.

Saka et al., found a positive association between NC and various anthropometric measures such as body weight, waist circumference, hip circumference, waist-to-hip ratio, and BMI in both genders (Saka, Türker, Ercan, Kiziltan, & Baş, 2014). This supports the notion that NC reflects not only overall adiposity but also central obesity. This is in line with our observation that NC correlated well with visceral adiposity and truncal fat. Further, the correlation of NC with visceral fat was more than for the overall total body fat. Hence, NC reflects visceral adipose tissue which is considered more important to assess cardiometabolic risk (Elffers et al., 2017; Hatipoglu et al., 2010; Sánchez-López et al., 2013). Consistent with our findings, H.-X. Li et al. also reported a relationship between NC and visceral adipose tissue (Li et al., 2014).

Hatipoğlu *et al.,* put forth NC, as an index of upper-body subcutaneous adipose tissue distribution. In our study, we observed that NC correlated well with visceral fat than subcutaneous fat (Hatipoglu, Mazicioglu, Kurtoglu, & Kendirci, 2010). Further, its association with overall body fat was less than subcutaneous fat. Hence, NC reflects visceral fat better than subcutaneous fat or overall body fat percentage. Lopez et al., stated that the region where fat is accumulated might have a differential effect on lipid profile: trunk fat has an adverse effect, leg fat has a protective effect, and arm fat has no effect (Lopez et al., 2013). Thus, rather than overall body fat percentage measurement, it is important to asses local distribution of fat. NC correlated well with truncal fat than arm or leg fat. This further, add to our hypothesis that NC could be a better alternate anthropometric tool to measure adiposity with the aim to assess the metabolic risk.

While waist circumference is widely recognized as a screening tool for central obesity and a diagnostic criterion for metabolic syndrome, inconsistencies exist regarding the standard technique and location for its measurement. Waist circumference can be influenced by factors such as measurement technique (Patry-Parisien, Shields, & Bryan, 2012; Pettitt et al., 2012; Yang & Wang, 2017), positioning, respiration, and recent meals (Agarwal et al., 2009). In contrast, NC remains relatively unaffected by these factors, making it a valuable anthropometric tool. In addition, various studies have shown relationship between NC and waist circumference (Aswathappa, Garg, Kutty, & Shankar, 2013; Liang et al., 2013; Onat et al., 2009; Wang, Zhang, Yu, & Ji, 2015). Our study strengthens the evidence for using NC as a surrogate measure for body fat percentage, as we observed a positive association between NC and regional fat, including truncal fat, arm fat, visceral fat, and leg fat.

In conclusion, our findings support the utility of NC as a reliable and accessible measurement for assessing body composition, specifically body fat percentage. The simplicity and cultural appropriateness of NC measurement, along with its minimal interference from external factors, make it a valuable tool for obesity assessment and intervention strategies. Further research is warranted to explore the full potential of NC as a surrogate measure for body fat percentage and its implications for public health initiatives aimed at addressing the global obesity epidemic.

Limitations of the study: Body fat percentage, subcutaneous fat percentage and visceral fat percentages were derived parameters using bioimpendance analysis and not a direct measurement. The logical extension of the study would be the correlation of NC with direct measurement of the above variables.

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Conflicts of Interest

The Authors have no Conflicts of Interest to declare that they are relevant to the content of this Article.

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