Correlations of Anthropometric and Calculation-Modified Anthropometric Measurements with Cardiometabolic Risk Factors in Korean Adults: A National Survey-Based Study

Kihong Hong (hkhtech@nate.com)
Seoul Veterans Hospital https://orcid.org/0000-0001-6054-1456

Research Article

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Abstract

Background and Aims: There are studies that show NC measurements are associated with central obesity and upper body fat distribution and are strongly associated with metabolic markers. Recently, studies have been conducted regarding neck circumference (NC) as a novel index to screen for obesity and cardiometabolic risk factors. Here, we investigated various anthropometric measurements and their correlations with cardiometabolic risk factors, pulmonary function test (PFT) results and metabolic syndrome among the adult Korean population.

Methods: This study was based on data acquired from the 8th edition (2019) of the Korea National Health and Nutrition Examination Survey (KNHANES), consisting of survey data on smoking and alcohol consumption, cardiometabolic risk factors, PFT results, metabolic syndrome profile and baseline characteristics such as age, gender and blood pressure. Continuous variables were analyzed by independent t-test, while categorical variables were analyzed using the Rao-Scott chi-square test Precision-recall (PR) plots were used to assess the diagnostic value of anthropometric measurements for cardiometabolic risk profiles such as insulin resistance, impaired glucose tolerance, dyslipidemia, hypertension, central obesity and PFT results. Area under the curve (AUC) was used to evaluate the predictive ability of the anthropometric measurements and calculation-modified anthropometric measurements (CMAMs) such as NC(neck circumference) devided by BMI(body mass index) and WC(waist circumference) and BMI devided by WC at different preset thresholds. Calculation was used to distinguish each anthropometric measurements aside from common features they may share.

Results: A total of 3525study subjects aged over 40 years were included in the study the mean age for male and female were 56.8 and 58.5 respectively, percentage of male and female was 42% and 58% respectively. PR plots of anthropometric measurements and the metabolic syndrome profile indicated that in the presence of 3 metabolic syndrome criteria, waist circumference (WC) and body mass index (BMI) had the highest AUCs 0.62 and 0.587 respectively, in the presence of 4 metabolic syndrome criteria, waist circumference (WC) and body mass index (BMI) had the highest AUCs 0.342 and 0.317 respectively whereas in the presence of more than 5 metabolic syndrome criteria, NC and WC had the highest AUCs 0.09 and 0.083 respectively.

Conclusion: This study showed that NC is correlated with metabolic syndrome. Additionally, each anthropometric measurement was uniquely correlated with specific cardiometabolic risk factor and differed according to sex. In such cases, applications in smartphones could be used to calculate for cardiometabolic risk assessments. Also it may be necessary to screen for metabolic syndrome in people whose NC is over 39.9cm for males and 34.5cm for females.

Introduction

In Korea, the prevalence of obesity, which is defined as a body mass index (BMI) over 25 kg/m^2, has steadily remained at 30% of the general population over the past 10 years. The rate of obesity was higher among males than among females in the general population (41.8% and 25.0%, respectively) as of 2019 and generally increases with age and declines after the age of 70[2]. These rates are especially concerning given that obesity causes a variety of health issues, including chronic diseases. The health effects of obesity are not confined to only diabetes, atherosclerosis, heart diseases, and hypertension but also include sleep apnea and obstructive pulmonary diseases, which affect quality of life[3]. Therefore the need for early screening for obesity before it starts to cause harmful conditions is important.

The most commonly used and standardized anthropometric measure is body mass index (BMI)[4]. However, some argue that BMI may not be a suitable measure for those with low height and that it does not represent body composition[5]. Other methods, such as dual energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA), are available to evaluate body composition[6]. These are known to accurately estimate body composition, but due to the large size and high cost of the equipment required, there methods have poor accessibility.

Thus, people are searching for easier-to-obtain measures that correlate with body composition and other metabolic risk factors, such as low-density lipoprotein (LDL), triglycerides (TGs) and hemoglobin A1c (HbA1c), for earlier cardiometabolic risk factors detection. Apart from BMI, anthropometric measurements such as waist circumference (WC), hip width, and neck circumference (NC) are also used to screen for obesity. The studies of anthropometric measurements show that each measurements has its unique correlation with specific cardiometabolic risk factors[7].

Studies have found that NC is correlated with visceral adipose tissue (VAT) measured by computed tomography (CT) and that it is associated with central obesity and upper body fat distribution[9]. Since upper body fat distribution is strongly associated with metabolic markers, such as dyslipidemia, diabetes and glucose intolerance, studies of NC show that it also correlates well with cardiovascular diseases (CVDs) and cerebrovascular accidents (CVAs)[10]. Also studies of body fat distribution and serum free fatty acids demonstrated that free fatty acids are derived more from upper body subcutaneous fat than from visceral fat[11], we postulate that NC could also be used to assess cardiovascular disease risk factors, as has been postulated in previous studies.

In Korea, BMI and WC is well studies but NC is not as well studied as it is in other countries. Since ethnicity affects various health aspects, studies of NC from other ethnic groups cannot be implicated in Koreans with assurance. Therefore, the aim of this study was to analyze the correlations between NC (as well as other measurements) and health-related measurements and laboratory results and then also analyze the prevalence of a variety of diseases and metabolic syndrome and to compare the effectiveness of NC as compared to BMI and WC in order to assess whether NC is a usefull tool for screening obesity and cardiometabolic risk assessments. This study also explored the anthropometric measurements and calculation-modified anthropometric measurements (CMAMs) that correlated best with cardiometabolic profile such as LDL, TG, HbA1c and blood pressure as well as PFT.

Methods

This study was based on data acquired from the 8th edition (2019) of the Korea National Health and Nutrition Examination Survey (KNHANES). The collected data consisted of survey data on smoking and alcohol consumption; pulmonary function test (PFT) results; prevalence of various diseases including certain types of cancer; anthropometric measurements such as BMI, NC, WC and CMAM; and blood test results. CMAM was calculated by deviding NC with BMI(NC/BMI), NC with WC(NC/WC) and WC with BMI(WC/BMI). The data were further stratified by smoking and alcohol consumption habits.

BMI has been grouped into six as been proposed by Korean Society For The Study Of Obesity. BMI less than 18.5 kg/m² was considered underweight, BMI from 18.5 kg/m² to 22.9 kg/m² was considered normal, BMI from 23 kg/m² to 24.9 kg/m² was considered preobese, BMI from 25 kg/m² to 29.9 kg/m² was considered obese class 1, BMI from 30 kg/m² to 34.9 kg/m² was considered obese class 2 and BMI over 35 kg/m² was considered obese class 3[12].

For determining the Precision of Anthropometric Measurements and CMAMs with laboratory measurements and PFT, Precision-recall Plot was done. The dependent variables were analyzed in two ways, y1 and y2, where y1 stands for the >90th percentile value, and y2 stands for higher than the upper-normal value or lower than the lower-normal value. The exact value of y1 and y2 for each variables are shown in the statistical analysis section.

For determining the precision of anthropometric measurements and CMAMs with metabolic syndrome criteria, precision-recall plot was done. The study was performed by analyzing the AUC of each anthropometric measurement for more than 3 metabolic syndrome criteria, more than 4 metabolic syndrome criteria and 5 metabolic syndrome criteria.

Linear trend p value was done to find association between categorical variables; number of metabolic syndrome criteria and continuous variables; anthropometric measurements and CMAMs.

The study protocol was approved by the Institutional Review Board of the Veterans Hospital Seoul (IRB File No. BOHUN 2021-03-007-002) and was performed in compliance with Declaration of Helsinki ethical standards[13].

Study Population

2019 KNHANES consisted of data collected from 1st of January 2019 to 31th of December 2019. Subjects with anthropometric measurements(NC, WC, BMI) were included in the study. Subjects with age over 40 were included in the study. Subjects without blood tests or PFTs were excluded from the data. Subjects with inadequate data on alcohol consumption and smoking were excluded from the study.

Laboratory Measurements

KNHANES data consists of health questionnaire survey, nutrition examination survey and health check up survey. Individuals consent to participate in KNHANES has been obtained in detail throughout all aspects of KNHANES. Health check up survey consists of body measurements, blood pressure measurements, blood tests, urine tests, dental examination, PFT, eye examination, otolaryngology examination and hand grip strength. Blood was drawn at 8 hours fasting state. Serum total cholesterol, high-density lipoprotein (HDL), TGs, LDL, blood urea nitrogen (BUN) and uric acid were tested using a Labospect 008AS (Hitachi/Japan). Serum HbA1c was tested using a Tosoh G8 (Tosoh/Japan). Serum creatinine was tested using a Cobas (Roche/Germany). Serum white blood cell (WBC) count, hemoglobin, and hematocrit were tested using an XN-9000 (Sysmex/Japan). Pulmonary function tests were assessed using standard protocols. Participants were guided to breathe in with maximal effort to reach maximal inspiration status, to forcefully breath out and to continuously breath out for 6 seconds. FEV1 was obtained through calculating forced expiratory volume in one second, FVC was obtained through calculating the total amount of air expirated from maximal inspiration to maximal expiration FEF25-75 was obtained through calculating the middle 50% of expiration flow; by excluding the first 25% and last 25% expiration flow.

Anthropometric Measurements(Nc, Bmi, Wc) And Cmams(Nc/bmi, Nc/wc, Wc/bmi)

CMAM was calculated by deviding NC with BMI(NC/BMI), NC with WC(NC/WC) and WC with BMI(WC/BMI).

Metabolic Syndrome Criteria

Diagnostic criteria for metabolic syndrome from American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement has been used. Any 3 of 5 criteria constitute diagnosis of metabolic syndrome[14].

1. Elevated wasist circumference: ≥102 cm (≥40 inches) in men and ≥88 cm (≥35 inches) in women

2. Elevated TG: ≥150 mg/dL (1.7 mmol/L) or Drug treatment for elevated TG
3. Reduced HDL-C: <40 mg/dL (1.03 mmol/L) in men and <50 mg/dL (1.3 mmol/L) in women or Drug treatment for reduced HDL-C
4. Elevated BP: ≥130 mm Hg systolic BP or ≥85 mm Hg diastolic BP or Drug treatment for hypertension
5. Elevated fasting glucose: ≥100 mg/dL or Drug treatment for elevated glucose

Statistical Analysis

Statistical analysis was performed using R software version 3.6.3 (R Foundation, Vienna, Austria). All analyses were performed with the sample weights from the KNHANES data in Phase VIII (2019). Data are presented as the means with standard errors (SEs) for continuous variables and as percentages with SEs for categorical variables. Continuous variables were analyzed by independent t-test, while categorical variables were analyzed using the Rao-Scott chi-square test.. All statistical tests were two-sided, and P-values <0.05 were considered to indicate statistical significance.

Assessment of the diagnostic value of anthropometric measurements and CMAMs for cardiometabolic risk profiles, laboratory results and PFTs was performed through precision-recall (PR) plots using the R package precrec (Saito and Rehmsmeier 2017). The measurements used in PR plots are NC, BMI, WC, NC/WC and NC/BMI. The thresholds applied were either a >90th percentile value (y1) or upper-normal or lower-normal value (y2) or both, depending on the variable For BMI y1; 90% and over or y2; 30 kg/m² and over, for WC y1; 90% and over or y2; Male: 90cm and over, Female: 80cm and over, for cholesterol y1; 90% and over or y2' 200mg/dL and over, for HDL y1; 10% and under or y2; Male: under 40mg/dL Female: under 50mg/dL, for TG y1; 90% and over or y2; 150mg/dL and over, for LDL y1; 90% and over or y2; 130mg/dL and over, for glucose y1; 90% and over or y2; 100mg/dL and over, for HbA1c y1; 90% and over or y2; 6.5 and over, for insulin y1; 90% and over or y2; 15uIU/mL and over, for BUN y1; 90% and over or y2; 23mg/dL and over, for Creatinine y1; 90% and over or y2; 1.2mg/dL and over, for AST y1; 90% and over or y2; 40U/L and over, for ALT y1; 90% and over or y2; 41U/L and over, for Hb y1; 90% and over or y2; Male: 17g/dL and over Female: 16g/dL and over, for Hct y1; 90% and over or y2; Male: 50% and over Female: 47% and over, for uric acid y1; 90% and over or y2; 7mg/dL and over.

For PFT, subjects were separated into 6 groups using age, FEV1/FVC, FVC and FEV1. PFT group 1 consisted of 40~60 years & FEV1/FVC>70 & FVC pred %<80 while the control group for group 1 consisted of 40~60years & FEV1/FVC>70 & FVC pred %>80 which is considered to be in normal range. PFT group 2 consisted of 60 years and over & FEV1/FVC>60 & FVC pred %<80 while the control group for group 2 consisted of 60 years and over & FEV1/FVC>60 & FVC pred %>80 which is considered to be in normal range. PFT group 3 consisted of 40~60years & FEV1/FVC<70 & FVC pred %<80 while the control group for group 3 consisted of 40~60years & FEV1/FVC<70 & FVC pred %>80 & FEV1>100 which is considered to be in normal range. PFT group 4 consisted of 60 years and over & FEV1/FVC<60 & FVC pred %<80 while the control group for group 4 consisted of 60 years and over & FEV1/FVC<60 & FVC pred %<80 & FEV1>100 which is considered to be in normal range. PFT group 5 consisted of 40~60 years & FEV1/FVC<70 & FVC pred %>80 & FEV1<100 while the control group for group 5 consisted of 40~60years & FEV1/FVC<70 & FVC pred %>80 & FEV1>100. PFT group 6 consisted of 60 years and over & FEV1/FVC<60 & FVC pred %>80 & FEV1<100 while the control group for group 6 consisted of 60 years and over & FEV1/FVC<60 & FVC pred %>80 & FEV1>100.

Results

1. General Characteristics of the Study Subjects

A total of 3525 study subjects were selected out of 8110 subjects. A total of 3525 subjects were included in the study; 1480 were males, 2045 were females, and all individuals were over the age of 40. In the 2019 KNHANES, NC was measured among people aged over 40 years. A total of 3302 subjects who were under the age of 40 years were excluded from the study. A total of 249 subjects who did not have NC measurement data were excluded from the study. Seventy subjects who did not have data on alcohol consumption and smoking were excluded from the study. A total of 196 subjects who did not submit medical diagnosis records were excluded from the study. A total of 615 subjects without PFT results were excluded from the study. A total of 153 subjects without laboratory results were excluded from the study. The patient flow chart is shown in Figure 1.

The prevalence of obesity was more common in females than males 2.9% and 1.4% respectively The prevalence of normal weight was more common in females than males 42.8% and 27.8% respectively.. Preobese was more common in males than females 28.8% and 23.4% respectively. The prevalence of obese class 1 was more common in males than females 37.0% and 25.8% respectively. The prevalence of obese class 2 was more common in females than males 4.5% and 4.2% recpectively.. The prevalence of obese class 3 was more common in males than females 0.8% and 0.6%, respectively. Obesity class was define by the Korean Society for the Study of Obesity 2018 guideline[12].

The PFT results differed by sex. The rates of normal PFT results were more common in females than males 72.1% and 57.8% respectively.. restrictive lung disease were more common in males than females 15.9% and 8.0%, respectively. obstructive lung disease were more common in males than females 14.9% and 5.4%, respectively. Forced expiratory flow at 25-75% (FEF25-75) was higher in males than females 2.7 L/sec and 2.3 L/sec, respectively.

Total cholesterol was higher in females than males 199.4mg/dL and 194.6mg/dL respectively.. HDL cholesterol level was higher in females than males 55.8mg/dL and 48.2mg/dL respectively.. LDL cholesterol level was higher in females than males 120.5mg/dL and 115.7mg/dL respectively.. TG level was higher in males than females 166.4 mg/dL and 119.1 mg/dL, respectively. Fasting glucose level was higherin males than females 165.8 mg/dL and 117.5 mg/dL, respectively. HbA1c level was higher in males than females 5.9 mmol/mol and 5.8 mmol/mol, respectively. Fasting serum insulin level was higher in males than females 8.7 mIU/L and 8.2 mIU/L, respectively.

Serum BUN level was higher in males than females 16.5 mg/dL and 15.5 mg/dL, respectively. Serum creatinine level was higher in males than 0.9 mg/dL and 0.7 mg/dL, respectively. Serum aspartate transaminase (AST) level was higher in males than females 27.0 U/ml and 23.7 U/ml, respectively. Serum alanine transaminase (ALT) level was higher in males than females 27.8 U/ml and 20.0 U/ml, respectively. The hemoglobin level was higher in males than females 15.2 g/dL and 13.2 g/dL, respectively. The hematocrit percentages was higher in males than females 45.2% and 40.0%, respectively. The uric acid level was higher in males than females 5.9 mg/dL and 4.5 mg/dL, respectively.

2. Correlations of Anthropometric Measurements and CMAMs with Laboratory Data in All Study Subjects (Males and Females)

2.1.1 Correlations between NC and Laboratory Data in All Study Subjects (Males and Females)

To find if NC had a positive correlation with cardiometabolic risk factors and PFT, NC and its correlation with various laboratory results and measurements were analyzed. NC had positive correlations with BMI, WC, total cholesterol, TGs, LDL, fasting glucose, HbA1c, serum insulin, BUN, creatinine, AST, ALT, hemoglobin, hematocrit, uric acid, FVC, FEV1, FEV1/FVC and FEF25_75. The highest beta coefficient was observed for TGs at 10.62, followed by WC at 3.23. NC had a negative correlation with HDL, with a beta coefficient of -1.28. The above results all had p-values <0.05 (Table 2). he observed findings suggest that NC had a positive correlation with cardiometabolic risk factors and also had a positive correlation with normal PFT function.

2.1.2 Correlations of NC/BMI with Laboratory Data in All Study Subjects (Males and Females)

Next, to find if combination of NC and BMI had a positive correlation with cardiometabolic risk factors and PFT, NC devided by BMI and its correlation with various laboratory results and measurements were analyzed.. NC/BMI was positively correlated with HDL, FVC and FEV1, with HDL showing the highest beta coefficient (17.71). NC/BMI was negatively correlated with BMI, WC, total cholesterol, TGs, LDL, fasting glucose, HbA1c, serum insulin, BUN, creatinine, AST, ALT, hemoglobin, hematocrit, uric acid, FEV1/FVC and FEF25-75. The lowest beta coefficient was observed for TGs at -118.66, followed by WC at -50.45 (Table 2).

2.1.3 Correlations of NC/WC with Laboratory Data in All Study Subjects (Males and Females)

Next to find if combination of NC and WC had a positive correlation with cardiometabolic risk factors and PFT, NC devided by WC and its correlation with various laboratory results and measurements were analyzed. NC/WC was positively correlated with HDL and FVC, with beta coefficients of 82.65 and 0.88, respectively. NC/WC was negatively correlated with BMI, WC, TGs, fasting glucose, HbA1c, serum insulin, AST, ALT, hemoglobin, hematocrit, uric acid, FEV1/FVC and FEF25_75. The lowest beta coefficient was observed for TGs (-577.75), followed by WC (-252.16), fasting glucose (-117.88), ALT (-116.65), BMI (-73.77), AST (-44.14), hematocrit (-13.09) and uric acid (-6.10) (Table 2).

2.2 Correlations of Anthropometric Measurements(NC, BMI, WC) and CMAMs(NC/BMI, NC/WC) with Laboratory Data in Male Subjects

2.2.1 Correlations of NC and Laboratory Data in Male Subjects

NC and its correlations with various laboratory results and measurements were further analyzed among male subjects. NC was positively correlated with BMI, WC, total cholesterol, TGs, fasting glucose, HbA1c, serum insulin, BUN, creatinine, AST, ALT, hemoglobin, hematocrit, uric acid, FVC, FEV1, FEV1/FVC and

FEF25_75. The highest beta coefficient was observed for TGs (9.77), followed by WC (2.95) and ALT (2.55). There was negative correlation between NC and HDL, with a beta coefficient of -0.94 (Table 3). NC had a positive correlation with cardiometabolic risk factors in males.

2.2.2 Correlations of NC/BMI with Laboratory Data in Male Subjects

Regarding NC/BMI and its correlations with various laboratory results and measurements among male subjects, NC/BMI was positively correlated with HDL, FVC and FEV1, with the highest beta coefficient being observed for HDL at 15.15. NC/BMI was negatively correlated with BMI, WC, TGs, fasting glucose, HbA1c, serum insulin, creatinine, AST, ALT, hemoglobin, hematocrit, uric acid, FEV1/FVC and FEF25_75. The lowest beta coefficient was observed for TGs (-122.50), followed by WC (-49.70), ALT (-33.78), BMI (-20.95), fasting glucose (-19.66) and AST (-10.78) (Table 3).NC/BMI had a negative correlation with cardiometabolic risk factors in males.

2.2.3 Correlations of NC/ WC with Laboratory Data in Male Subjects

Then, NC/WC and its correlations with various laboratory results and measurements among male subjects were analyzed. NC/WC was positively correlated with HDL, FVC, and FEV1, and the highest beta coefficient was for HDL at 68.15. NC/WC was negatively correlated with WC, TGs, fasting glucose, HbA1c, serum insulin, AST, ALT, hemoglobin, hematocrit, uric acid and FEF25_75. The lowest coefficient was observed for TG at -658.32, followed by WC (-249.09), ALT (-153.46), fasting glucose (-103.41), serum insulin (-88.75), AST (-60.97) and hematocrit (-11.79) (Table 3). NC/WC had a negative correlation with cardiometabolic risk factors in males.

The observed findings suggested that NC had a positive correlation with cardiometabolic risk factors whereas NC/BMI and NC/WC had a negative correlation with cardiometabolic risk factors.

2.3 Correlations of Anthropometric Measurements(NC, BMI, WC) and CMAMs(NC/BMI, NC/WC) with Laboratory Data in female Subjects

2.3.1 Correlations of NC with Laboratory Data in Female Subjects

NC and its correlations with various laboratory results and measurements among female subjects were analyzed. NC alone had positive correlations with BMI, WC, TGs, fasting glucose, HbA1c, serum insulin, creatinine, AST, ALT, hemoglobin, hematocrit, uric acid and FEF25_75 among female subjects. The highest beta coefficient was observed for TG (10.68), followed by WC (3.54) and fasting glucose (3.07). There was negative correlation between NC and HDL, with a beta coefficient of -1.67 (Table 4. NC had positive correlation with cardiometabolic risk factors in females.

2.3.2 Correlations of NC/BMI with Laboratory Data in Female Subjects

NC/BMI and its correlations with various laboratory results and measurements among female subjects were also analyzed. NC/BMI had positive correlations with HDL and FVC (highest beta coefficient was observed for HDL at 18.94) and negative correlations with BMI, WC, TGs, fasting glucose, HbA1c, serum insulin, AST, ALT, hemoglobin, hematocrit, uric acid, FEV1/FVC and FEF 25_75. The lowest beta coefficients were observed for TGs (-100.92), WC (-50.43), BMI (-22.18), ALT (-21.09) and serum insulin (-15.65). NC/BMI had negative correlation with cardiometabolic risk factors in females.

2.3.3 Correlations of NC/WC with Laboratory Data in Female Subjects

NC/WC and its correlations with various laboratory results and measurements among female subjects were analyzed. NC/WC was positively correlated with HDL, with a beta coefficient of 90.83, and negatively correlated with BMI, WC, TGs, fasting glucose, HbA1c, serum insulin, AST, ALT, hemoglobin, hematocrit and uric acid. The lowest beta coefficient was observed for TG (-456.27), followed by WC (-251.61), fasting glucose (-128.92), BMI (-77.66), ALT (-77.17), serum insulin (-63.97) and AST (-26.72). NC/WC had negative correlation with cardiometabolic risk factors in females.

The observed correlations of NC, NC/BMI and NC/WC with various laboratory results and measurements showed that the beta coefficients were not the same across the three variables but were unique for certain laboratory results and measurements.

3. Determining the Precision of Anthropometric Measurements and CMAMs with Precision-recall Plots

Since correlation studies do not indicate precision, precision-recall plot analysis was performed.

3.1.1. Precision Among All Study Subjects (Both Males and Females)

Precision-recall plots and areas under the curve (AUCs) were used to evaluate the precision of the anthropometric measurements and CMAMs at each present threshold. These data can be seen in Figure 2. When the BMI thresholds were applied, WC had the highest AUCs (0.73 and 0.729), followed by NC/BMI (0.603 and 0.591). In contrast, when WC thresholds were used, BMI had the highest AUCs (0.779 and 0.907), followed by NC/WC (0.534 and 0.905). These results show that BMI 30 kg/m^2 and over was best predicted with WC whereas WC for male 90cm and over for female 80cm and over was best predicted with BMI.

WC/BMI had the highest AUCs (0.121 and 0.514), followed by NC/BMI (0.119 and 0.478) when total cholesterol thresholds were applied, but NC/WC had the highest AUCs (0.159 and 0.418) when HDL thresholds were used, while NC/BMI (0.113) and WC/BMI (0.396) had the highest AUCs depending on if LDL_y1 (>90th) or LDL_y2 (>130) was applied. Thus, Total cholesterol 200mg/dL and over was best predicted with WC/BMI where as HDL for male under 40mg/dL and for female under 50mg/dL was best predicted with NC/WC. LDL was best predicted with NC/BMI and WC/BMI. LDL of 90% and over was best predicted with NC/BMI whereas LDL 130mg/dL and over was best predicted with WC/BMI.

Regardless of the TG threshold, NC had the highest AUCs (0.194 and 0.46), while WC had the highest AUCs (0.209 and 0.615) for both glucose thresholds. Similarly, WC also had the highest AUCs (0.236 and 0.259) for both HbA1c thresholds, while BMI had the highest AUCs (0.359 and 0.359) for both insulin thresholds.

WC/BMI had the highest AUCs (0.141 and 0.108) for both BUN thresholds. However, NC/BMI had the highest AUC (0.154) for crea_y1 (creatinine >90th), but NC had the highest AUC (0.061) for crea_y2 (>1.2), showing that kidney dysfunction which is characterized by elevation of serum creatinine of more than 1.2mg/dL is best predicted with NC. Moreover, WC had the highest AUCs (0.187 and 0.143) for both AST thresholds and for both ALT thresholds (AUCs of 0.233 and 0.223) showing that liver dysfunction such as fatty liver can be best predicted with WC.

For hemoglobin levels, both the upper and lower ends of the distribution were analyzed. The highest AUCs were observed for BMI (0.133), NC (0.065), WC/BMI (0.161) and NC (0.166) for the hemoglobin thresholds (Hb >90th percentile, >17, <10th percentile, and < 13.5), respectively showing that excess red blood cell (polycythemia) was best predicted with BMI whereas anemia was best predicted with NC. Similarly, the highest AUCs were observed for BMI (0.139), NC (0. 094), WC/BMI (0. 0.145) and WC/BMI (0.151) for the Hct (Hematocrit) thresholds (>90th percentile, >50, <10th percentile and <41, respectively). For the uric acid threshold of >90th percentile, NC had the highest AUC (0.234), but the number of cases was too small for analysis for uacid_y2. Therefore, for elevation of uric acids such as in gout, NC had the highest predictive value.

Regarding PFT results, WC had the highest AUCs (0.319 and 0.487) for both PFT_y1 (aged between 40 and 60 years, FEV1/FVC>70 and FVC pred %<80 equivalent to restrictive pattern) and PFT_y2 (aged 60 years and over, FEV1/FVC>60 and FVC pred %<80 equivalent to restrictive pattern). However, BMI had the highest AUC of 0.35 for PFT_y3 (aged between 40 and 60 years, FEV1/FVC<70 and FVC pred %<80 equivalent to combined restrictive pattern), while NC/WC had the highest AUC of 0.445 for PFT_y4 (aged 60 years and over, FEV1/FVC<60 and FVC pred %<80 equivalent to combined restrictive pattern). For PFT_y5 (aged between 40 and 60 years, FEV1/FVC<70, FVC pred %>80 and FEV1<100 equivalent to obstructive pattern) and PFT_y6 (aged 60 years and over, FEV1/FVC<60, FVC pred %>80 and FEV1<100 equivalent to obstructive pattern), the number of cases was too small to be analyzed. These results indicate thatthat people age over 40 with restrictive lung disease was best predicted with WC, whereas people ages between 40 to 60 with combined restrictive disease was best predicted with BMI and for people age over 60 with combined restrictive disease was best predicted with NC/WC. Since NC/WC is negatively correlated with FEV1/FVC and FEF25_75 as been found in this study, elderlies(people age over 60) with high NC/WC ratio should get PFT screening in order to early detect lung disease.

In all subjects, total cholesterol was best predicted by WC/BMI, HDL was best predicted by NC/WC, TGs were best predicted by NC, LDL was best predicted by WC/BMI, fasting glucose was best predicted by WC, HbA1c was best predicted by WC, serum insulin was best predicted by BMI, BUN was best predicted by WC/BMI, creatinine was best predicted by NC, AST was best predicted by WC, ALT was best predicted by WC, Hb (upper range) and Hb (lower range) were both best predicted by NC, Hct (upper range) was best predicted by NC, and Hct (lower range) was best predicted by WC/BMI. For PFT, a restrictive pattern was best predicted by WC in age groups of 40 to 60 years and 60 years and older. The combined restrictive pattern was best predicted by BMI in patients aged 40 to 60 years old, whereas in patients aged 60 years and older, the combined restrictive pattern was best predicted by NC/WC. The numbers for obstructive patterns were too small to be analyzed.

3.1.2 Precision Among Male Subjects

A similar analysis was carried out in male subjects. These data can be seen in Figure 3. Total cholesterol was best predicted with NC (AUC of 0.113) for chol_y1(>90th) and with WC/BMI (AUC of 0.471)for chol_y2(total cholesterol>200). HDL_y1 (<10th) was best predicted with NC and WC (AUC of 0.132) whereas HDL_y2 (HDL<40) was best predicted with WC (AUC of 0.305). TG_y1 (>90th) and TG_y2(TG>150)was both best predicted with NC (AUC of 0.228 and 0.512 respectively). LDL_y1 (>90th) was best predicted with NC (AUC of 0.087) and LDL_y2 (>130) was best predicted with WC/BMI (AUC of 0.36. glucose_y1 (>90th) was best predicted with WC and NC (AUCs, both 0.233whereas glucose_y2 (>100) was best predicted with WC (AUC of 0.652), HbA1c_y1 (>90th) and HbA1c_y2(6.5 and over) was best predicted with WC (AUC of 0.257 and 0.278 respectively). insulin_y1 (>90th) and insulin_y2(15uIU/mL and over) was best predicted with BMI(AUC of 0.392 and 0.39 respectively). BUN_y1 (>90th) and BUN_y2(23mg/dL and over) was best predicted with WC/BMI (AUC of 0.159 and 0.126 respectively) crea_y1 (creatinine >90th) and crea_y2(Creatinine>1.2mg/dL) was best predicted with NC/WC(AUC of 0.231 and 0.086 respectively)., AST_y1 (>90th) and AST_y2(40mg/dL) was best predicted with WC (AUC of 0.224 and 0.161 respectively), ALT_y1 (>90th) and ALT_y2(>41mg/dL) BMI had the highest predictive value, AUC of 0.294 and 0.287 respectively.

For hemoglobin levels, both the upper and lower ends of the distribution were analyzed. Hb_y1 (Hemoglobin>90th) was best predicted with NC(AUC of 0.138), whereas Hb_y2 (Hemoglobin>17g/dL) was best predicted with BMI (AUC of 0.073)Hb_y3 (Hemoglobin<10th) was best predicted with NC and WC/BMI(both AUC of 0.202) whereas Hb_y4 (Hemoglobin<13.5g/dL) was best predicted with NC (AUC of 0.175). Hct_y1 (Hematocrit >90th) was best predicted with BMI and WC (AUC of 0.133) Hct_y2 (Hematocrit >50%) was best predicted with WC (AUC of 0.111 Hct_y3 (Hematocrit<10th) and Hct_y4 (Hematocrit<41) was best predicted withNC (AUC of 0.2 and 0.209 respectively). uacid_y1 (Uric acid >90th) was best predicted with WC and BMI (both AUC 0.267), for uacid_y2, the number of cases was too small for analysis.

For PFT_y1 (aged between 40 and 60 years, FEV1/FVC>70 and FVC pred %<80 equivalent to restrictive pattern) and PFT_y2 (aged 60 years and over, FEV1/FVC>60 and FVC pred %<80 equivalent to restrictive pattern) was best predicted with WC(AUC of 0.351 and 0.6 respectively) PFT_y3 (aged between 40 and 60 years, FEV1/FVC<70 and FVC pred %<80 equivalent to combined restrictive pattern) was best predicted with (AUC of 0.348), PFT_y4 (aged 60 years and over, FEV1/FVC<60 and FVC pred %<80 equivalent to combined restrictive pattern) was best predicted with NC/BMI PFT_y5 (aged between 40 and 60 years, FEV1/FVC<70, FVC pred %>80 and FEV1<100 equivalent to obstructive pattern) and PFT_y6 (aged 60 years and over, FEV1/FVC<60, FVC pred %>80 and FEV1<100 equivalent to obstructive pattern), the number of cases was too small to be analyzed.

In male subjects, the predictions were the same as in the total number of subjects except for HDL, creatinine, ALT, Hb (upper range), Hct (lower range) and combined restrictive pattern in individuals aged 60 years and over. HDL was best predicted by WC. Creatinine was best predicted by NC/WC. ALT was best predicted by WC, and Hb (hemoglobin>17) was best predicted by BMI. Hct (<41) was best predicted by NC. The combined restrictive PFT pattern in individuals aged 60 years and over was best predicted by NC/BMI.

3.1.3 Precision Among Female Subjects

Finally, the same PR plots and AUCs were analyzed in female subjects. These data can be seen in Figure 4. chol_y1 (>90th) was best predicted with NC (AUC of 0.137) whereas chol_y2 (total cholesterol>200) was best predicted with WC/BMI (AUC of 0.535) HDL_y1 (<10th) was best predicted with NC (AUC of 0.197) whereas HDL_y2(HDL<50mg/dL) was best predicted with WC (AUC of 0.487) TG_y1 (>90th) and TG_y2(TG>150mg/dL) was best predicted with NC (AUC of 0.228 and 0.369 respectively) LDL_y1 (>90th) was best predicted with NC (AUC of 0.126) whereas LDL_y2 (>130mg/dL) was best predicted with WC/(AUC of 0.413) glucose_y1 (>90th) and glucose_y2(>100mg/dL) was best predicted with WC (AUC of 0.176 and 0.566 respectively) HbA1c_y1 (>90th) and HbA1c_y2(>6.5) was best predicted with WC (AUC of 0.216 and 0.202 respectively) insulin_y1 (>90th) and insulin_y2(15uIU/mL) was best predicted with WC (AUC of 0.345 and 0.347 respectively) BUN_y1 (>90th) and BUN_y2(23mg/dL) was best predicted with NC/WC (AUC of 0.136 and 0.106 respectively). crea_y1 (creatinine >90th) was best predicted with NC/WC and WC (both AUC of 0.028) whereas crea_y2 (>1.2) was best predicted with WC/BMI (AUC of 0.018 AST_y1 (>90th) was best predicted with NC and BMI (both AUCof 0.138) whereas AST_y2 (>40mg/dL) was best predicted with BMI (AUC of 0.128) ALT_y1 (>90th) and ALT_y2(41mg/dL) was best predicted with BMI (AUC of 0.173 and 0.162 respectively).

For hemoglobin levels, both the upper and lower ends of the distribution were analyzed. Hb_y1 (Hemoglobin>90th) was best predicted with NC (AUC of 0.149whereas Hb_y2 (Hemoglobin>16g/dL) was best predicted with BMI (AUC of 0.01) Hb_y3 (Hemoglobin<10th) was best predicted with (AUC of 0.129) whereas Hb_y4 (Hemoglobin<12g/dL) was best predicted with WC (AUC of 0.169) Hct_y1 (Hematocrit >90th) and Hct_y2(Hematocrit >47%) was best predicted with NC (AUC of 0.165 and 0.02 respectively). Hct_y3 (Hematocrit<10th) and Hct_y4(Hematocrit< 36g/dL) was best predicted with WC (both AUC of 0.124) uacid_y1 (Uric acid >90th) was best predicted with BMI (AUC of 0.04For uacid_y2, the number of cases was too small for analysis.

PFT_y1 (aged between 40 and 60 years, FEV1/FVC>70 and FVC pred %<80 equivalent to restrictive pattern) and PFT_y2 (aged 60 years and over, FEV1/FVC>60 and FVC pred %<80 equivalent to restrictive pattern) was best predicted with WC (AUC of 0.292 and 0.371 respectively) PFT_y3 (aged between 40~60, FEV1/FVC<70 and FVC pred %<80 equivalent to combined restrictive pattern) was best predicted with WC (AUC of 0.374 PFT_y4 (aged 60 years and over, FEV1/FVC<60 and FVC pred %<80 equivalent to combined restrictive pattern) was best predicted with WC and NC/WC (both AUC of 0.818For PFT_y5 (aged between 40 and 60 years, FEV1/FVC<70, FVC pred %>80 and FEV1<100 equivalent to obstructive pattern) and PFT_y6 (aged 60 years and over, FEV1/FVC<60, FVC pred %>80 and FEV1<100 equivalent to obstructive pattern), the number of cases was too small to be analyzed.

In female subjects, the predictions were the same as in the total number of subjects except for HDL, serum insulin, BUN, creatinine, AST, ALT, Hb (upper range), Hb (lower range), Hct (lower range) and combined restrictive pattern in individuals aged 40 to 60 years old. HDL was best predicted by WC. Serum insulin was best predicted by WC. BUN was best predicted by NC/WC, creatinine was best predicted by WC/BMI, AST was best predicted by BMI, ALT was best predicted by BMI, and Hb (Hemoglobin>16) was predicted by BMI. Hct (Hematocrit<36) was best predicted by WC. The combined restrictive pattern in individuals aged 40 to 60 years old was best predicted by WC.

Correlation Analysis of Anthropometric Measurements with the Number of Metabolic Syndrome Criteria Met

NC, BMI, WC, NC/WC, WC/BMI, NC/BMI were analyzed based on the number of metabolic syndrome criteria present. These data are shown in Table 6. Clear trends were shown with NC, BMI and WC.

Among all subjects, the mean NC in subjects with zero metabolic syndrome criteria was 33.4cm, and increased to 34.7cm for one criterion, 35.7cm for two criteria, 36.7cm for three criteria, 37.5cm for four criteria and 37.3cm for five criteria. Similarly, the mean BMI increased from 21.9 kg/m^2 to 23.1 kg/m^2, 24.5 kg/m^2, 25.7 kg/m^2, 27.1 kg/m^2, and 27.0 kg/m^2 for subjects with zero to five metabolic syndrome criteria, respectively. Similarly, the mean WC increased from 77.1cm to 81.7cm, 86.8cm, 90.5cm, 93.8cm and 95.3cm for subjects with zero to five metabolic syndrome criteria, respectively.

In male subjects, the mean NC in subjects with zero metabolic syndrome criteria was 36.6cm, and increased to 37.4cm for one criterion, 38.2cm for two criteria, 38.8cm for three criteria, 39.9cm for four criteria and 39.8cm for five criteria. Similiarly the mean BMI increased from 22.4 kg/m^2 to 23.6 kg/m^2, 24.6 kg/m^2, 25.6 kg/m^2, 27.2 kg/m^2 and 27.0 kg/m^2 for subjects with zero to five metabolic syndrome criteria, respectively. The mean WC increased from 81.4cm to 85.3cm, 89.3cm, 91.8cm, 96.1cm and 96.6cm for subjects with zero to five metabolic syndrome criteria, respectively.

Similarly, In female subjects, the mean NC increased from31.7cm, 32.4cm, 33.0cm, 33.9cm, 34.5cm and 34.8cm for subjects with zero to five metabolic syndrome criteria, respectively. The mean BMI increased from 21.6 kg/m^2 to 22.7 kg/m^2, 24.3 kg/m^2, 25.9 kg/m^2, 26.8 kg/m^2 and 27.0 kg/m^2 for subjects with zero to five metabolic syndrome criteria, respectively. The mean WC increased from 74.9cm to 79.0cm, 84.0cm, 88.5cm, 91.4cm and 92.9cm for subjects with zero to five metablic syndrome criteria, respectively.

A positive linear pattern was found between NC/BMI, NC/WC, BMI, WC and the number of metabolic syndrome criteria present. Linear trend p value between NC/BMI, NC/WC, BMI, WC and the number of metabolic syndrome criteria was statistically significant before adjusted, adjusted for alcohol and smoking and adjusted for alcohol, smoking, age and gender(in total subjects). For further analysis of the precision of anthropometric measurements in predicting the number of metabolic syndrome criteria present. precision-recall plot analysis was performed.

Precision-recall plot of anthropometric measurements and CMAMs with metabolic syndrome criteria

Precision-recall plots showing the precision of anthropometric measurements and CMAMs for metabolic syndrome criteria were generated. These data are shown in Figure 5.

Among all study subjects, including both males and females, in the presence of more than 3, more than 4 and all 5 metabolic syndrome criteria, WC had the highest AUCs (0.62, 0.342 and 0.09), followed by BMI (0.587, 0.317 and 0.083), followed by NC (0.519, 0.263, 0.063), followed by NC/WC (0.49, 0.229, 0.064)

In male study subjects, in males, in the presence of more than 3, more than 4 and all metabolic syndrome criteria, WC had the highest AUCs (0.626, 0.354, 0.083), followed by BMI (0.601, 0.331, 0.076), followed by NC (0.599, 0.329, 0.083) (Figure 6).

In female study subjects, in females, in the presence of more than 3, more than 4 and all metabolic syndrome criteria, WC had the highest AUCs (0.628, 0.349, 0. 108) followed by BMI (0.575), NC(0.321, 0.093). (Figure 7).

There was a difference in the AUC of each anthropometric measurement evaluated according to the number of metabolic syndrome criteria present and gender The highest AUC observed in WC through all metabolic syndrome criteria is probably because NC is one of the factors in metabolic syndrome. In males, the second highest prediction value was BMI but AUCs of BMI did not show much difference with NC. But, when all metabolic syndrome criteria were met, NC had the highest prediction value.

Similarly, in female, the highest AUC was observed in WC. The second highest prediction value was observed with BMI and NC. The obove finding suggests that NC has more prediction value in females than in males with metabolic syndrome.

Discussion

The observed findings indicate that NC was closely related to HDL, TG, creatinine, Hb, combined restrictive disease and severe metabolic syndrome(more than 4 criteria) whereas WC was closely related to fasting glucose, HbA1c, total cholesterol, LDL, BUN, AST, ALT, Hct, restrictive lung disease and all metabolic syndrome(more than 3,4, and all criteria). WC/BMI was closely related to total cholesterol, LDL, BUN and Hct whereas NC/WC was closely related to HDL and combined restrictive lung disease.

The analyzed data showed that BMI, WC, NC/BMI and NC/WC all shared common characteristics in regard to correlations with cardiometabolic risk factors but did not necessarily share identical characteristics with each other.

Nc And Diabetes

Studies of NC and diabetes revealed an association between NC and homeostatic model assessment - insulin resistance (HOMA-IR)[15], and in this study, NC and serum insulin levels showed a positive correlation. Increased serum insulin levels or also known as hyperinsulinemia is caused by decreased efficiency of insulin signaling. Hyperinsulinemia increases the risk of obesity, type 2 diabetes and cardiovascular risk[16]. Therefore it may be possible that NC and its correlations with various cardiometabolic risk factors may primarily be linked with hyperinsulinemia.

The exact cause for NC and its positive correlation with serum insulin levels is not well understood but, genetic link between NC and hyperinsulinemia may be the missing puzzle as described in the NC and genetic predisposition section.

Findings in analyzed data may point to a correlation between NC and insulin resistance, but since direct measurement was not made, further studies are warranted to determine the association between NC and HOMA-IR in Koreans.

Nc And Fat Distribution

The analyzed data showed that BMI, WC, NC/BMI and NC/WC shared some common characteristics but did not necessarily share identical characteristics with each other. And this difference is known to make a difference in cardiometabolic risk assessment. Studies indicate that different fat distributions in the body (visceral fat, upper body fat, lower body fat) affect the cardiovascular system differently and independently[17,18]. Studies also indicate that there is a positive correlation between NC and upper body fat or visceral fat[19]. This study found that there were positive correlations between NC and serum TG and serum LDL levels and a negative correlation between NC and serum HDL, which is a risk factor for oxidative stress and vascular injury[20].

Nc And Genetic Predisposition

There are several genes that are involved in obesity. The most widely known obesity genes are the melanocortin 4 receptor (MC4R) gene and the fat mass and obesity-associated gene (FTO)[21]. Other obesity-related genes include adipocyte-, C1q, and collagen domain-containing (ADIPOQ); leptin (LEP); leptin receptor (LEPR); insulin-induced gene 2 (INSIG2); proprotein convertase subtilisin/kexin type 1 (PCSK1); peroxisome proliferator-activated receptor gamma (PPARG); Noggin (NOG) PDZ domain-containing ring finger 2 (PDZRN3); and Le (a-b-) (Lewis blood group) phenotypes[22,23].

Studies show that genetic variations in the FTO gene have positive associations with BMI and NC in men and that MC4R has positive associations with BMI and NC in women[24]. Another study showed that NC has a unique genetic basis independent of BMI. The NOG and PDZRN3 genes were found to have a positive association with NC and to affect NC at different developmental stages. Both the NOG and PDZRN3 genes were shown to influence the regulation of the extracellular matrix and patterning of fat deposits through interaction with transforming growth factor-beta (TGF-β)[25]. Other studies indicate that LEPR gene polymorphisms may be involved in the regulation of neck regional fat distribution in obstructive sleep apnea hypopnea syndrome (OSAHS) patients but are not involved in the pathogenesis of OSAHS[26].

Many studies have shown that the aforementioned obesity genes are associated with increased risks of metabolic syndrome and insulin resistance[27]. Since NC is also associated with metabolic syndrome and insulin resistance, we carefully hypothesized that NC, BMI, WC may be a phenotype reflecting an genetic information, as well as other body measurements such as hip width, height, weight, chest circumference, wrist circumference. And future studies are warranted for investigation of genetic link between above measurements thus making a guideline for selecting possible candidates for genetic tests.

Future studies of NC as a screening tool (for cardiometabolic risk factors)

WC is one of the 5 components of metabolic syndrome, but considering the effect of NC on HDL, TG and severe metabolic syndrome(more than 4 criteria) as been analyzed in the study, NC should be carefully assessed for its implementation in metabolic syndrome diagnostic criteria or caridometabolic risk assessment. This is especially true for people whose NC is over 39.9cm for males and 34.5cm for females which is the mean value of NC in more than 4 metabolic syndrome criteria as been analyzed in the study. Or it may be necessary to screen for metabolic syndrome or cardiometabolic risk factors in people whose NC is over 39.9cm for males and 34.5cm for females.

Implementation of NC has its benefits in that NC is not greatly affected by outside factors such as position and prandial status as well as respiration and also NC measurement is easily performed in bed-ridden patients and patients with abdominal distension, such as ascites[28] .Also there has been an increasing number of publications that state that NC measurement is an easier, more comfortable, less time consuming and less embarrassing method for diagnosing obesity than other anthropometric measurements (such as WC)[29]..

Conclusion

This study showed that NC is correlated with metabolic syndrome. This study also found that anthropometric measurements and CMAMs were correlated with cardiometabolic risk factors, but the correlations were not consistent among different genders and different age groups. Each anthropometric measurement and CMAMs exhibited unique distinguishing correlations with cardiometabolic risk factors, and the correlations were not consistent between the sexes.. Potential application of findings in this study may be to screen for metabolic syndrome or cardiometabolic risk factors in people whose NC is over 39.9cm for males and 34.5cm for females.

Strengths And Limitations

KNHANES is a representative sample of Korean subjects and is a continuous survey that has been implemented since 1998. Anthropometrical measurements, nutrition surveys and medical interviews were used together to assess correlations between variables. The strengths of this study include the large sample size, intricacy of statistics and assessment of modern health trends.

Nonetheless, some limitations need to be addressed. KNHANES is a large-scale study, but the analyzed data can show only correlations. Cause-and-effect relationships could not be determined from the aforementioned data.

The 8th edition (2019) of KNHANES contains NC data for people over the age of 40 years. Thus, no analyses of adolescents and people under the age of 40 years could be performed. Although other studies have depicted the association between NC and obesity in children[30], further studies are warranted to determine the association between NC and childhood obesity in Koreans.

Abbreviations

CMAM (Calculation-modified anthropometric measurements), WC (Waist circumference), BMI (Body mass index), NC (Neck circumference), PFT (Pulmonary function test), KNHANES (Korea National Health and Nutrition Examination Survey), PR (Precision-recall), AUC (Area under the curve), DXA (Dual energy X-ray absorptiometry), BIA (Bioelectrical impedance analysis), LDL (Low-density lipoprotein), HDL (High-density lipoprotein), TGs (Triglycerides), HbA1c (Hemoglobin A1c protein), BUN (Blood urea nitrogen), AST (Aspartate transaminase), ALT (Alanine transaminase), Hb (Hemoglobin), Hct (Hematocrit), VAT (Visceral adipose tissue), CVD (Cardiovascular diseases), CVA (Cerebrovascular accidents), FEV1 (Forced expiratory volume), FVC (Forced vital capacity), FEF25-75 (Forced expiratory flow at 25-75%), MI (Myocardial infarction), COPD (Chronic obstructive lung disease), MC4R (Melanocortin 4 receptor), FTO (Fat mass and obesity associated gene), ADIPOQ (Adipocyte-, C1q, and collagen domain-containing), LEP (Leptin), LEPR (Leptin receptor), INSIG2 (Insulin-induced gene 2), PCSK1 (Proprotein convertase subtilisin/kexin type 1), PPARG (Peroxisome proliferator-activated receptor gamma), NOG (Noggin) PDZRN3 (PDZ Domain-containing ring finger 2), Le (a-b-) (Lewis blood group), TGF-β (Transforming growth factor-beta), OSAHS (Obstructive sleep apnea hypopnea syndrome), HOMA-IR (Homeostatic model assessment - Insulin resistance)

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Veterans Hospital Seoul (IRB Number BOHUN 2021-03-007-002) and was conducted in compliance with the ethical principles for medical research involving human subjects (World Medical Association Declaration of Helsinki, 2013).

Consent for publication

The author of this manuscript approve this version to be submitted for publication.

Availability of data and materials

The 2019 8th edition of Korea National Health and Nutrition Examination Survey (KNHANES) can be accessed through https://knhanes.kdca.go.kr/knhanes/sub03/sub03_02_05.do

Competing Interests

The author declare that one has no competing interests.

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Author contribution

KHH: original idea, methods, writing, content expertise

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Tables

Due to technical limitations, Tables are only available as a download in the Supplemental Files section.

Figures

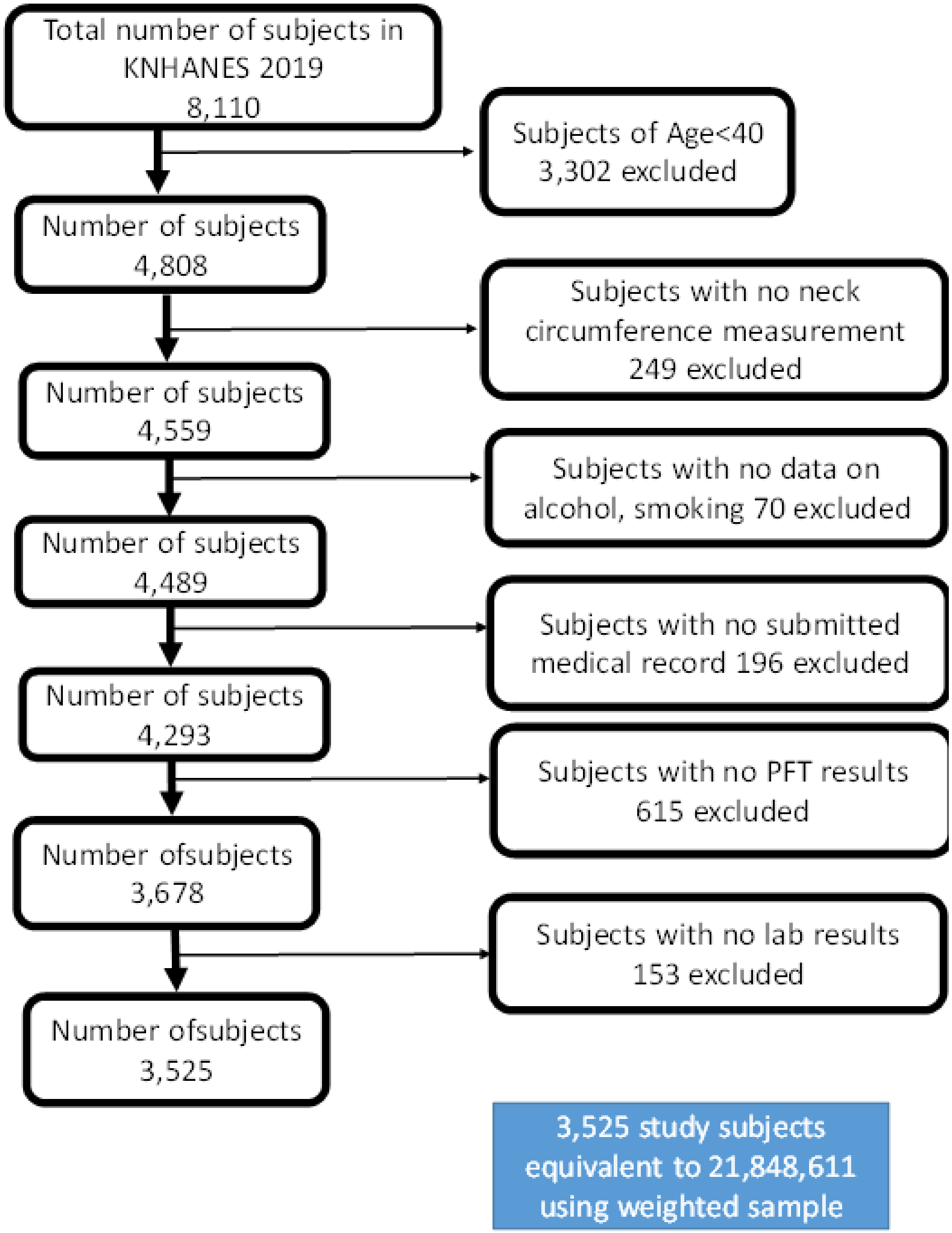

Figure 1

KNHANES: Korea National Health and Nutrition Examination Survey Study Subject Selection

Figure 2 is available in the Supplemental Files section

Figure 2

PR plot of all subjects

Figure 3 is available in the Supplemental Files section

Figure 3

PR plot for male subjects

Figure 4 is available in the Supplemental Files section

Figure 4

PR plot female subjects

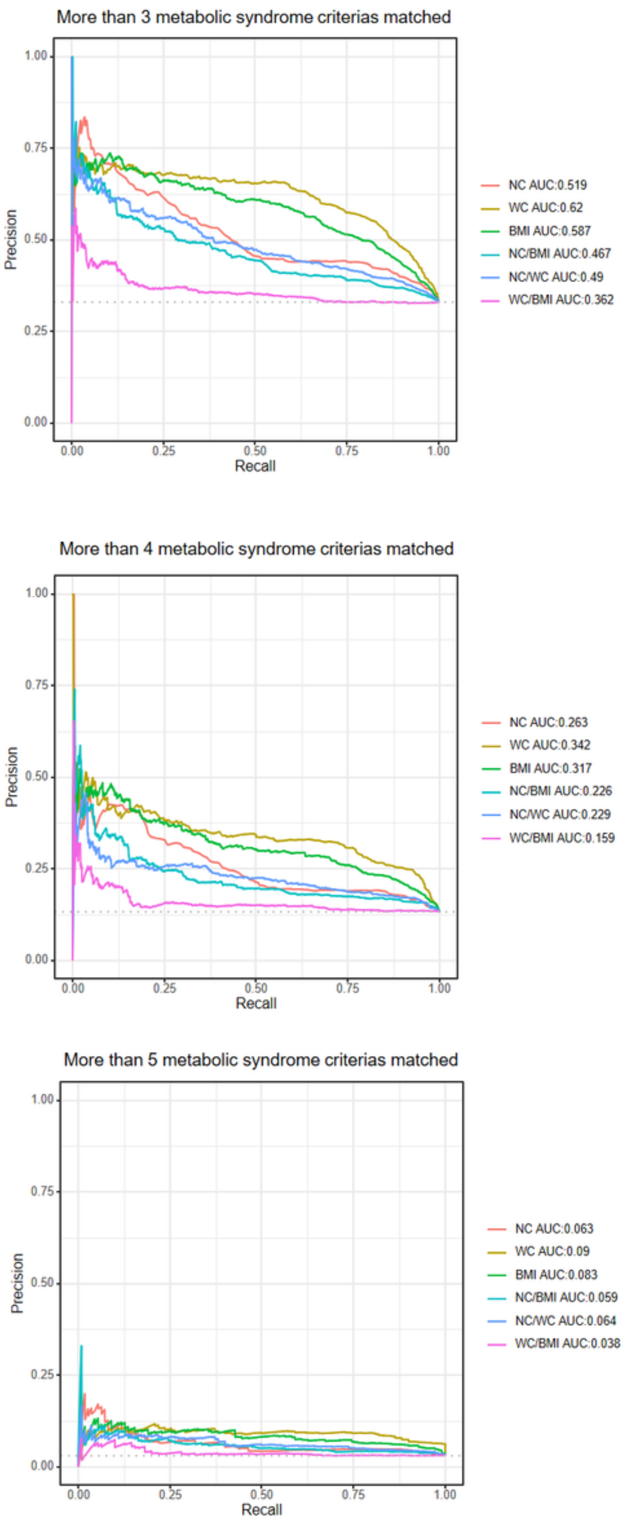

Figure 5

PR plot for metabolic syndrome in all subjects

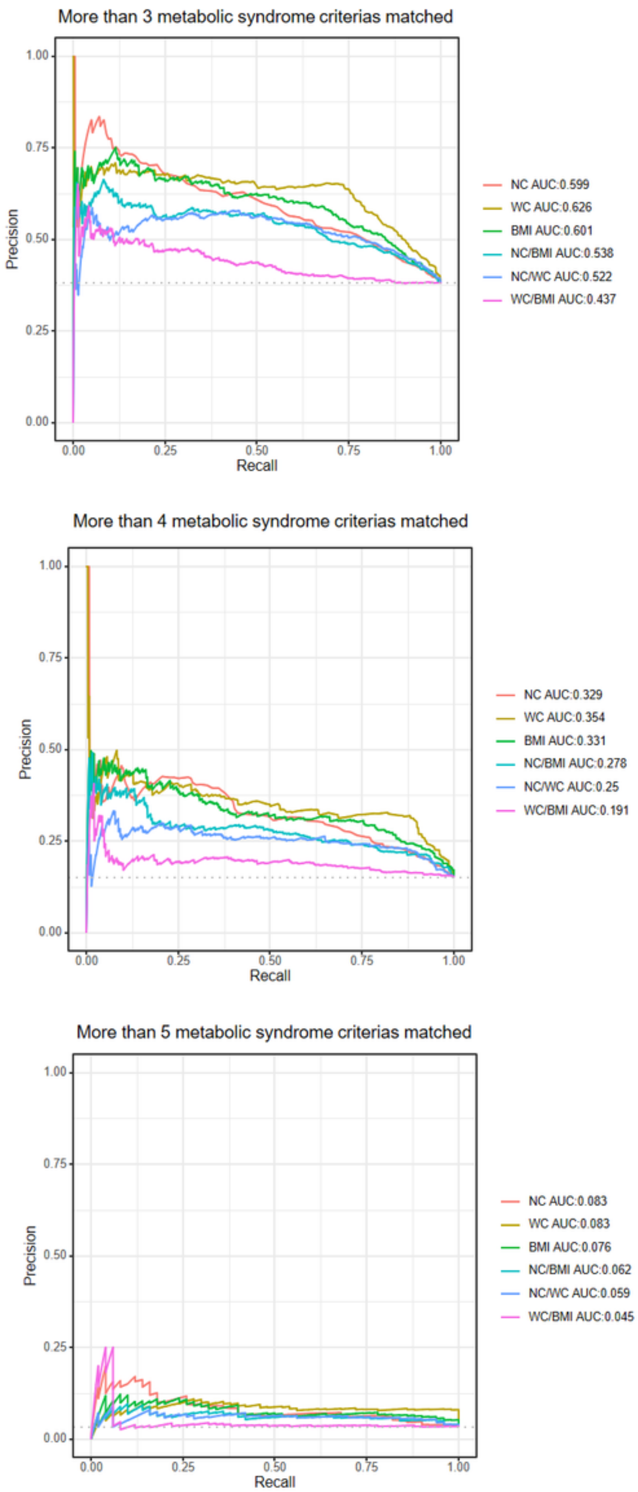

Figure 6

PR plot of metabolic syndrome in male subjects

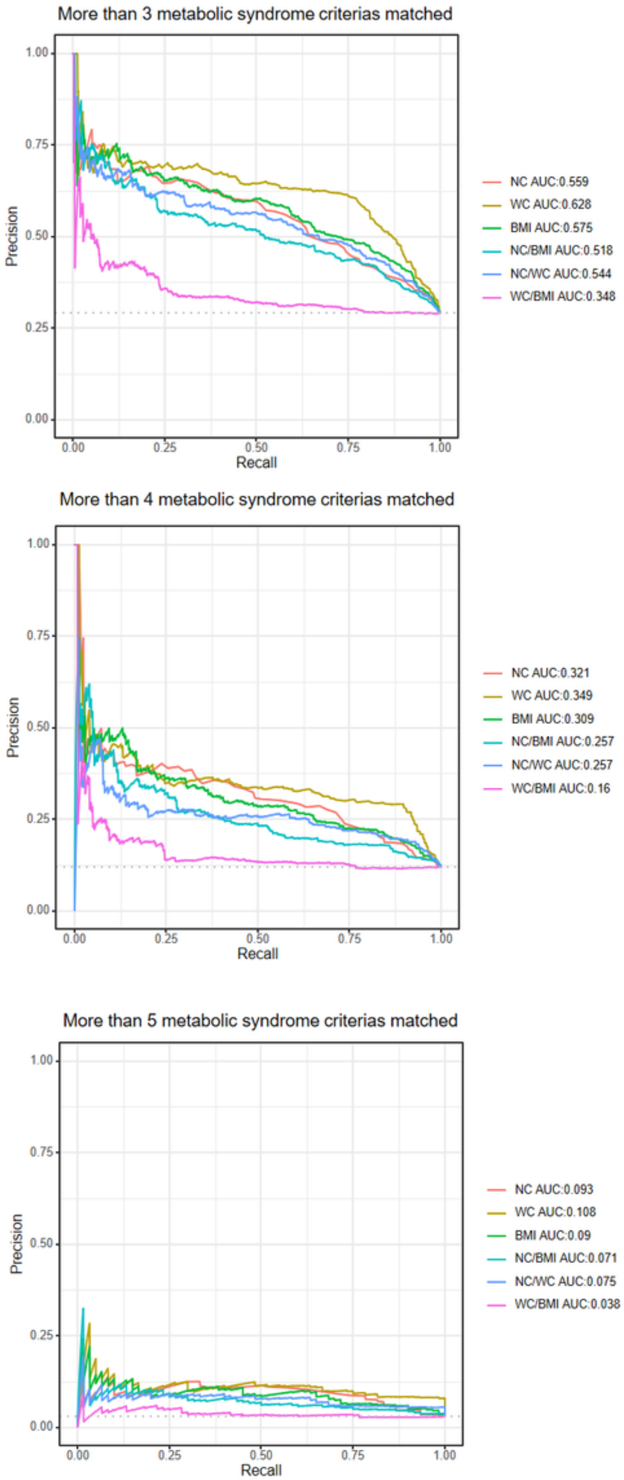

Figure 7

PR plot of metabolic syndrome in female subjects

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1Generalcharacteristicstotalnumberofsubjects.xlsx
- Table2CorrelationofNCNCBMINCWCintotalsubjects.xlsx
- Table3CorrelationofNCNCBMINCWCinmalesubjects.xlsx
- Table4CorrelationofNCNCBMINCWCinfemalesubjects.xlsx
- Table5LogisticRegressionPRplotcriteria.xlsx
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