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Assessment of neck to height ratio as a predictive tool for metabolic dysfunction-associated steatotic liver disease in Korean adults: a cross-sectional analysis from Korea National Health and Nutrition Examination Survey 2019–2021

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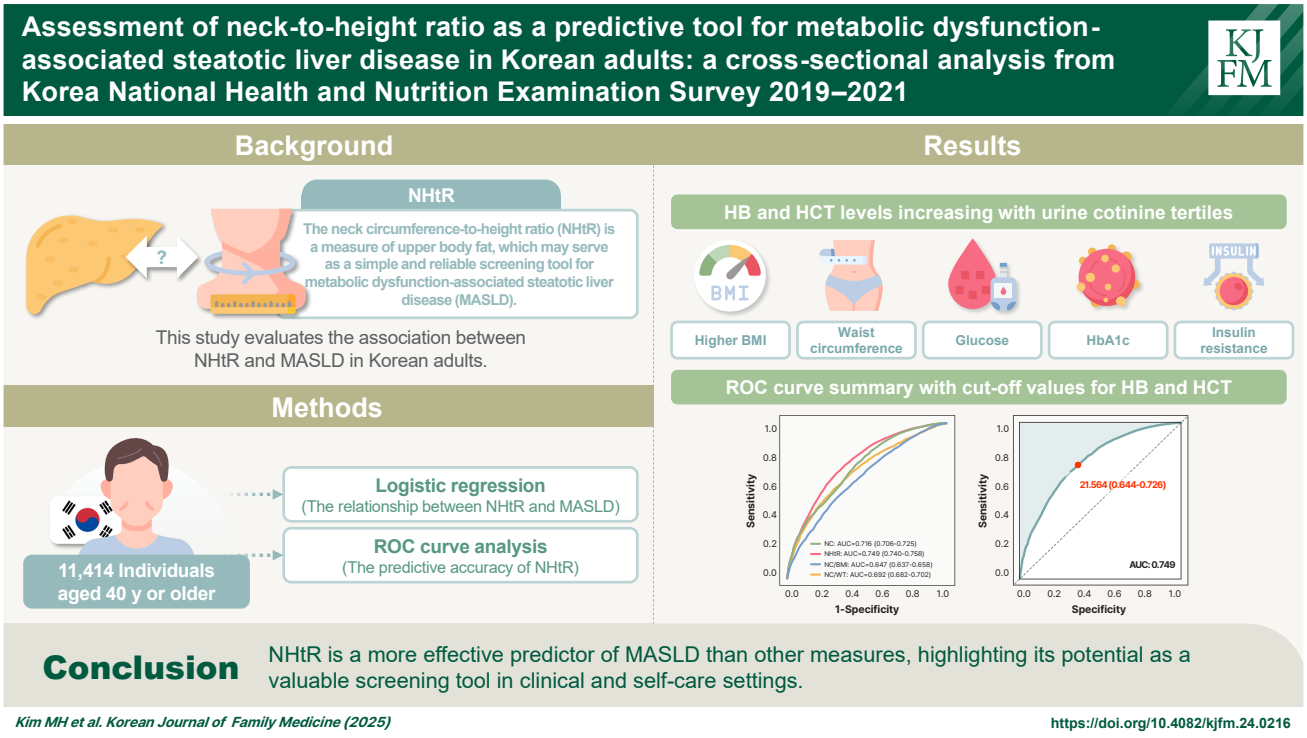

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ABSTRACT

Background: Early screening and management of metabolic dysfunction-associated steatotic liver disease (MASLD) are essential to prevent progression to fibrosis, cirrhosis, and related chronic diseases. The neck circumference to height ratio (NHtR) is a reliable measure of upper body fat. This study explored the relationship between the NHtR and MASLD in the Korean population, with the aim of validating it as a reliable screening tool.

Methods: We analyzed data from the 2019 to 2021 Korea National Health and Nutrition Examination Survey, including 11,414 participants aged 40 years or older. The association between the NHtR and MASLD was evaluated using logistic regression analysis, while predictive accuracy was evaluated using receiver operating characteristic curve analysis.

Results: A total of 11,414 participants aged 40 years or older were included in the study. Participants in the highest NHtR quartile had higher levels of metabolic risk markers, including body mass index, waist circumference, glucose, hemoglobin A1c, and homeostatic model assessment of insulin resistance (P<0.001). In logistic regression analysis, the odds ratio for MASLD in quartile 4 compared to quartile 1 was 1.77 (95% confidence interval [CI], 1.31–2.40; P<0.001) in the fully adjusted model. The area under the curve and 95% CI of NHtR for MASLD were 0.749 (95% CI, 0.740–0.758), demonstrating superior accuracy compared with other indicators. The optimal NHtR cut-off for MASLD was 21.564, with a sensitivity and specificity of 0.726 and 0.644, respectively.

Conclusion: NHtR is a more effective predictor of MASLD than other measures, highlighting its potential as a valuable screening tool in clinical and self-care settings.

Keywords: Non-alcoholic Fatty Liver Disease; Neck; Height; Obesity

Introduction

The increasing prevalence of obesity and metabolic syndrome (MetS) has contributed to fatty liver disease becoming one of the most widespread liver conditions globally, currently affecting around 30% of the world's population [1]. In 2023, the term "steatotic liver disease (SLD)" was introduced to better reflect this condition and has since evolved into "metabolic dysfunction-associated SLD (MASLD)," replacing the term nonalcoholic fatty liver disease (NAFLD) [2]. The prevalence of MASLD is rising rapidly, with an estimated 20%–30% of the Korean population affected [3]. This condition poses a significant risk of progression to severe liver disease, such as cirrhosis and hepatocellular carcinoma, primarily driven by increasing rates of obesity, type 2 diabetes mellitus (DM), and MetS [4].

There are currently no approved pharmacological treatment options for SLD. Consequently, SLD management primarily focuses on lifestyle modifications, including weight loss, caloric restriction, and increased physical activity. Additionally, management strategies target the risk factors associated with SLD, such as obesity, DM, dyslipidemia, and MetS [5].

Neck circumference (NC) is a validated measure of upper body subcutaneous fat accumulation, a predictor of MetS, and an indicator of NAFLD [6-8]. However, the NC to height ratio (NHtR) offers a key advantage by adjusting for height variations in NC measurements, making it a superior metric for assessing upper body fat accumulation. This adjustment allows the NHtR to serve as a more accurate and reliable indicator for evaluating the risk and presence of NAFLD than NC alone [9].

Previous studies have demonstrated that NC is associated with metabolic dysfunction-associated fatty liver disease (previously termed MAFLD and currently referred to as MASLD), linking higher NC with an increased risk of developing the disease and a decreased likelihood of disease resolution [10]. This establishes NC as a potential predictive marker for MAFLD management. However, no studies have specifically investigated the relationship between NHtR and MASLD, especially in the Korean population.

This study used representative data from the Korean population to explore the association between NHtR and the occurrence of MASLD. Additionally, it sought to determine the optimal NHtR cut-off value for predicting the risk of MASLD among Koreans.

Methods

Study population and data source

This study utilized data from the 8th Korea National Health and Nutrition Examination Survey (KNHANES VIII), conducted from 2019 to 2021. The KNHANES is a continuous nationwide surveillance system initiated in 1998 by the Korea Centers for Disease Control and Prevention. The survey assessed the health and nutritional status of the Korean population, monitored trends in health risk factors and prevalence of major chronic diseases, and supported the development and evaluation of health policies and programs in Korea. The KNHANES employs a multistage, stratified, cluster-based random sampling method. This approach ensures a sample that proportionally represents the sex, residential area, and age distribution of the Korean population, providing a comprehensive overview of the nation's health trends [11]. This study utilized data from the KNHANES, which included NC measurements taken only for adults aged 40 years or older. Of the 22,559 participants, 11,414 were selected for this study after excluding those with incomplete data. The selection process for the study participants is shown in Figure 1.

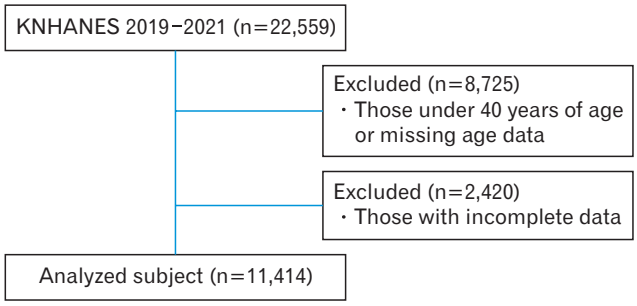

Figure 1. Flow chart for enrollment. KNHANES, Korea National Health and Nutrition Examination Survey.

Anthropometric measurements in KNHANES

In the KNHANES, anthropometric measurements including height, weight, NC, and waist circumference (WC) were conducted by trained personnel. These measurement protocols were standardized to ensure consistency and accuracy across the datasets.

NC measurement: participants were seated with their hips, waist, and back forming a right angle, maintaining a straight neck with the head aligned parallel to the Frankfort plane. Their arms were positioned in a neutral posture at their sides. NC was measured to the nearest 1 mm using nonstretchable tape (Lufkin W606pm; Lufkin Industries), placed just below Adam's apple and perpendicular to the longitudinal axis of the neck. For males, the tape was positioned after locating Adam's apple, while for females, the neck was extended to accentuate the thyroid cartilage before taking the measurement. Each measurement was performed twice to minimize errors, and the averages of these two readings were recorded.

WC measurement: WC was measured at the midpoint between the lower margin of the last rib and the top of the iliac crest along the right axillary line. This method ensures that measurement is performed at the narrowest part of the torso, thereby providing a reliable indicator of abdominal adiposity.

Height and weight measurements: height and weight were measured according to the standard procedures outlined in the KNHANES manual. Height was measured to the nearest 0.1 cm and weight to the nearest 0.1 kg. Body mass index (BMI) was calculated as weight in kilograms divided by height in square meters (kg/m^2).

The NHtR was calculated by dividing the NC (measured in cm) by the height of the individual (measured in cm). This ratio provides a standardized measurement that adjusts for variations in height and offers a more accurate assessment of upper body fat distribution.

Biochemical measurements in KNHANES

Blood pressure measurement: blood pressure was assessed using a standard protocol in which trained nurses took three measurements, allowing the participant to rest for 5 minutes between each reading. The average of these three readings was used for analysis to ensure accuracy and minimize variability due to temporary factors, such as stress or recent activity.

Biochemical measurements: serum levels of total cholesterol (TC), triglycerides, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and fasting blood glucose (FBG) are quantified using a Hitachi Automatic Analyzer 7600 (Hitachi). This method ensures high reliability and precision of biochemical measurements.

Glycosylated hemoglobin (HbA1c) was measured by high-performance liquid chromatography using a Tosoh G8 analyzer (Tosoh), which provides high specificity and accuracy for monitoring long-term glucose control. Cholesterol and triglyceride levels were determined using enzymatic methods, which are known for their sensitivity and precision. FBG was assessed using the hexokinase ultraviolet method, which is recognized for its high accuracy in glucose measurement. AST and ALT levels were measured using the International Federation of Clinical Chemistry and Laboratory Medicine method with gamma-glutamyl-carboxy-nitroanilide (without pyridoxal phosphate) to enhance the specificity of the assay for liver enzymes' activity.

Homeostatic model assessment for insulin resistance (HOMA-IR) calculation method: insulin resistance was assessed by multiply fasting insulin level (μU/mL) by FBG level (mg/dL). The results were then divided by 405.

Quantitative Insulin Sensitivity Check Index (QUICKI) calculation method: the fasting insulin (μU/mL) and FBG (mg/L) values were measured then converted into their logarithms. The logarithmic values were then added. The reciprocal of this sum was used to obtain QUICKI values.

Covariates

In our study, the participants were grouped into two categories based on their smoking status via self-reported questionnaires: current smokers and noncurrent smokers. To quantify alcohol consumption, we used a formula that calculates daily intake in grams. Specifically, daily intake was determined by multiplying the grams of alcohol per glass (10 g) by the number of glasses consumed at each occasion and the frequency of such occasions per month [12]. This product was then divided by the average number of days in a month (30) to obtain the average daily alcohol intake. Based on this calculation, males who consumed 30 g or more per day and females who consumed 20 g or more per day were identified as heavy drinkers [13].

Physical activity was assessed using the Korean version of the Global Physical Activity Questionnaire. Activity data were converted into metabolic equivalents to quantify the intensity and duration of daily physical activity in minutes per day. This metric allowed us to understand and compare the physical activity levels

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Table 1. Clinical characteristics of participants according to neck circumference to height ratio (cm/m) quartiles

Characteristic	Overall	Quartile 1 (>17 & ≤20.5)	Quartile 2 (>20.5 & ≤21.6)	Quartile 3 (>21.6 & ≤22.7)	Quartile 4 (>22.7 & ≤28.9)	P-value
No. of participants (unweighted)	11,414	2,854	2,853	2,854	2,853	
Age (y)	57.1±11.1	53.7±10.2	57.5±11.2	58.5±11.1	58.7±11.2	<0.001
Sex (%, SE)						<0.001
Male	48.5 (0.4)	14.7 (0.8)	40.8 (1.1)	60.9 (1.1)	77.1 (0.8)	
Female	51.5 (0.4)	85.3 (0.9)	59.2 (1.1)	39.1 (1.1)	22.9 (0.8)	
NC (cm)	35.4±3.4	31.8±1.7	34.3±2.1	36.3±2.2	39.0±2.5	<0.001
NC/BMI	1.5±0.2	1.5±0.2	1.5±0.2	1.5±0.2	1.4±0.2	<0.001
NC/weight	0.6±0.1	0.6±0.1	0.6±0.1	0.5±0.1	0.5±0.1	<0.001
Height (cm)	163.4±9.0	161.8±7.3	162.7±9.5	164.1±9.7	164.7±9.0	<0.001
Weight (kg)	65.1±12.2	55.9±7.7	62.2±9.6	67.5±10.1	74.6±12.0	<0.001
BMI (kg/m^2)	24.3±3.4	21.3±2.2	23.4±2.3	25.0±2.5	27.4±3.1	<0.001
WC (cm)	85.4±9.8	76.1±6.9	83.1±7.0	88.0±6.9	94.3±8.0	<0.001
SBP (mm Hg)	121.4±16.2	114.6±15.9	121.0±16.3	123.7±15.4	126.2±14.9	<0.001
DBP (mm Hg)	76.6±9.9	73.4±9.2	75.9±9.4	77.7±9.4	79.3±10.4	<0.001
MAP (mm Hg)	91.5±10.8	87.1±10.5	91.0±10.4	93.0±10.1	94.9±10.6	<0.001
Glucose (mg/dL)	104.3±23.7	96.3±14.4	101.7±20.3	107.3±26.4	112.0±28.0	<0.001
HbA1c	5.9±0.9	5.6±0.6	5.8±0.7	6.0±1.0	6.2±1.0	<0.001
Insulin (μIU/mL)	8.8±7.1	6.1±3.3	7.7±5.7	9.3±6.9	12.1±9.4	<0.001
QUICKI	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.1±0.0	<0.001
HOMA-IR	2.4±2.3	1.5±0.9	2.0±1.8	2.5±2.1	3.5±3.2	<0.001
Triglyceride (mg/dL)	139.6±111.8	101.7±63.8	129.6±101.9	151.3±117.0	175.1±136.9	<0.001
Total cholesterol (mg/dL)	193.7±39.9	196.9±36.5	195.6±39.3	193.0±40.7	189.3±42.3	<0.001
HDL-C (mg/dL)	51.3±12.6	58.1±12.9	52.5±12.3	48.8±11.3	45.9±10.4	<0.001
LDL-C (mg/dL)	116.1±35.6	118.8±32.6	118.2±35.2	115.9±36.3	111.8±37.6	<0.001
AST (IU/L)	25.5±13.0	23.1±12.8	24.6±12.8	25.9±11.4	28.4±14.1	<0.001
ALT (IU/L)	24.2±17.5	18.1±10.8	21.6±14.3	25.5±16.6	31.3±22.8	<0.001
Smoking status (%, SE)	17.2 (0.5)	8.8 (0.7)	16.5 (0.8)	20.4 (1)	22.9 (0.9)	<0.001
Alcohol consumption (%, SE)	50.7 (0.6)	43.1 (1.0)	48.6 (1.1)	53.1 (1.1)	57.9 (1.1)	<0.001
Physical activity (%, SE)	39.9 (0.6)	41.7 (1.1)	39.7 (1.1)	40.8 (1.2)	37.6 (1.1)	0.053
Diabetes (%, SE)	18.4 (0.5)	6.8 (0.5)	13.7 (0.7)	22 (0.9)	30.6 (1.0)	<0.001
Hypertension (%, SE)	14.9 (0.5)	3.5 (0.3)	10.6 (0.7)	18.7 (1.0)	30.3 (1.3)	<0.001
Dyslipidemia (%, SE)	43.9 (0.6)	30 (1.0)	40.3 (1.1)	49.6 (1.1)	54.9 (1.1)	<0.001
Metabolic syndrome (%, SE)	59 (0.6)	30.1 (1.1)	54.1 (1.2)	68.2 (1.1)	83.2 (0.9)	<0.001
NAFLD liver fat score	–0.8±1.8	–2.0±1.2	–1.2±1.5	–0.5±1.7	0.3±2.0	<0.001
MASLD (%, SE)	41 (0.6)	13.4 (0.7)	31.4 (1.0)	50 (1.2)	68.5 (1.0)	<0.001

Values are presented mean±standard deviation or % (SE), unless otherwise stated.
NC, neck circumference; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; HbA1c, hemoglobin A1c; QUICKI, Quantitative Insulin Sensitivity Check Index; HOMA-IR, homeostatic model assessment for insulin resistance; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; AST, aspartate aminotransferase; ALT, alanine aminotransferase; SE, standard error; NAFLD, nonalcoholic fatty liver disease; MASLD, metabolic dysfunction-associated steatotic liver disease.

among the participants in a standardized format [14].

Definition of MASLD

MASLD is diagnosed based on well-established cardiometabolic risk factors associated with insulin resistance, as outlined in a recent Delphi consensus statement. These factors have been validated in the context of cardiovascular diseases [15].

NAFLD liver fat score (NLFS): the diagnosis of SLD depended on the NLFS, which was designed to assess the probability of hepatic fibrosis. This score incorporated several parameters, including age, hyperglycemia, BMI, platelet count, albumin levels, and AST/ALT ratio. An NLFS greater than −0.64 was used as the threshold for diagnosing SLD [15].

Criteria for MASLD diagnosis: individuals diagnosed with SLD were further evaluated for MASLD by meeting at least one of the following cardiometabolic criteria [15]: (1) BMI ≥ 25 kg/m^2 (23 for Asian participants) or WC greater than 94 cm (male) or 80 cm (female) or ethnicity adjusted; (2) FBG level ≥5.6 mmol/L (100 mg/dL) or 2-hour post-load glucose levels ≥7.8 mmol/L (≥140 mg/dL) or HbA1c level ≥5.7% (39 mmol/L) or DM or treatment for DM; (3) blood pressure ≥130/85 mm Hg or specific antihypertensive drug treatment; (4) plasma triglyceride level ≥1.70 mmol/L (150 mg/dL) or lipid-lowering therapy; and (5) plasma HDL-C ≤1.0 mmol/L (40 mg/dL for males) and ≤1.3 mmol/L (50 mg/dL for females) or lipid-lowering therapy.

Statistical analysis

Data from the KNHANES, which uses a complex survey

Table 2. Clinical characteristics of participants according to MASLD presence

Characteristic	Overall	Without MASLD	With MASLD	P-value
No. (unweight)	11,414	6,735	4,679	
Age (y)	57.1±11.1	56.5±11.1	58.0±11.1	<0.001
Sex (%, SE)				<0.001
Male	48.5 (0.4)	42.6 (0.6)	57 (0.8)	
Female	51.5 (0.4)	57.4 (0.6)	43 (0.8)	
NC (cm)	35.4±3.4	34.2±3.1	37.0±3.3	<0.001
NC/height	21.6±1.6	21.1±1.4	22.5±1.5	<0.001
NC/BMI	1.5±0.2	1.5±0.2	1.4±0.2	<0.001
NC/weight	0.6±0.1	0.6±0.1	0.5±0.1	<0.001
Height (cm)	163.4±9.0	162.6±8.7	164.4±9.3	<0.001
Weight (kg)	65.1±12.2	60.8±10.0	71.2±12.3	<0.001
BMI (kg/m^2)	24.3±3.4	22.9±2.7	26.3±3.3	<0.001
WC (cm)	85.4±9.8	81.1±8.4	91.7±8.3	<0.001
SBP (mm Hg)	121.4±16.2	118.2±16.0	126.0±15.4	<0.001
DBP (mm Hg)	76.6±9.9	74.9±9.2	79.1±10.3	<0.001
MAP (mm Hg)	91.5±10.8	89.3±10.3	94.7±10.6	<0.001
Glucose (mg/dL)	104.3±23.7	96.6±13.4	115.5±30.1	<0.001
HbA1c	5.9±0.9	5.7±0.5	6.3±1.1	<0.001
Insulin (μIU/mL)	8.8±7.1	5.8±2.5	13.1±9.1	<0.001
QUICKI	0.2±0.0	0.2±0.0	0.1±0.0	<0.001
HOMA-IR	2.4±2.3	1.4±0.6	3.8±3.0	<0.001
Triglyceride (mg/dL)	139.6±111.8	108.6±69.2	184.2±142.1	<0.001
Total cholesterol (mg/dL)	193.7±39.9	196.1±36.7	190.2±43.8	<0.001
HDL-C (mg/dL)	51.3±12.6	54.8±12.6	46.2±10.8	<0.001
LDL-C (mg/dL)	116.1±35.6	119.9±33.1	110.7±38.2	<0.001
AST (IU/L)	25.5±13.0	22.6±6.5	29.8±17.9	<0.001
ALT (IU/L)	24.2±17.5	17.9±7.8	33.3±22.7	<0.001
Smoking status (%, SE)	17.2 (0.5)	14.8 (0.5)	20.5 (0.7)	<0.001
Alcohol consumption (%, SE)	50.7 (0.6)	50.3 (0.7)	51.3 (0.9)	0.373
Physical activity (%, SE)	39.9 (0.6)	41.5 (0.8)	37.7 (0.9)	0.001
Diabetes (%, SE)	18.4 (0.5)	5.5 (0.3)	36.8 (0.9)	<0.001
Hypertension (%, SE)	14.9 (0.5)	3.3 (0.2)	32.9 (1)	<0.001
Dyslipidemia (%, SE)	43.9 (0.6)	31.9 (0.7)	60.7 (0.9)	<0.001
Metabolic syndrome (%, SE)	59 (0.6)	33.1 (0.8)	96.3 (0.4)	<0.001

Values are presented mean±standard deviation or % (SE), unless otherwise stated.
NC, neck circumference; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; HbA1c, hemoglobin A1c; QUICKI, Quantitative Insulin Sensitivity Check Index; HOMA-IR, homeostatic model assessment for insulin resistance; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; AST, aspartate aminotransferase; ALT, alanine aminotransferase; SE, standard error; MASLD, metabolic dysfunction-associated steatotic liver disease.

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framework to represent the Korean population, were analyzed using sample weights. These weights were adjusted for age and sex distribution based on inverse selection probabilities and response rates (post-stratification). Participants were categorized into quartiles of NHtR: Q1 (≤20.5), Q2 (>20.5 and ≤21.6), Q3 (>21.6 and ≤22.7), and Q4 (>22.7).

Group characteristics were presented as mean±standard error (SE) for continuous variables and percentage±SE for categorical variables, applying sampling weights to account for the survey's design. Group differences were evaluated using analysis of variance for continuous variables and Pearson chi-square test for categorical variables. Multiple logistic regression was used to calculate odds ratio (OR) and 95% confidence interval (CI) to assess the association between NHtR quartiles and the incidence of MASLD.

Adjustments to the regression models were made progressively. Model 1 was adjusted for age, sex, and BMI; model 2 included additional adjustments for physical activity, smoking status, and alcohol consumption; and model 3 was further adjusted for WC, mean arterial pressure (MAP), TC, glucose, and insulin levels.

Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive accuracy of the NHtR for MASLD, with area under the curve (AUC) calculated using DeLong's method. SE and 95% CI of the AUC were determined. The optimal NHtR cut-off value for predicting MASLD was identified by maximizing the sensitivity and specificity (Youden Index).

Statistical significance was set at a two-sided P-value of less than 0.05. All analyses were performed using the R ver. 4.3.0 (R Foundation).

RESULTS

Clinical characteristics of the study population

The clinical characteristics of the study population are summarized in Table 1 and are illustrated in Figure 1. Of the 11,414 individuals enrolled, the mean age was 57.1 years, 48.5% were male, and the mean BMI was 24.3±3.4 kg/m^2. The prevalence rates of hypertension, DM, MetS, and MASLD were 14.9%, 18.4%, 59%, and 41%, respectively. The participants were grouped into four quartiles based on the NHtR and labeled as quartiles 1, 2, 3, and 4. Subjects in the highest NHtR quartile had higher NC, BMI, WC, glucose, HbA1c, HOMA-IR, ALT, and LDL-C levels and lower HDL-C levels. They also have higher rates of hypertension, DM, dyslipidemia, MetS, MASLD, and NAFLD. All major variables showed statistically significant differences across the NHtR quartiles (P<0.001) (Table 1).

Table 2 outlines the clinical characteristics of participants according to the presence or absence of MASLD. Participants with MASLD were older and had a higher proportion of males than those without MASLD. They exhibited greater NC, higher NHtR, and higher BMI and WC. Additionally, the MASLD group showed elevated FBG levels, HbA1c, and markers of insulin resistance such as fasting insulin and HOMA-IR.

Lipid profiles revealed higher triglyceride levels, lower HDL-C levels, and elevated levels of liver enzymes, including ALT and AST, in the MASLD group, indicating impaired liver and metabolic functions. Furthermore, participants with MASLD had a significantly higher prevalence of MetS, DM, hypertension, and dyslipidemia than those without. These findings highlight the distinct metabolic and clinical profiles of patients with MASLD.

Logistic regression analysis of MASLD risk with increasing NHtR quartiles

Table 3 presents the results of logistic regression analysis evaluating the association between NHtR quartiles and MASLD risk. The analysis revealed a clear dose-dependent relationship, in which higher NHtR quartiles were significantly associated with increased odds of MASLD. In the fully adjusted model (model 3), which accounted for confounders such as age, sex, BMI, physical activity, smoking status, alcohol intake, WC, MAP, TC, glucose, and insulin levels, the OR for MASLD increased progressively across the quartiles.

Compared to quartile 1 (reference group), the OR for MASLD was 1.26 (95% CI, 1.01–1.58; P=0.043) in quartile 2, 1.62 (95% CI, 1.25–2.10; P<0.001) in quartile 3, and 1.77 (95% CI, 1.31–2.40; P<0.001) in quartile 4. This trend demonstrated that individuals in the highest NHtR quartile had a significantly elevated risk of MASLD, nearly 77% higher than those in the lowest quartile, after adjusting for comprehensive metabolic and lifestyle factors.

Table 3. Logistic regression analysis to determine the relationship between neck circumference to height ratio quartiles and MASLD

Model[a)]	Quartile 1		Quartile 2		Quartile 3		Quartile 4	
	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Model 1	1 (ref)	Ref	1.50 (1.26–1.77)	<0.001	2.03 (1.65–2.49)	<0.001	2.28 (1.80–2.88)	<0.001
Model 2	1 (ref)	Ref	1.47 (1.24–1.74)	<0.001	1.99 (1.62–2.44)	<0.001	2.23 (1.76–2.82)	<0.001
Model 3	1 (ref)	Ref	1.26 (1.01–1.58)	0.043	1.62 (1.25–2.10)	<0.001	1.77 (1.31–2.40)	<0.001

MASLD, metabolic dysfunction-associated steatotic liver disease; OR, odds ratio; CI, confidence interval; Ref, reference; BMI, body mass index; WC, waist circumference; MAP, mean arterial pressure; TC, total cholesterol.
[a)]Model 1: adjusted for age, sex, and BMI; model 2: adjusted for age, sex, BMI, physical activity, smoking status, and alcohol intake; model 3: adjusted for age, sex, BMI, physical activity, smoking status, alcohol intake, glucose, insulin, WC, MAP, and TC.

Sex-specific analyses, as shown in Supplement 1, further supported these findings. Among males, the ORs were 1.40 (95% CI, 1.09–1.79; P=0.008) for quartile 3 and 1.43 (95% CI, 1.08–1.90; P=0.012) for quartile 4. Similarly, in females, the ORs were 1.51 (95% CI, 1.11–2.04; P=0.008) for quartile 3 and 1.61 (95% CI, 1.07–2.40; P=0.021) for quartile 4. These consistent patterns across sexes emphasize the robust relationship between higher NHtR quartiles and an increased risk of MASLD.

To further refine these findings, additional analyses were conducted to compare MASLD and non-MASLD groups, excluding individuals with alcohol-related conditions. These results, detailed in Supplement 2, provide a more straightforward assessment of the association between the NHtR and MASLD risk, independent of alcohol-related confounding factors. After adjusting for alcohol consumption, the analysis revealed that NHtR remained significantly associated with MASLD incidence OR (1.74; 95% CI, 1.18–2.56; P=0.005). Additionally, a comparison between MASLD and non-MASLD individuals who abstained from alcohol yielded consistent results (Supplement 2).

ROC curve analysis and cut-off values of NHtR

Figure 2 shows the ROC curves for NC, NHtR, NC/BMI, and NC/WC, comparing their predictive values for MASLD. Pairwise comparisons of the ROC curves revealed significant differences in the AUC results among these measures, with the NHtR showing the highest AUC of 0.749 (SE, 0.005; 95% CI, 0.740–0.758).

ROC curve analysis was used to evaluate the predictive value of the NHtR for MASLD, resulting in an AUC of 74.9% (SE, 0.005; 95% CI, 0.740–0.758). The derived ROC curve demonstrated significant predictive accuracy for classifying MASLD, with an optimal cut-off value of 21.564 (specificity, 0.644; sensitivity, 0.726) (Figure 3).

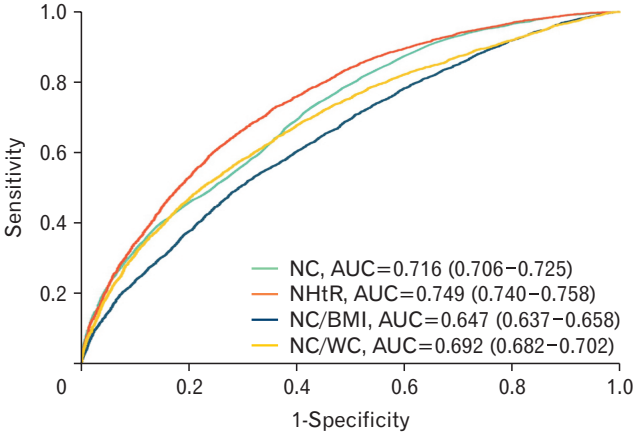

Figure 2. Receiver operating characteristic comparison of neck circumference (NC), neck circumference to height ratio (NHtR), NC/body mass index (BMI), and NC/waist circumference (WC). The area under the curve (AUC) of NC was 0.716 (standard error [SE], 0.005; 95% confidence interval [CI], 0.706–0.725), the AUC of NHtR was 0.749 (SE, 0.005; 95% CI, 0.740–0.758), the AUC of NC/BMI was 0.647 (SE, 0.005; 95% CI, 0.637–0.658), and the AUC of NC/WC was 0.692 (SE, 0.005; 95% CI, 0.682–0.702).

DISCUSSION

This study demonstrates that a higher NHtR is significantly associated with an increased risk of MASLD in adults aged 40 years or older, even after adjusting for various confounding factors. Specifically, higher NHtR quartiles were associated with a 1.77-fold increase in MASLD risk in the fully adjusted model. Moreover, the NHtR exhibited superior predictive accuracy for MASLD compared with other indicators, such as NC, NC/BMI, and NC/weight, with an AUC of 0.749. The optimal NHtR cut-off for predicting MASLD was 21.564, with a specificity of 0.644 and a sensitivity of 0.726. Sex-specific and alcohol-exclusion analyses yielded similar results, confirming that the NHtR is a consistent predictor of MASLD risk across sexes and is independent of alcohol consumption. These findings highlight the potential of the NHtR as a valuable and reliable tool for predicting MASLD in the Korean population, offering a more accurate assessment than that of traditional anthropometric measures.

MASLD is closely associated with metabolic conditions such as obesity, DM, and dyslipidemia and shares common risk factors with cardiovascular and cerebrovascular diseases [16]. This condition is emerging as a significant health problem. Early screening and management of MASLD are crucial for preventing progression to advanced fibrosis or cirrhosis and for managing associated chronic diseases. Therefore, the development of an easy and accurate screening tool for the general population is vital for effective management.

NC measurement is simple, noninvasive, and inexpensive, making it a valuable tool for assessing upper body subcutaneous fat and predicting cardiovascular risk factors [17-20]. Previous studies have shown that NC is significantly associated with obesi-

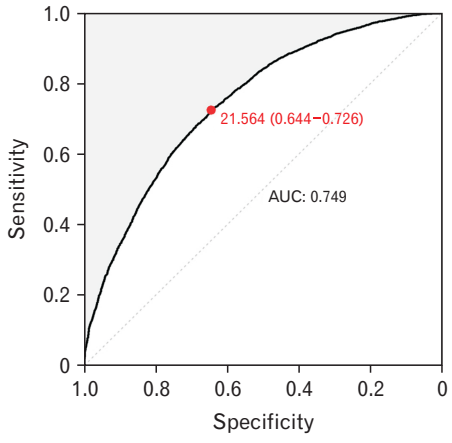

Figure 3. Receiver operating characteristic curve. The area under the curve (AUC) was 0.749 (standard error, 0.005; 95% confidence interval, 0.740–0.758), and the cut-off value was 21.564.

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ty, DM, obstructive sleep apnea, and cerebrovascular disease [20-24]. It also has the potential to predict MetS and its components better than traditional anthropometric indices such as BMI, WC, and WC to NHtR and is associated with NAFLD [25]. The NHtR similarly measures upper body fat while accounting for height differences, providing an advantage over NC [25-27]. Previous studies have shown that NHtR predicts metabolic abnormalities and disease risk more effectively than NC or other measurements [19,28]. However, its association with NAFLD or MASLD in the Korean population has not yet been established.

Our study found that the NHtR provides higher predictive accuracy for MASLD than that of NC, NC/BMI, and NC/weight. This superior accuracy is likely due to the ability of the NHtR to adjust for height, enabling a more independent assessment of upper body fat distribution and minimizing the confounding effects of overall body size [9,27]. Therefore, a higher NHtR reflects relatively greater upper body fat, offering a more precise evaluation of adiposity and its association with MASLD. However, the exact mechanism underlying this superior predictive ability remains unclear and requires further investigation.

In this study, we established a cut-off value for NHtR in predicting MASLD, which closely aligns with those reported in previous studies linking NHtR to NAFLD and other metabolic diseases. In a study targeting a Chinese population, the NHtR cut-off values for predicting NAFLD were 22.4 for males and 20.8 for females, which are relatively consistent with the cut-off value for predicting MASLD derived in our study (21.564) [25]. In addition, a study targeting an Indian population also found that NHtR was the optimal predictor for diagnosing liver stiffness measure, NAFLD, and MetS, and the cut-off values for diagnosing significant liver stiffness were reported to be 21.62 for males and 21.54 for females [9]. Thus, the fact that NHtR showed similar cut-off values for predicting liver and metabolic diseases in various populations contributes to confirming the consistent predictive ability of NHtR and suggests that NHtR can be used as an important predictive indicator in various populations.

Our study had several limitations. The short NC measurement period and restriction to adults aged 40 years or older in the KNHANES limited the scope of the data. The cross-sectional design prevented the establishment of a causal relationship between the NHtR and MASLD, and the findings may not be generalizable because of the specific racial focus. Another limitation is the lack of imaging or pathological tools for MASLD diagnosis, which may affect accuracy. While this study used noninvasive methods, such as NLFS, future studies should incorporate imaging or pathological tools to improve diagnostic precision and strengthen the findings. Additionally, the variability in body measurements and the unclear mechanism underlying the superiority of the NHtR over the NC require further investigation. Future research should include long-term longitudinal studies across diverse races and age groups to enhance the validity and reliability of the NHtR as an indicator.

The strength of this study lies in its identification of the NHtR as a simple, noninvasive, and convenient tool for assessing MASLD risk, which can be easily applied in primary care settings or for self-monitoring. By enabling quick assessments, the NHtR can facilitate the timely identification of individuals at risk, promote earlier intervention, and manage metabolic diseases more effectively. Additionally, the use of a large nationally representative sample from the Korean population enhances the generalizability of the findings, making them applicable to broader demographic groups. Robust statistical adjustments for various confounding factors, such as BMI, WC, physical activity, smoking status, and alcohol consumption, further strengthened the validity of the association between the NHtR and MASLD risk. Moreover, the focus of this study on the NHtR offers a novel approach by refining the predictive accuracy of traditional anthropometric measures, thereby providing a more reliable metric that accounts for individual height variations. Thus, the NHtR is a potentially valuable tool not only for clinical practice but also for public health strategies aimed at the early detection and prevention of MASLD.

In conclusion, this study identified a significant association between NHtR and MASLD in Koreans aged 40 years or older, demonstrating that NHtR is a more effective indicator for predicting MASLD than other measures. This finding supports its potential as a valuable screening tool in the clinical and self-care contexts. However, further research is required to fully understand and validate its application for broader use in MASLD risk assessment.

Article Information

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Data availability

Data of this research are available from the corresponding author upon reasonable request.

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Supplementary materials

Supplementary materials can be found via https://doi.org/10.4082/kjfm.24.0216. Supplement 1. Sex-specific logistic regression analysis of NHtR quartiles and MASLD risk. Supplement 2. Logistic regression analysis for MASLD vs. non-MASLD (excluding alcohol-related cases) across NHtR quartiles.

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