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Research Article

# Comparison of several anthropometric measurements and blood lipid-related indexes in metabolic-dysfunction associated fatty liver disease in adults: A cross-sectional study

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## ABSTRACT

Dyslipidemia is strongly related to metabolic-dysfunction associated fatty liver disease (MAFLD). Therefore, the lipid profile may be a potential indicator of defining MAFLD. Anthropometric measurements are widely used as simple and practicable tools to screen metabolic dysfunction, and no study determined the relationship between anthropometric measurements and blood lipid-related indexes. The aim of this study was to examine the relationship between several anthropometric measurements and blood lipid-related indexes in MAFLD patients. This study was conducted among 123 MAFLD patients in a private University Hospital in Istanbul, Turkey, between 01.06.2021 – 30.12.2021. Anthropometric and biochemical measurements were taken from all patients. Hepatic steatosis was determined using ultrasonography. SPSS was used to analyze the data. Neck circumference (NC) was moderately associated with triglyceride glucose index (TyG) in both genders. It was found that there was a moderate correlation between NC and cardiometabolic index (CMI), triglyceride (TG), and triglyceride to high-density lipoprotein ratio (TG/HDL-C) in women, whereas it was weakly correlated with CMI index in men. Neck-to-height ratio (NHtR) was moderately associated with CMI, and TyG indexes in women, while it was weakly correlated with TyG index in men. There was a moderate association between waist-to-hip ratio (WHR) and low-density lipoprotein (LDL-C) in women. However, it was only weakly correlated with CMI index in men. It was observed that the waist-to-height ratio (WHtR) was only linked with TyG index in men. Additionally, the body mass index (BMI) and blood lipid-related indicators had no association. Our finding suggests that both NC and NHtR could be used to predict the risk of dyslipidemia in MAFLD, especially among women.

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## INTRODUCTION

Metabolic (dysfunction)-associated fatty liver disease (MAFLD), is thought to be the major precursor to the development of chronic liver disease. Additionally, more than a third of the world's population is affected by MAFLD [1,2]. MAFLD is becoming a major public health problem as its prevalence continues to increase globally in recent years [3,4]. Evidence suggests a close connection between MAFLD and obesity, insulin resistance (IR), diabetes mellitus (DM), and dyslipidemia. Today, as the epidemic of these diseases associated with MAFLD increases day by day, the risk of MAFLD is also increasing [5,6]. Additionally, the leading cause of death among patients with MAFLD is cardiovascular disease (CVD) [7]. Therefore, early diagnosis and intervention can decrease adverse outcomes of MAFLD.

Many methods are used to diagnose the presence of hepatic steatosis. The gold standard for diagnosing steatosis is liver biopsy, which is an invasive procedure. However, it cannot be used widely in the general population for severe risks, including morbidity, mortality, bleeding, infection, and pain [8]. Liver ultrasonography is a non-invasive and simple technique that is an alternative tool for liver biopsy and is the most frequently applied procedure for the defining of hepatic steatosis in practical management [9]. Additionally, biomarkers based on blood samples are used to diagnose MAFLD when ultrasonography imaging is not available [10].

MAFLD is a multisystem disease with a complex pathophysiology and the underlying mechanisms that lead to MAFLD are still poorly understood [2]. Dyslipidemia has a strong impact on the prevalence of MAFLD [11]. Alterations in lipoprotein metabolism and hepatic lipid are the main factors associated with an increased risk of CVD in MAFLD patients [12,13]. It was reported that mixed hyperlipidemia was in 50% of MAFLD patients, isolated hypertriglyceridemia was in 27% of them, and hypercholesterolemia was in 17% [14]. Therefore, changes in plasma lipid profile may be a possible indicator of defining CVD risk in MAFLD patients. According to the recent studies, it was observed that several indexes associated with blood lipids, including low-density lipoprotein cholesterol (LDL-C) to high-density lipoprotein cholesterol (HDL-C) ratio (LDL-C/HDL-C) [15], total cholesterol (TC) to HDL-C ratio (TC/HDL-C) [16], triglycerides (TG) to HDL-C ratio (TG/HDL-C) [17,18], the triglyceride glucose index (TyG) [19], and cardiometabolic index (CMI) [20] have strongly associated with MAFLD.

Anthropometric measurements are widely used as simple and practicable tools to screen metabolic dysfunction in the general population. The body mass index (BMI) has been extensively used traditional index, however, metabolic diseases are more complex and BMI reflects total body obesity value, not fat distribution [21]. Waist circumference (WC), waist to height ratio (WHtR), and waist to hip ratio (WHR) are more accurate to measure central obesity and are highly related to MAFLD, DM, hypertension, other metabolic disorders, and CVD [21-23]. In recent years, studies have shown that there is a strong association between upper body subcutaneous adipose tissue and metabolic disorders [24-27], however, limited studies have demonstrated the relationship between NC and MAFLD [28-30]. Furthermore, there is no study that determined the relationship between anthropometric measurements and blood lipid-related indexes. Therefore, the aim of this study was to examine the correlation between several anthropometric measurements and blood lipid-related indexes in MAFLD patients.

## MATERIALS AND METHODS

### Participants

The present study was cross-sectional and descriptive, and conducted in a private University Hospital in Istanbul, between 01.06.2021 – 30.12.2021. We used power analysis for estimating the study population size, with the prevalence of 20%, type I error rate as α: 0.05, type II error rate as β: 0.20, and test power 1- β: 0.80. Accordingly, a total of 150 participants were randomly assigned to the study. All patients provided a detailed medical history and blood samples. Ultrasonography was used for the diagnosis of hepatic steatosis. Anthropometric measurements (height, body composition analysis, neck circumference (NC), WC, hip circumference (HC), and middle-upper arm circumference (MUAC)) were taken by trained and qualified nutritionists.

The presence of any of the following was a criterion for exclusion: patients with <18 to ≥65 years old; without ultrasonography results; with >20 g/day for men and 10 g/day for women alcohol consumption in the past 1 year; with hepatitis B or C, chronic liver diseases associated with viral hepatitis, such as Wilson disease, hemochromatosis, and Cushing syndrome; autoimmune liver disease; history of cardiovascular diseases, cancer, severe liver, and kidney dysfunction; thyroid disease such as goiter, hypothyroidism or hyperthyroidism; with prolonged use of estrogen or regular consumption of drug associated with fatty liver diseases, such as corticosteroid, methotrexate, tamoxifen, and amiodarone; and those were pregnant. A total of 27 patients were excluded from the study based on the exclusion criteria because 7 patients had incomplete results in their blood samples, 8 were using drugs associated with hypothyroidism, 7 had a history of cardiovascular diseases, and 5 had chronic kidney failure.

### Determination of MAFLD

The criteria for the diagnosis of MAFLD relied on the presence of hepatic steatosis by ultrasonography with any one of the listed three criteria, namely overweight/obesity (BMI ≥25 kg/m$^2$), presence of type 2 DM, or at least two or more of the following metabolic dysfunctions presented in Figure 1 [31].

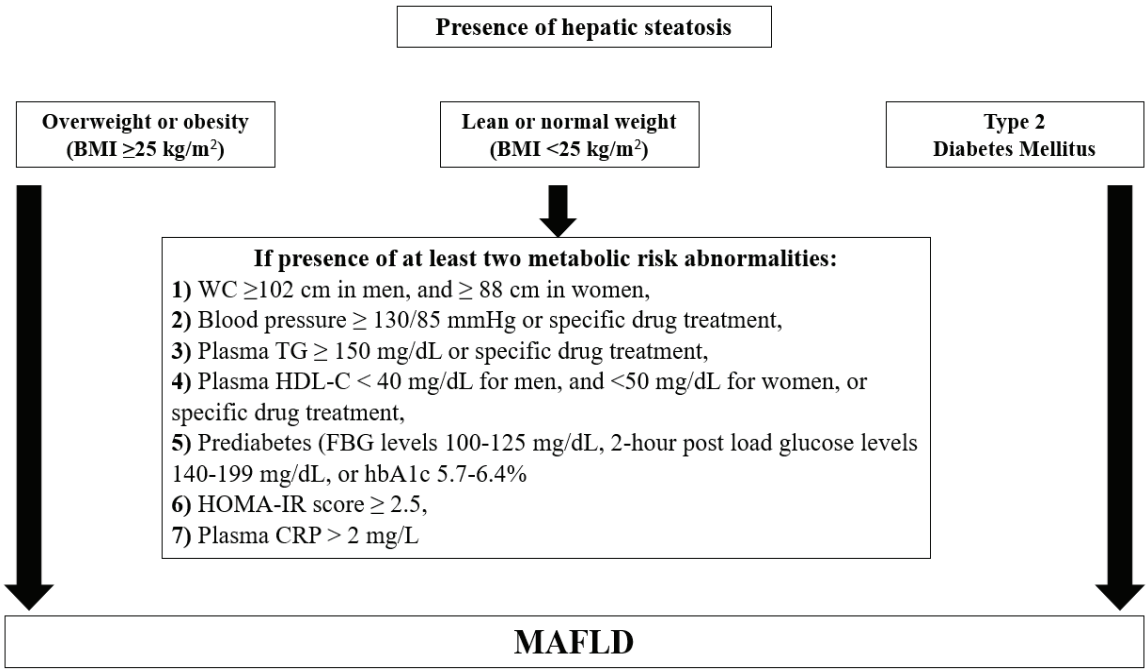



**Figure 1.** Criteria defining MAFLD.

MAFDL: metabolic-dysfunction associated fatty liver disease, BMI: body mass index, WC: waist circumference, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, FBG: fasting blood glucose, HbA1c: glycated hemoglobin A1c, CRP: C-reactive protein

The presence of hepatic steatosis was determined using liver ultrasonography (GE Logiq S7, Seongnam-Si, Seoul, Korea) after at least 8 h of fasting by an expert in gastroenterology. A combination of liver-kidney contrast (bright liver) and vascular blurring was used to identify fatty liver [32].

**Anthropometric Measurements**

Anthropometric measurements were measured by trained nutritionists according to the standardized protocols. The heights of the patients were measured with a stadiometer to the nearest 0.1 cm while each participant stood erect against the wall, heels together and touching the wall, without shoes. Body composition of patients was performed using TANITA SC-330 bioelectrical impedance analysis system. WC was taken after normal exhalation, at the umbilicus level, and without clothes in the area, using a non-stretch plastic tape within 1 mm [28]. NC was taken with a non-stretch plastic tape, on the midaxillary line at the approximate midway between the mid-cervical spine and mid anterior neck, with the head upright and eyes looking straight ahead. HC was taken from the widest area between the waist and the thigh with a non-stretch plastic tape. MUAC was measured at the midpoint of the left upper arm between the olecranon and acromion process using a non-stretch plastic tape [33].

BMI was defined using the calculation as body weight (kg) divided by body height squared ($m^2$), and was categorized based on the World Health Organization's cut-offs: underweight for adults was defined as a BMI less than 18.5 $kg/m^2$, healthy (normal) weight as a BMI from 18.5 to less than 25 $kg/m^2$, overweight as a BMI 25 to less than 30 $kg/m^2$, obese as a BMI 30 to less than 35 $kg/m^2$, severe obese as a BMI 35 to less than 40 $kg/m^2$, and very severely obese as a BMI of 40 $kg/m^2$ or greater [34].

The following equations were calculated according to some anthropometric measurements:

The waist-to-hip ratio (WHR): WC (cm) / HC (cm)

The waist-to-height ratio (WHtR): WC (cm) / height (cm)

The NC-to-height ratio (NHtR): NC (cm) / height (cm)

**Biochemical Parameters**

After an overnight fast of more than 8 hours, blood samples were collected, and laboratory data such as blood lipid parameters (TG, TC, LDL-C, HDL-C), fasting blood glucose (FBG), fasting insulin, glycated hemoglobin A1c (HbA1c), C-reactive protein (CRP), and liver enzymes (alanine aminotransferase (ALT), aspartate aminotransferase (AST), and gamma-glutamyl transpeptidase (GGT), alkaline phosphatase (ALP)) were analyzed.

The following formula was used to calculate Homeostatic Model Assessment Insulin Resistance (HOMA-IR): Fasting insulin (μU/mL) x fasting glucose (mg/dL) / 405 [35]

The following equation was used to calculate TC to HDL-C ratio: TC (mg/dL) / HDL-C (mg/dL)

The following equation was used to calculate TG to HDL-C ratio: TG (mg/dL) / HDL-C (mg/dL)

The following equation was used to calculate LDL-C to HDL-C ratio: LDL-C (mg/dL) / HDL-C (mg/dL)

The following equation was used to calculate CMI index: TG / HDL-C x WHtR [36]

The following equation was used to calculate TyG index: ln (fasting TG (mg/dL) × FPG (mg/dL)/2) [37]

**Statistical Analysis**

The collected data were analyzed with the Statistical Package for the Social Sciences (IBM SPSS Statistics) program version 24.0. Descriptive statistics were presented as percentages and the mean ± standard deviation (SD). Normal distribution was determined using the Kolmogorov Smirnov test. A correlation of normally distributed variables was detected using Spearman's correlation coefficient, and a correlation of non-normally distributed variables was detected using Pearson's correlation coefficient. Statistical significance was defined as a P-value of less than 0.05.

## RESULTS AND DISCUSSION

One hundred twenty-three patients with MAFLD (49.6% men, 50.4% women) participated in this study. Another metabolic disorder was present in 50.4% of the participants in addition to MAFLD, and DM was the most common with 23.4%. There was no statistical difference between the hepatosis grades, and the majority of them were grade II with 69.9% (Table 1).

The mean body weight of participants was 96.05 ± 16.19 kg for men, and 80.12 ± 11.10 kg for women, and the BMI values were 31.13 ± 4.53 kg/m$^2$ and 31.68 ± 4.46 kg/m$^2$, respectively. According to BMI classification, a total of 3.3% of patients were normal weight, 38.2% overweight, 38.2% obese, 16.3% severely obese, and 4.0% very severely obese. The mean value of WC was 111.18 ± 11.55 cm in men and 103.43 ± 9.20 cm in women, and the mean HC was 113.47 ± 9.57 cm and 114.76 ± 11.44 cm, respectively. Additionally, men had a mean NC of 42.14 2.26 cm, whereas women had a mean NC of 42.06 3.61 cm (Table 2).

Table 3 shows the mean levels of several biochemical parameters in MAFLD patients. According to our results, the mean levels of HOMA-IR, HbA1c, TC, ALP, HDL-C, LDL-C, and CRP in women were higher compared to men.

According to our results, there were no correlation between BMI and blood-lipid relates indexes in both genders, however, it was only showed a weak correlation with HOMA-IR (r: 0.322, p: 0.001), and insulin (r: 0.331, p: 0.009) in men. NC was moderately associated with TyG index (r: 0.438, p< 0.001) in men, however, it was moderately associated with TG (r: 0.495, p<0.001), TG/HDL-C ratio (r: 0.539, p<0.001), CMI index (r: 0.541, p<0.001), and TyG index (r: 0.461, p<0.001) in women. NHtR showed a weak association with hepatosis severity (r: 0.335, p: 0.008), and TyG index (r: 0.259, p: 0.047) in men. In women, it was moderately associated with CMI index (r: 0.425, p: 0.001),

**Table 1.** Characteristics of participants

| | Men (n= 61) | Women (n= 62) | Total (n= 123) |
|---|---|---|---|
| **Age** | 43.06 ± 11.22 | 49.03 ± 9.46 | 46.07 ± 10.80 |
| **Educational status** | | | |
| Illiterate | - | 2 (3.2) | 2 (1.6) |
| Primary school | 8 (13.1) | 32 (51.6) | 40 (32.5) |
| Middle and High School | 22 (36.1) | 12 (19.4) | 34 (27.7) |
| University | 31 (27.9) | 16 (25.8) | 47 (38.2) |
| **Working status** | | | |
| No | 35 (57.4) | 31 (50.0) | 66 (53.7) |
| Yes | 26 (42.6) | 31 (50.0) | 57 (46.3) |
| **Presence another disease** | | | |
| No | 53 (57.4) | 26 (41.9) | 61 (49.6) |
| Yes | 26 (42.6) | 36 (58.1) | 62 (50.4) |
| Diabetes Mellitus | 12 (19.7) | 17 (27.4) | 29 (23.4) |
| Hypertension | 13 (21.3) | 13 (21.0) | 26 (21.1) |
| Ulcer/reflux/gastritis | 7 (11.5) | 6 (9.7) | 13 (10.6) |
| Rheumatic Disease | 2 (3.3) | 2 (3.2) | 4 (3.3) |
| **Hepatosis Grade** | | | |
| Grade I | 8 (13.1) | 16 (25.8) | 23 (19.5) |
| Grade II | 45 (73.8) | 41 (66.1) | 86 (69.9) |
| Grade III | 8 (13.1) | 5 (8.1) | 13 (10.6) |

**Table 2.** Anthropometric measurements

| | Men (n= 61) | | Women (n=62) | |
|---|---|---|---|---|
| | **Mean ± SD** | **Min-Max** | **Mean ± SD** | **Min-Max** |
| Weight (kg) | 96.05 ± 16.19 | 70.30-129.50 | 80.12 ± 11.10 | 61.00-110.50 |
| Height (cm) | 175.50 ± 7.66 | 162.0-195.0 | 159.13 ± 5.29 | 148.0-169.0 |
| BMI (kg/m$^2$) | 31.13 ± 4.53 | 24.51-46.02 | 31.68 ± 4.46 | 21.74-44.83 |
| WC (cm) | 111.18 ± 11.55 | 90.00-137.00 | 103.43 ± 9.20 | 87.00-121.00 |
| HC (cm) | 113.47 ± 9.57 | 101.00-142.00 | 114.76 ± 11.44 | 92.00-145.00 |
| Body fat ratio (%) | 29.22 ± 6.15 | 20.00-44.30 | 40.23 ± 4.90 | 31.70-50.00 |
| Body fat mass (kg) | 28.37 ± 9.95 | 16.30-55.30 | 32.61 ± 7.99 | 19.70-55.20 |
| Body muscle ratio (%) | 63.80 ± 11.33 | 35.46-76.81 | 52.49 ± 10.03 | 32.61-64.73 |
| Body muscle mass (kg) | 60.79 ± 12.53 | 35.10-82.30 | 41.85 ± 8.75 | 23.20-55.30 |
| MUAC (cm) | 36.13 ± 3.13 | 31.00-43.00 | 35.40 ± 4.47 | 30.00-53.00 |
| NC (cm) | 42.14 ± 2.26 | 38.00-47.00 | 42.06 ± 3.61 | 35.00-50.00 |
| WHtR | 0.63 ± 0.06 | 0.52-0.82 | 0.65 ± 0.06 | 0.53-0.78 |
| NHtR | 0.24 ± 0.01 | 0.21-0.28 | 0.26 ± 0.02 | 0.21-0.32 |
| WHR | 0.98 ± 0.05 | 0.88-1.08 | 0.90 ± 0.08 | 0.74-1.13 |
| **BMI classification (n, %)** | | | | |
| 18.5-24.9 normal weight | 2 (3.3) | | 2 (3.2) | |
| 25-29.9 overweight | 28 (45.9) | | 19 (30.6) | |
| 30-34.9 moderate obesity | 20 (32.8) | | 27 (43.5) | |
| 35-39.9 severe obesity | 10 (16.4) | | 10 (16.1) | |
| ≥40 very severe obesity | 1 (1.6) | | 4 (6.5) | |

BMI: body mass index, WC: waist circumference, HC: hip circumference, MUAC: middle-upper arm circumference, NC: neck circumference, WHtR: waist to height ratio, WHR: waist to hip ratio, NHtR: neck to height ratio.

**Table 3.** Biochemical parameters

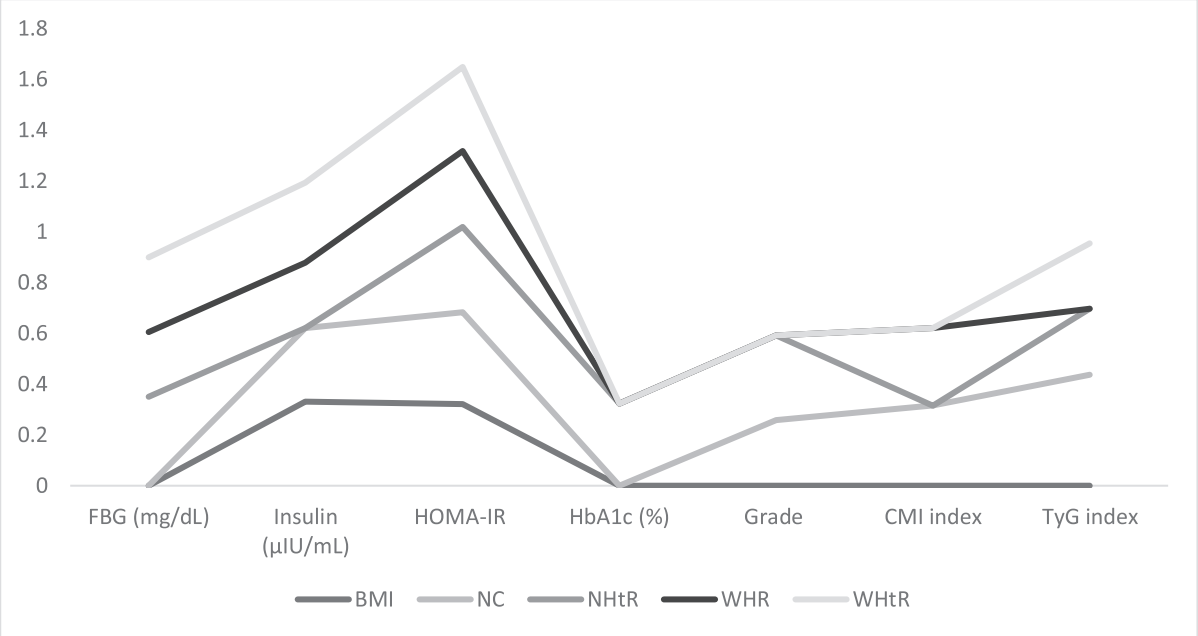
| | Men (n= 61) | | Women (n= 62) | |
|---|---|---|---|---|
| | **Mean ± SD** | **Min-Max** | **Mean ± SD** | **Min-Max** |
| FBG (mg/dL) | 101.80 ± 16.04 | 66.00-149.00 | 101.64 ± 14.07 | 81.00-137.00 |
| Insulin (μIU/mL) | 19.47 ± 9.10 | 8.00-47.00 | 17.74 ± 4.53 | 9.20-27.00 |
| HOMA-IR | 4.68 ± 2.73 | 2.18-17.29 | 6.31 ± 5.44 | 2.04-31.50 |
| HbA1c (%) | 5.91 ± 0.55 | 5.00-8.00 | 5.93 ± 0.37 | 5.30-7.00 |
| AST (u/L) | 48.81 ± 62.72 | 13.00-382.00 | 30.91 ± 13.17 | 11.00-53.00 |
| ALT (u/L) | 73.34 ± 76.96 | 22.00-451.00 | 34.67 ± 20.25 | 7.00-80.00 |
| ALP (u/L) | 73.12 ± 22.19 | 30.00-151.00 | 77.44 ± 27.12 | 26.00-128.00 |
| GGT (u/L) | 52.28 ± 30.50 | 15.20-161.00 | 37.12 ± 26.07 | 5.00-102.00 |
| TG (mg/dL) | 207.0 ± 93.66 | 111.00-521.00 | 167.79 ± 127.16 | 52.00-597.00 |
| TC(mg/dL) | 203.62 ± 35.74 | 129.00-264.00 | 220.41 ± 37.28 | 156.00-300.00 |
| HDL-C (mg/dL) | 42.39 ± 8.73 | 27.70-64.00 | 50.66 ± 13.66 | 28.60-74.00 |
| LDL-C (mg/dL) | 140.09 ± 39.12 | 60.00-227.00 | 141.83 ± 33.96 | 85.00-224.00 |
| CRP (mg/L) | 2.12 ± 2.15 | 0.10-10.10 | 2.98 ± 4.28 | 0.10-20.17 |
| Grade | 2.00 ± 0.50 | 1.00-3.00 | 1.83 ± 0.55 | 1.00-3.00 |
| TC/HDL-C | 4.87 ± 1.42 | 1.15-10.94 | 4.40 ± 1.39 | 2.58-8.57 |
| TG/HDL-C | 4.53 ± 2.74 | 0.82-15.32 | 3.67 ± 3.10 | 0.85-20.87 |
| LDL/HDL-C | 3.25 ± 1.31 | 0.60-8.13 | 2.76 ± 1.00 | 1.25-6.40 |
| CMI index | 2.89 ± 1.86 | 0.54-9.68 | 2.41 ± 2.07 | 0.55-13.96 |
| TyG index | 9.03 ± 0.49 | 7.89-10.57 | 8.93 ± 0.59 | 7.65-10.62 |

FBP: fasting blood glucose, HOMA-IR: Homeostasis model assessment for insulin resistance, HbA1c: hemoglobin A1c, AST: aspartate aminotransferase, ALT: alanine aminotransferase, ALP: alkaline phosphatase, GGT: gamma-glutamyl transpeptidase, TG: total triglyceride, TC: total cholesterol, LDL-C: low-density lipoprotein cholesterol, HDL-C: high-density lipoprotein cholesterol, TG/HDL-C: total triglyceride / high-density lipoprotein cholesterol, TC/HDL-C: total cholesterol / high-density lipoprotein cholesterol ratio, LDL/HDL-C: low-density lipoprotein cholesterol / high-density lipoprotein cholesterol ratio, CMI: cardiometabolic index, TyG: triglyceride glucose index.

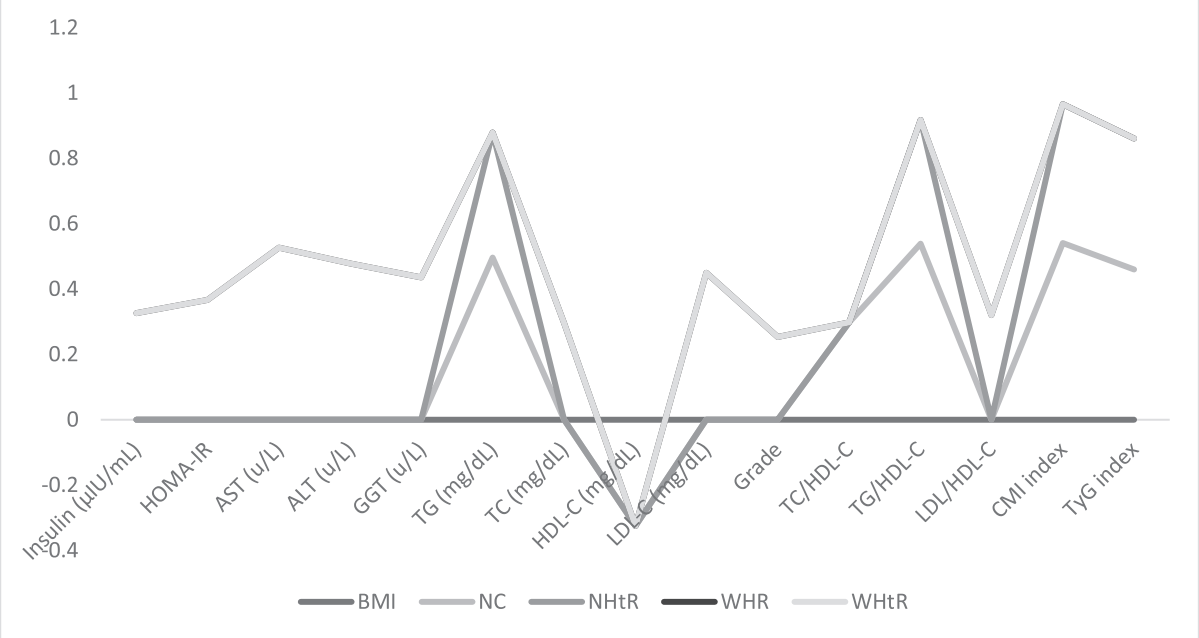
**Table 4.** Correlation between some anthropometric measurements (BMI, NC, NHtR, WHR, WHtR) and biochemical parameters

| | BMI | NC | NHtR | WHR | WHtR |
|---|---|---|---|---|---|
| **Men** | | | | | |
| FBG (mg/dL) | 0.161 (p= 0.215) | 0.0109 (p= 0.401) | **0.350* (p= 0.006)** | **0.254* (p= 0.048)** | **0.294* (p= 0.021)** |
| Insulin (μIU/mL) | **0.331** (p= 0.009)** | **0.290* (p= 0.002)** | 0.234 (p= 0.070) | **0.258* (p= 0.045)** | **0.315* (p= 0.013)** |
| HOMA-IR | **0.322* (p= 0.001)** | **0.361** (p= 0.008)** | **0.336** (p= 0.008)** | **0.299* (p= 0.019)** | **0.331** (p= 0.009)** |
| HbA1c (%) | 0.137 (p= 0.294) | 0.230 (p= 0.074) | **0.323* (p= 0.011)** | 0.221 (p= 0.086) | 0.232 (p= 0.072) |
| AST (u/L) | -0.114 (p= 0.392) | -0.031 (p= 0.815) | 0.010 (p= 0.940) | -0.251 (p= 0.055) | -0.211 (p= 0.108) |
| ALT (u/L) | -0.012 (p= 0.928) | 0.084 (p= 0.522) | 0.008 (p= 0.954) | -0.147 (p= 0.257) | -0.141 (p= 0.279) |
| ALP (u/L) | -0.069 (p= 0.698) | -0.179 (p= 0.312) | -0.088 (p= 0.619) | 0.029 (p= 0.869) | 0.164 (p= 0.354) |
| GGT (u/L) | 0.038 (p= 0.775) | 0.155 (p= 0.246) | 0.011 (p= 0.935) | -0.150 (p= 0.261) | -0.129 (p= 0.335) |
| TG (mg/dL) | -0.029 (p= 0.826) | 0.136 (p= 0.296) | 0.104 (p= 0.425) | 0.159 (p= 0.222) | 0.019 (p= 0.887) |
| TC (mg/dL) | -0.122 (p= 0.350) | -0.026 (p= 0.843) | -0.068 (p= 0.602) | -0.054 (p= 0.678) | -0.003 (p= 0.983) |
| HDL-C (mg/dL) | 0.033 (p= 0.800) | -0.245 (p= 0.05) | -0.106 (p= 0.417) | -0.198 (p= 0.126) | 0.012 (p= 0.927) |
| LDL-C (mg/dL) | -0.146 (p= 0.263) | -0.006 (p= 0.597) | -0.178 (p= 0.169) | -0.124 (p= 0.339) | -0.078 (p= 0.548) |
| Grade | 0.106 (p= 0.415) | **0.257* (p= 0.046)** | **0.335** (p= 0.008)** | 0.105 (p= 0.419) | 0.166 (p= 0.200) |
| TC/HDL-C | -0.111 (p= 0.395) | 0.208 (p= 0.108) | 0.027 (p= 0.836) | 0.087 (p= 0.506) | -0.036 (p= 0.781) |
| TG/HDL-C | -0.009 (p= 0.944) | 0.197 (p= 0.129) | 0.066 (p= 0.615) | 0.200 (p= 0.122) | 0.032 (p= 0.806) |
| LDL/HDL-C | -0.144 (p= 0.277) | 0.092 (p= 0.482) | -0.074 (p= 0.572) | -0.035 (p= 0.789) | -0.090 (p= 0.491) |
| CMI index | 0.101 (p= 0.440) | **0.315* (p= 0.022)** | 0.112 (p= 0.392) | **0.307* (p= 0.022)** | 0.165 (p= 0.204) |
| TyG index | 0.009 (p= 0.946) | **0.438** (p<0.001)** | **0.259* (p= 0.047)** | 0.171 (p= 0.188) | **0.258* (p= 0.04)** |
| **Women** | | | | | |
| FBG (mg/dL) | -0.049 (p= 0.707) | 0.117 (p= 0.364) | 0.148 (p= 0.250) | 0.236 (p= 0.065) | 0.000 (p= 0.998) |
| Insulin (μIU/mL) | 0.221 (p= 0.084) | 0.079 (p= 0.544) | 0.151 (p= 0.241) | **0.327** (p= 0.009)** | 0.207 (p= 0.106) |
| HOMA-IR | 0.147 (p= 0.252) | 0.096 (p= 0.459) | 0.175 (p= 0.174) | **0.366** (p= 0.003)** | 0.160 (p= 0.215) |
| HbA1c (%) | 0.025 (p= 0.847) | 0.140 (p= 0.310) | 0.181 (p= 0.159) | 0.104 (p= 0.421) | 0.037 (p= 0.773) |
| AST (u/L) | 0.054 (p= 0.767) | 0.059 (p= 0.651) | 0.097 (p= 0.453) | **0.526** (p<0.001)** | 0.105 (p= 0.417) |
| ALT (u/L) | -0.056 (p= 0.664) | 0.069 (p= 0.593) | 0.096 (p= 0.460) | **0.478** (p<0.001)** | -0.016 (p= 0.900) |
| ALP (u/L) | 0.152 (p= 0.440) | -0.06 (p= 0.974) | 0.100 (p= 0.613) | 0.082 (p= 0.679) | 0.272 (p= 0.161) |
| GGT (u/L) | 0.016 (p= 0.908) | 0.221 (p= 0.101) | 0.184 (p= 0.174) | **0.435** (p= 0.001)** | 0.170 (p= 0.209) |
| TG (mg/dL) | 0.051 (p= 0.695) | **0.495** (p<0.001)** | **0.383** (p= 0.002)** | 0.126 (p= 0.331) | 0.0128 (p= 0.322) |
| TC (mg/dL) | -0.047 (p= 0.721) | -0.016 (p= 0.900) | -0.047 (p= 0.720) | **0.295* (p= 0.021)** | -0.066 (p= 0.613) |
| HDL-C (mg/dL) | 0.155 (p= 0.248) | **-0.325* (p= 0.014)** | -0.162 (p= 0.209) | -0.075 (p= 0.563) | 0.101 (p= 0.436) |
| LDL-C (mg/dL) | -0.019 (p= 0.721) | -0.064 (p= 0.623) | -0.073 (p= 0.573) | **0.450** (p<0.001)** | -0.185 (p= 0.150) |
| Grade | 0.004 (p= 0.975) | 0.064 (p= 0.620) | 0.030 (p= 0.818) | **0.253* (p= 0.047)** | 0.007 (p= 0.955) |
| TC/HDL-C | 0.069 (p= 0.599) | **0.298* (p= 0.037)** | 0.162 (p= 0.212) | -0.103 (p= 0.428) | -0.004 (p= 0.973) |
| TG/HDL-C | 0.004 (p= 0.757) | **0.539** (p<0.001)** | **0.379** (p= 0.002)** | 0.138 (p= 0.285) | 0.092 (p= 0.476) |
| LDL/HDL-C | 0.024 (p= 0.853) | 0.130 (p= 0.315) | 0.041 (p= 0.752) | **0.321* (p= 0.011)** | -0.167 (p= 0.194) |
| CMI index | 0.109 (p= 0.397) | **0.541** (p<0.001)** | **0.425** (p= 0.001)** | 0.169 (p= 0.189) | 0.183 (p= 0.154) |
| TyG index | 0.004 (p= 0.973) | **0.461** (p<0.001)** | **0.399** (p= 0.002)** | 0.204 (p= 0.112) | 0.197 (p= 0.451) |

*p<0.05, **p<0.001. FBP: fasting blood glucose, HOMA-IR: Homeostasis model assessment for insulin resistance, HbA1c: hemoglobin A1c, AST: aspartate aminotransferase, ALT: alanine aminotransferase, ALP: alkaline phosphatase, GGT: gamma-glutamyl transpeptidase, TG: total triglyceride, TC: total cholesterol, LDL-C: low-density lipoprotein cholesterol, HDL-C: high-density lipoprotein cholesterol, TG/HDL-C: total cholesterol / high-density lipoprotein cholesterol ratio, TC/HDL-C: total cholesterol / high-density lipoprotein cholesterol ratio, LDL/HDL-C: low-density lipoprotein cholesterol / high-density lipoprotein cholesterol ratio, CMI: cardiometabolic index, TyG: triglyceride glucose index, BMI: body mass index, NC: neck circumference, NHtR: neck to height ratio, WHR: waist to hip ratio, WHtR: waist to height ratio.




(a) For men




(b) For women

**Figure 2.** Statistically differences between some anthropometric measurements (BMI, NC, NHtR, WHR, WHtR) and biochemical parameters according to gender.

and TyG index (r: 0.399, p: 0.002). Additionally, WHR was moderately correlated with LDL-C (r: 0.450, p<0.001) and liver enzymes in women (AST (r: 0.536, p<0.001), ALT (r: 0.478, p<0.001), GGT (r: 0.435, p: 0.001)). WHtR showed only a weak association with TyG index (r: 0.258, p: 0.04) in men (Table 4, and Figure 2).

MAFLD is a multisystem disorder that affects hepatic structure and function causing cirrhosis, liver failure, and hepatocellular cancer, as well as morbidity and mortality [8]. MAFLD is strongly associated with obesity, IR, and dyslipidemia, and is the leading cause of chronic liver disease [2]. To the best of our knowledge, this is the first study to determine

the relationship between various anthropometric measurements and blood lipid-related indexes in MAFLD patients. In this study, it was found that the majority of participants (38.2%) were overweight and obese, whereas only 3.3% of participants were normal body weight. NC and NHtR were highest correlated with blood-lipid parameter indexes compared to other anthropometric measurements, especially among women. According to our results, NC was moderately associated with TyG index, and weakly associated with CMI index, and hepatosis severity in men; while it was moderately associated with TG, CMI index, TyG index, and TG/HDL-C in women. A moderate correlation was found between NHtR and TyG and CMI indexes, whereas it was weakly associated with TG, TG/HDL-C ratio in women; in men, it was weakly correlated with hepatosis severity and TyG index. Additionally, WHR was moderately correlated with liver enzymes (AST, ALT, and GGT), and LDL-C; and weakly associated with TC, hepatosis severity, LDL/HDL-C ratio in women, while it was weakly correlated with CMI index in men. It was observed that WHtR was only linked with TyG index and some prediabetes parameters (FBG, insulin, HOMA-IR) in men. However, BMI was not associated with blood lipid-related indexes.

In recent years, studies have reported that upper body subcutaneous adipose tissue has a strong link with metabolic disorders [24-26], however, limited studies have demonstrated the relationship between NC and MAFLD [28-30]. According to these studies, NC was determined as an independent predictor for MAFLD [28-30]. We found that NC was moderately correlated with TyG index, and weakly correlated with CMI index, hepatosis severity in men; in women, it was moderately correlated with CMI index, TyG index, TG, and TG/HDL-C ratio, while it was weakly correlated with TC/HDL-C ratio and HDL-C. Additionally, a recent study reported that NHtR was superior to NC as a measure for upper body fat deposition, as it adjusts for differences in NC attributable to height, and it was observed that NHtR had a better odds ratio than NC for predicting liver fibrosis [29]. In the present study, NHtR showed a moderate correlation with CMI and TyG indexes, and weak correlation with TG, and TG/HDL-C ratio in women whereas it was weakly correlated hepatosis severity, and TyG index in men. Based on our findings, both NC and NHtR were highest correlated with blood-lipid parameter indexes compared to other anthropometric measurements, especially in women. Therefore, both of them can be used as a simple and feasible tool for screening dyslipidemia in MAFLD patients.

There is an important link between MAFLD and dysregulated lipid metabolism. Blood lipid levels are important parameters for predicting dysregulated lipid metabolism [11,31]. Therefore, MAFLD screening can be done using blood-lipid-related indices. In metabolic deterioration, there is an increase in TG and a decrease in HDL-C. Additionally, the ratio of TG to HDL-C has been shown to be a predictor of IR [38,39]. IR increases lipolysis of adipocytes and de novo synthesis of TG in the hepatocytes that promotes MAFLD [40]. Furthermore, MAFLD and the TG/HDL-C ratio were found to be linked [17,18]. According to a study, the cut-off value of TG/HDL-C for determining MAFLD was 1.4 in men and 0.9 in women [18]. Another study conducted on women reported that the best cut-off value of TG/HDL-C was 4.17 [36]. Based on our findings, the mean TG/HDL-C ratio was 4.53 ± 2.74 in men and 3.67 ± 3.10 in women. The difference in cut-off values may be due to the fact that it was performed in different populations. Also, previous studies did not include patients according to the new diagnostic criteria of fatty liver diseases (MAFLD) [18,36]. In our study, the new recommended diagnostic criteria for MAFD were used. According to these diagnostic criteria, the level of TG and HDL-C were not in the risky range for every patient.

The WHtR, which is thought to be a predictor of abdominal obesity, is strongly associated with MAFLD [21-23]. CMI index is a new marker of abdominal fat accumulation and represented a profile of metabolic abnormalities [36]. Only one study reported the association between CMI index and MAFLD [20]. According to this study, CMI index may be useful for screening and detecting women with MAFLD. Additionally, the optimal cut-off value was 0.62. We found that the mean levels of CMI index were 2.89 ± 1.86 in men and 2.41 ± 2.07 in women. Our study results confirm the previous study, which was conducted only on women, however, there is no study conducted on men. Future studies are required to confirm the usability and cut-off value of the CMI index in MAFLD patients of both genders.

There is growing interest in the TyG index, and it is closely related to MAFLD. Possible mechanisms between them are: TG is synthesized from free fatty acids produced in the liver. When the storage capacity of adipose tissue is limited (such as obesity), there is an increase in free fatty acids and fat accumulation in hepatocytes [41]. Additionally, IR causes an increase in de novo lipogenesis [40]. It was observed a relationship between the TyG index and simple steatosis and NASH in asymptomatic women [42]. Furthermore, the optimal cut-off points were TyG ≥8.5 in MAFLD patients [37]. In this study, the mean value of the TyG index was 9.03 ± 0.49 in men, and 8.93 ± 0.59 in women. As a result, TyG index could be used to identify individuals who are at risk of MAFLD. A previous study was found that BMI was associated with TyG index in MAFLD patients [43]. However, there was no association between BMI and TyG index according to our study. TyG index showed a moderate relationship with NC and NHtR in women while it showed a moderate and weak relationship with NC and NHtR in men, respectively. This is due to the fact that the body's subcutaneous adipose tissue, which has attracted attention recently, has a stronger relationship with MAFLD [28,30]. Additionally, the TyG index weakly correlated with WHtR in men since WHtR defines abdominal obesity better than BMI. Moreover, the person may be metabolically obese status with a normal weight. It may not be related to BMI because BMI could not detect this [44].

LDL/HDL-C could prognosticate the risk of many metabolic diseases, however, only a recent study evaluated that MAFLD was closely related with LDL/HDL-C ratio. It was observed that LDL/HDL-C ratio was highly associated with predicting new-onset MAFLD compared to HDL-C and LDL-C [16]. A study reported that the optimal LDL/HDL-C cut-off value for women was 2.22 [36]. However, another study indicated that the best cut-off value of LDL/HDL-C was 1.66 for the determination of MAFLD, which was conducted on non-obese MAFLD patients [16]. We found that the mean LDL/HDL-C ratio was 3.25 ± 1.31 in men, and 2.76 ± 1.00 in women. In this study, there were only 3.3% of patients were normal-weight among the participants. Considering the strong relationship between obesity and the high prevalence of MAFLD, it was expected that the mean values of LDL/HDL-C were higher than in the previous study.

There are several limitations to the study. First, the present study was cross-sectional, which has its limitation, such as lack of study of the causality between factors. Second, our study was a single-center. Therefore, future studies are needed to verify these results with a large sample population. Third, liver biopsy is the gold standard for evaluating hepatic steatosis, but we used ultrasonography for imagining techniques due to the risks of liver biopsy such as bleeding, pain, infection, and mortality. Additionally, this method is invasive and costly.

## CONCLUSION

Considering the increasing prevalence of MAFLD as an important public health problem, it is necessary to control a patient's blood-lipid parameter indexes. Our finding suggests that both NC and NHtR could be used to predict the risk of dyslipidemia in MAFLD, especially among women. Future studies are required to confirm our results.

## AUTHORSHIP CONTRIBUTION

Concept: Hatice Merve Bayram, Raim İliaz, Arda Ozturkcan, Fatma Esra Gunes; Design: Hatice Merve Bayram, Raim İliaz, Arda Ozturkcan, Fatma Esra Gunes; Data analysis: Hatice Merve Bayram, Raim İliaz; Literature research: Hatice Merve Bayram; Writing: Hatice Merve Bayram; Critical revision: Hatice Merve Bayram, Raim İliaz, Arda Ozturkcan, Bagnu Dundar, Fatma Esra Gunes.

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## CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## ETHICS COMMITTEE APPROVAL

Ethics committee approval was received from the ethics committee of Marmara University Faculty of Medicine Clinical Research (Approval number: 09.2019.810), and the study was carried out in accordance with the principles of the Helsinki Declaration. All participants provided both written and verbal informed consent.

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