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RELATIONSHIP BETWEEN NECK CIRCUMFERENCE AND BODY MASS INDEX WITH DIABETES HYPERTENSION AND DYSLIPIDEMIA IN MALES

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ABSTRACT

Background: Increasing body mass index (BMI) is associated with diseases related to insulin resistance, hypertension, and dyslipidemia. The aim of this study was to examine the relationship between neck circumference and BMI with other cardiometabolic syndrome parameters. **Method:** A cross-sectional study was conducted on a randomly selected sample of 150 adult males visiting consulting clinics at Marjan Teaching Hospital from March 1, 2016, to January 1, 2017. The participants were divided into three groups based on neck circumference: 50 individuals with a neck circumference of less than 35 cm, 50 individuals with a neck circumference between 35 cm and 41 cm, and 50 individuals with a neck circumference greater than 41 cm. All participants underwent measurements of systolic and diastolic blood pressure, as well as BMI. Additionally, hemoglobin A1c (HbA1c) and lipid profile tests were conducted for all participants except for diabetic patients on antidiabetic medications and those on lipid-lowering drugs. **Results:** An increase in neck circumference among males was significantly associated with a higher BMI (p-value < 0.001). Neck circumference was also strongly correlated with increased systolic blood pressure and diastolic blood pressure (p-value < 0.001), total cholesterol (p-value = 0.009), LDL cholesterol (p-value = 0.019), triglycerides (p-value < 0.001), and HbA1c (p-value < 0.001), while it was inversely correlated with HDL cholesterol levels (p-value < 0.001). **Conclusion:** An increase in neck circumference is associated with metabolic diseases related to insulin resistance, hypertension, and dyslipidemia. Therefore, measuring neck circumference can serve as a simple, time-efficient, and non-invasive screening tool for assessing the risk of these disorders.

KEYWARDS: Obesity, neck circumference, body mass index.

INTRODUCTION

Obesity has been present throughout human history, as evidenced by early artistic and sculptural depictions of obese figures.[1] In 1997, the World Health Organization (WHO) officially recognized obesity as a global epidemic.[2] Obesity rates have been rising worldwide, particularly in urban areas.[3] It is a significant risk factor for cardiometabolic disorders, including hypertension, diabetes mellitus, dyslipidemia, and coronary heart disease.[4,5] Additionally, obesity is considered an independent predictor of these conditions and overall mortality. Recent studies suggest that chronic inflammation, triggered by cytokines secreted by adipocytes, plays a key role in the development of insulin resistance and metabolic disturbances. Due to this inflammatory response, metabolic syndrome is sometimes referred to as "inflammatory syndrome".[6]

Various anthropometric measurements are used to assess obesity, including those targeting overall body fat and specific fat distributions such as central or abdominal obesity, visceral fat, and subcutaneous fat. While computed tomography (CT) and magnetic resonance imaging (MRI) are considered the gold standard for measuring visceral fat, and dual-energy X-ray absorptiometry (DXA) is a highly reliable alternative[7], these methods are expensive and impractical for large-scale epidemiological studies.[8]

Body mass index (BMI) is widely used to diagnose obesity, calculated as weight in kilograms divided by the square of height in meters (kg/m^2). BMI is a simple, cost-effective, and non-invasive measure that requires minimal time and effort. However, one limitation is that it does not account for body composition. For example, physically active individuals with a high proportion of lean muscle mass may be misclassified as overweight or obese due to their higher body mass relative to height.[9] BMI classifications include normal weight (18.5–24.9 kg/m²), underweight (<18.5 kg/m²), overweight (25–29.9 kg/m²), and obesity (≥30 kg/m²).[10] Neck circumference (NC) has emerged as a relatively new anthropometric measure for differentiating between normal and abnormal fat distribution. It serves as a marker of upper body subcutaneous adipose tissue distribution. Upper body obesity, characterized by excessive subcutaneous fat in the upper body, is associated with metabolic disorders such as glucose intolerance, diabetes mellitus, and hypertriglyceridemia. Research suggests that free fatty acid release from upper body subcutaneous fat is greater than from lower body fat, further emphasizing the importance of measuring upper-body fat depots.[11] Given these findings, NC is considered a useful indicator of upper body fat distribution and can help identify overweight and obese individuals.[12] Several studies suggest that NC may independently correlate with metabolic risk factors beyond BMI.[13] Moreover, it has been recognized as a marker of upper body obesity, showing a strong positive correlation with blood pressure and other metabolic syndrome components.[14]

Aim of the study

The purpose of this study was set up to determine whether there is a relationship between changes in NC and changes in BMI, blood pressure, diabetes mellitus, and finally dyslipidemia, and the reliability of the relationship.

PATIENTS AND METHODS

A cross-sectional study was conducted on a randomly selected group of 150 adult male participants visiting consulting clinics at Merjan Teaching Hospital between March 1, 2016, and January 1, 2017. Participants were categorized into three groups based on their neck circumference:

- **Group 1:** Neck circumference less than 35 cm (n = 50)
- **Group 2:** Neck circumference between 35 cm and 41 cm (n = 50)
- **Group 3:** Neck circumference greater than 41 cm (n = 50)

Informed oral consent was obtained from all participants before their inclusion in the study.

Data Collection

All participants underwent measurements for body mass index (BMI), systolic and diastolic blood pressure. Additionally, hemoglobin A1c (HbA1c) and lipid profile tests were performed on all participants, except for those with diabetes who were on antidiabetic medications and individuals taking lipid-lowering drugs.

Exclusion Criteria

Participants were excluded from the study if they had:

- Malignancy
- Renal impairment
- Thyroid dysfunction
- Goiter or other neck masses/deformities
- Excessive alcohol consumption

Exclusions were determined based on medical history, clinical examination, and additional investigations in suspected cases.

Blood Pressure Assessment

Blood pressure was measured using a mercury manometer after the participant had rested for five minutes. Measurements were taken with the participant's arm positioned at heart level, with two readings taken 60 seconds apart.

- **Systolic blood pressure (SBP):** Defined as the mean of the two SBP readings.
- **Diastolic blood pressure (DBP):** Defined as the mean of the two DBP readings.

Hypertension was defined according to the **Eighth Report of the Joint National Committee (JNC-8)** as:

- SBP ≥ 140 mmHg or
- DBP ≥ 90 mmHg

To minimize measurement errors in obese individuals, a cuff with a bladder covering at least two-thirds of the arm circumference was used. A participant was classified as hypertensive if they had a previous diagnosis of hypertension and were receiving treatment or had an SBP of ≥140 mmHg and a DBP of ≥90 mmHg.

Anthropometric Measurements

- **Neck Circumference (NC):** Measured in centimeters with participants maintaining an erect posture and eyes looking forward. The measurement was taken horizontally at the upper border of the laryngeal prominence using a non-stretchable flexible tape.
- **Height and Weight:** Measured with participants standing without shoes or heavy outer garments.
- **Body Mass Index (BMI):** Calculated as weight (kg) divided by height squared (m²).

Biomarker Assessment

Diabetes mellitus (DM) was diagnosed based on **American Diabetes Association (ADA) criteria**, which include:

- Random plasma glucose **≥ 200 mg/dL (11.1 mmol/L)** with classic hyperglycemic symptoms.
- Fasting plasma glucose **≥ 126 mg/dL (7.0 mmol/L)**.
- Plasma glucose during a **2-hour 75-g oral glucose tolerance test ≥ 200 mg/dL (11.1 mmol/L)**.
- Hemoglobin A1c (HbA1c) **≥ 6.5%** (to be confirmed by repeat testing).

Blood samples were collected in two glass tubes:

1. **HbA1c Measurement:** Conducted manually.
2. **Lipid Profile:** Blood was allowed to clot at room temperature, then serum was separated by centrifugation for 15 minutes at 3000 rpm (Eppendorf, Germany). Total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were analyzed using an autoanalyzer (Spotchem, Tokyo, Japan).

According to the **2016 European Society of Cardiology (ESC) and European Atherosclerosis Society (EAS) Guidelines**, lipid testing was conducted using non-fasting blood samples to improve patient compliance. The following lipid profile thresholds were considered abnormal:

- **Triglycerides (TG) ≥ 2 mmol/L (175 mg/dL)**
- **Total cholesterol (TC) ≥ 5 mmol/L (190 mg/dL)**
- **LDL cholesterol (LDL-C) ≥ 3 mmol/L (115 mg/dL)**
- **HDL cholesterol (HDL-C) ≤ 1 mmol/L (40 mg/dL)**

A participant was considered diabetic if they had a previous diagnosis and were receiving treatment or met the ADA criteria for diabetes diagnosis.

Data Analysis

Statistical analysis was performed using **SPSS version 20**.

- Categorical variables were presented as **frequencies and percentages**.
- Continuous variables were presented as **means ± standard deviation (SD)**.
- **ANOVA test** was used to compare means among the three groups.
- **Pearson's chi-square (χ^2) test** was applied to assess the association between categorical variables.
- A **p-value ≤ 0.05** was considered statistically significant.

RESULTS

A cross sectional study was conducted in Merjan teaching hospital, mean age(48.4 ± 7)years oldest was 66 years old and youngest was 41 years old. (50) of them their neck circumference less than 35cm, the second(50) were from 35cm to 41cm and the last(50) were more than 41cm.

3.1 Mean Differences of Body Mass Index According to Neck Circumference

Table 3.2 shows mean differences of body mass index according to neck circumference including (less than 35 cm), (35-41 cm) and more than 41cm). There were significant differences between means of body mass index by study groups.

Table 3.2: The mean differences of BMI by neck circumference.

Study Variable	Neck circumference	N	Mean ± SD	F-test	P value
BMI (Kg/ m^2)	Less than 35 cm	50	23.46 ± 0.89	**54.178**	**<0.001***
	(35-41) cm	50	26.59 ± 3.88		
	More than 41 cm	50	30.02 ± 3.72		

*P value ≤ 0.05 was significant.

3.2 Mean Differences of HbA1C According to Neck Circumference

Table 3.3 shows mean differences of HbA1C according to neck circumference including (less than 35 cm, (35-41 cm) and more than 41cm). There were significant differences between means of HbA1C by study groups.

Table 3.2: The mean differences of HbA1C by neck circumference.

Study Variable	Neck circumference	N$^{×}$	Mean ± SD	F-test	P value
HbA1C (%)	Less than 35 cm	47	5.30 ± 0.19	**27.179**	**<0.001***
	(35-41) cm	43	5.50 ± 0.07		
	More than 41 cm	38	5.67 ± 0.36		

*P value ≤ 0.05 was significant. Diabetic patients excluded (n=128).

3.3 The Distribution of Study Group According to Neck Circumference and Diabetes Mellitus

Figure 3.1 shows distribution of study group according to neck circumference and Diabetes Mellitus.

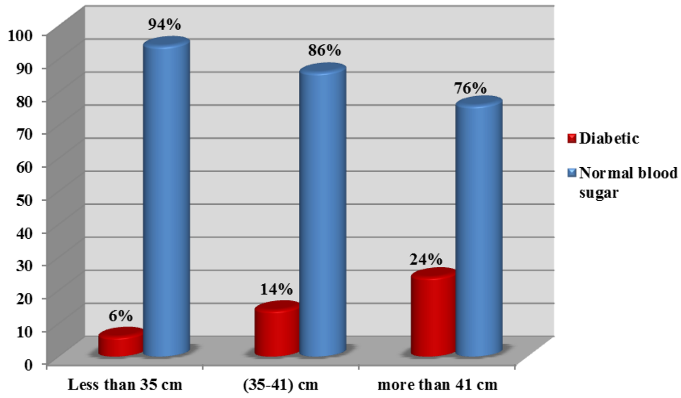

Figure 3.1: Distribution of patients according to neck circumference andDiabetes Mellitus.

3.4 Mean Differences of Lipid Profile According to Neck Circumference

Table 3.4 shows mean differences of Lipid Profile including (total cholesterol, triglyceride, HDL and LDL) according to neck circumference including (less than 35 cm), (35-41 cm) and (more than 41cm). There were significant differences between means of total cholesterol, triglyceride, HDL and LDLby study groups.

Table 3.3: The mean differences of Lipid Profile by neck circumference.

Study Variable	Neck Circumference	N	Mean ± SD	F-test	P value
Total cholesterol level (mmol/l)	Less than 35 cm	47	4.89 ± 0.25	**4.831**	**0.009***
	(35-41) cm	47	5.08 ± 0.76		
	More than 41 cm	46	5.41 ± 1.15		
Triglyceride (mmol/l)	Less than 35 cm	47	1.40 ± 0.3	**43.885**	**<0.001***
	(35-41) cm	47	1.79 ± 0.2		
	More than 41 cm	46	2.10 ± 0.5		
HDL (mmol/l)	Less than 35 cm	47	1.44 ± 0.31	**12.941**	**<0.001***
	(35-41) cm	47	1.31 ± 0.19		
	More than 41 cm	46	1.19 ± 0.14		
LDL (mmol/l)	Less than 35 cm	47	2.87 ± 0.38	**4.104**	**0.019***
	(35-41) cm	47	3.00 ± 0.48		
	More than 41 cm	46	3.20 ± 0.73		

*P value ≤ 0.05 was significant. Patients use Statin were excluded (n=140)

Figure 3.2 shows distribution of study group according to neck circumference and hyperlipidemia.

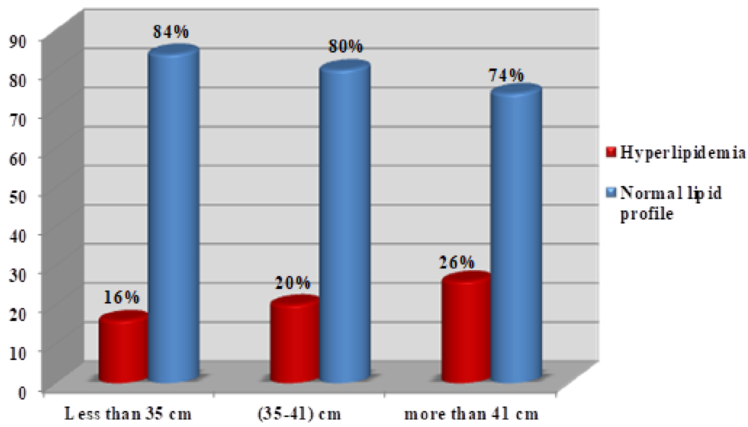

Figure 3.3: Distribution of patients according to neck circumference and hyperlipidemia.

*patient considered to have dyslipidemia when the triglycerides ≥2 mmol/L (175 mg/dL) and/ or total cholesterol ≥5 mmol/L (190 mg/dL) and/or LDL cholesterol ≥3 mmol/L (115 mg/dL) and/orHDL cholesterol ≤1 mmol/L (40 mg/dL).

3.8 Mean Differences of Systolic and Diastolic Blood Pressure According to Neck Circumference

Table 3.5 shows mean differences of systolic and diastolic blood pressure according to neck circumference including (less than 35 cm), (35-41 cm) and (more than 41cm). There were significant differences between means of systolic and diastolic blood pressureby study groups.

Table 3.5: The mean differences of systolic and diastolic blood pressure by neck circumference.

Study Variable	Neck circumference	N	Mean ± SD	F-test	P value
Systolic Blood Pressure (mmHg)	Less than 35 cm	47	120.63 ±9.86	**15.181**	**<0.001***
	(35-41) cm	45	124.88 ± 5.27		
	More than 41 cm	43	129.90 ± 7.99		
Diastolic Blood Pressure (mmHg)	Less than 35 cm	47	75.21 ±6.07	**41.572**	**<0.001***
	(35-41) cm	45	79.88 ± 5.16		
	More than 41 cm	43	85.11 ± 3.85		

*P value ≤ 0.05 was significant. Hypertensive patients use antihypertensive drug were excluded (n=135).

Figure 3.1 Shows distribution of study group according to neck circumference and hypertension.

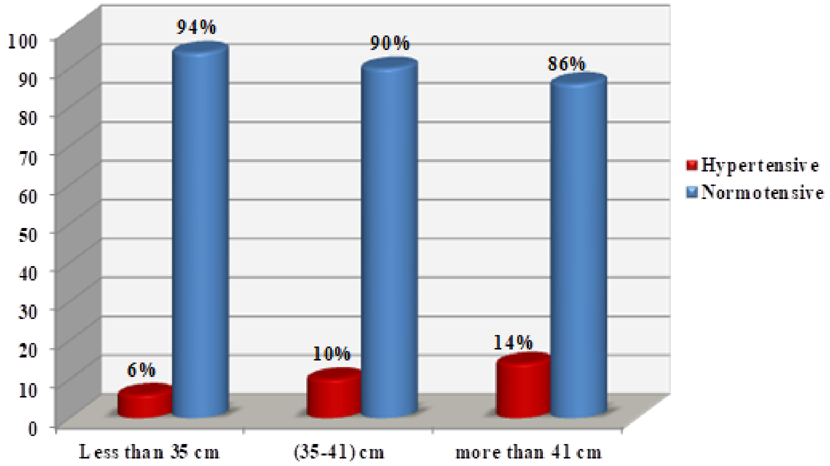

Figure 3.1: Distribution of patients according to neck circumference and hypertension.

DISCUSSION

This study demonstrated that an increase in neck circumference (NC) among males was significantly associated with a higher body mass index (BMI) (p-value < 0.001). These findings are consistent with the study conducted by Nagendran Vijaya et al. (p-value < 0.001), which was a cross-sectional study performed at a tertiary care hospital in South India, aiming to establish an association between NC and cardiometabolic syndrome.[16] Similarly, our results align with the findings of M. Laakso et al., where NC strongly correlated with BMI (p-value < 0.0001) in a prospective study conducted in Finland to investigate the association between NC and insulin resistance-related factors.[17]

Additionally, our study revealed a significant association between increased NC and diabetes mellitus (DM), as reflected by the significant rise in HbA1c levels across the study groups (p-value < 0.001). This finding is in agreement with the study by Jagadamba Aswathappa et al., a cross-sectional study conducted in India involving 350 type 2 diabetics and 350 non-diabetics over the age of 30. Their study showed a statistically significant positive correlation between DM and increased BMI and NC (p-value = 0.016 and 0.001, respectively).[18] Likewise, our findings align with the study by Jun Liang et al., which was a cross-sectional study on 2,318 adults from a community-based health examination survey in central China, reporting a significant association between NC and DM (p-value = 0.0062).[19] However, the percentage of diabetic patients within the study groups varied. In individuals with NC 35–41 cm, 10% had DM in Jun Liang et al.'s study, whereas 14% had DM in our study. Similarly, in those with NC > 41 cm, the percentage was 12.6% in their study compared to 24% in ours. This discrepancy may be attributed to the diagnostic method, as their study primarily used fasting glucose, while our study incorporated HbA1c. Additionally, their study included both sexes, whereas ours focused solely on males. Interestingly, both studies reported a 6% prevalence of DM in individuals with NC < 35 cm.[19]

Our findings also indicated a significant relationship between increased NC and elevated systolic and diastolic blood pressure (p-value < 0.001 for both), consistent with the study by Jun Liang et al., where the association was even stronger (p-value < 0.0001 for both SBP and

DBP). However, their study reported a higher prevalence of hypertension across all groups, with 24% of participants diagnosed with hypertension, whereas our study found a prevalence of 10%. This discrepancy may be due to their larger sample size (2,318 participants) and the inclusion of both sexes.[19]

Similarly, our findings agree with Altan Onat et al., who conducted a cross-sectional analysis on 1,912 men and women with a mean age of 55.1 ± 12 years, representative of the Turkish adult population. Their study established a significant association between NC and metabolic syndrome parameters, showing a strong correlation between NC and SBP and DBP (p-value < 0.0001 for both).[20] Several mechanisms have been proposed to explain the link between obesity and hypertension. Excess body weight can lead to structural changes in the kidneys, resulting in tubular reabsorption and sodium retention.[21] Increased arterial pressure further exacerbates nephron damage, creating a vicious cycle of obesity, hypertension, and renal injury. As a result, obesity and metabolic syndrome are frequently associated with microalbuminuria and chronic kidney disease.[22] Another contributing mechanism is the increased activity of the sympathetic nervous system (SNS) observed in obese individuals.[23]

Our study further demonstrated a significant positive correlation between increased NC and higher levels of total cholesterol (TC), low-density lipoprotein (LDL), and triglycerides (TG) (p-value = 0.009, 0.019, and < 0.001, respectively), along with a significant negative correlation with high-density lipoprotein (HDL) (p-value < 0.001). These results align with the study by Jun Liang et al., which also reported a significant positive correlation between NC and TC, LDL, and TG (p-value = 0.001, < 0.0001, and < 0.0001, respectively) and a negative correlation with HDL (p-value = 0.0037).[19]

Conversely, our results differ from Altan Onat et al., where, despite a significant positive correlation between NC and TG (p-value < 0.0001) and a negative correlation with HDL (p-value < 0.0001), no significant association was observed between NC and TC or LDL. This discrepancy may be attributed to differences in study design, as their study classified participants into only two groups based on NC (≤ 38 cm and > 38 cm), while our study involved three NC groups in adult males.[20]

Dyslipidaemia is a recognised metabolic disorder that is commonly linked to obesity. Numerous studies have established a robust correlation between body size and adiposity indices—such as body mass index (BMI), waist-hip ratio, and percentage of body fat—and dyslipidaemia.[24] The association between excess weight and dyslipidaemia is intricate and not fully comprehended. Nonetheless, it is posited that insulin resistance constitutes the fundamental mechanism.[24] Under standard physiological conditions, insulin inhibits lipolysis and the release of free fatty acids (FFA) from adipose tissue, while concurrently suppressing the production of very-low-density lipoprotein (VLDL). Nevertheless, in conditions of insulin resistance, this inhibitory effect is significantly reduced. As a result, in individuals with obesity, the heightened influx of free fatty acids (FFAs) from adipose tissue to the liver promotes the synthesis of hepatic triglycerides and the overproduction of very low-density lipoprotein (VLDL), accompanied by an elevation in apolipoprotein B (ApoB) synthesis. Consequently, hypertriglyceridemia within the context of metabolic syndrome arises from both heightened lipid production and diminished lipid clearance.[25]

Furthermore, insulin resistance within adipose tissue promotes lipolysis and the mobilisation of free fatty acids (FFAs), resulting in an increased synthesis of hepatic triglycerides and very low-density lipoproteins (VLDL). The accumulation of adipose tissue within the liver may lead to the development of non-alcoholic fatty liver disease (NAFLD) and result in abnormal liver function test results. Furthermore, this mechanism is accountable for the dyslipidaemia observed in individuals with type 2 diabetes mellitus.[15]

CONCLSION

This study showed that the increase neck circumference is associated with metabolic disorders related to insulin resistance, hypertension and dyslipidemia. The measurement of NC can be useful as simple, time saving and least invasive screening measure for risk of these disorders.

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