**RESEARCH ARTICLE**

**Associations of four obesity indices with diabetes mellitus in Korean middle-aged and older adults: A population-based cohort study**

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**Abstract**

**Background:** Obesity is associated with a high risk of diabetes mellitus (DM); therefore, obesity-related indices are strongly associated with DM. This study evaluated the association of obesity indices, including body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), a body shape index (ABSI), with DM in Korean middle-aged and older adults.

**Methods:** Data from three population-based cohorts (Ansan and Ansung, Health Examinee, and Cardiovascular Disease Association Study, derived from the Korean Genome and Epidemiology Study) were analyzed. The chi-square and two-sample t-tests were used to analyze the differences among age groups (40–49, 50–59, and ≥60 years). Logistic analysis was used to evaluate the association of BMI, WC, WHR, and ABSI with DM, after adjusting for covariates according to sex and age. The integrated discrimination index (IDI) and category-free net reclassification improvement (cfNRI) and area under the curve (AUC) of the receiver operating characteristic (ROC) curve were analyzed by age group to investigate index-specific model performance.

**Results:** Among the 160,585 participants, 13,846 had DM (6,837; men [11.86%] and 7,009 women [6.81%]). Age increase was associated with an increased prevalence of DM: 2,339 (4.01%), 5,313 (8.74%), and 6,194 (14.93%) in the 40–49, 50–59, and ≥60 years age groups. After adjusting for covariates, the odds ratios (OR) for DM of WHR and WC were higher than those of the other indices in every age group. However, the OR for WHR, WC, and BMI decreased with age in both sexes. ABSI showed steady and slightly increasing ORs with increasing age although the ORs in both sexes were generally low for DM. For IDI and cfNRI, WHR had the highest values among all age groups. The AUC of the ROC curve showed that the WHR had the highest value in all age groups.

**Conclusion:** The WHR had the strongest association with DM, but was not a good DM index in older people. Therefore, age-related index criteria for DM, especially in women, were needed for the effective prevention and management of DM.

**Keywords:** age-stratified risk, obesity, diabetes mellitus, anthropometric indices

**Introduction**

Diabetes mellitus (DM) is a major public health concern worldwide. According to the International Diabetes Federation (IDF), three out of four people in low- and middle-income countries have been living with DM, and their number is predicted to increase to 783 million by 2045 [1]. DM is among the most prevalent diseases in Korea as well. According to the Korean Diabetes Association, 13.8% of people aged over 30 years and 27.6% of people older than 65 years had DM in 2018 [2]. In South Korea, the proportion of people aged over 65 years is expected to increase from 15.1% in 2019 to 16.8% in 2021 [3]. As the proportion of older adult increases, the importance of studying their public health risks increases.

Diabetes can be diagnosed by three criteria: glycated hemoglobin, fasting plasma glucose (FPG), and oral glucose tolerance test (OGTT) [4, 5]. These tests are undertaken using blood samples, which involves a need to visit the clinic, obtain blood samples, wait for the clinical test results, and incurs a cost. This long and costly process makes people hesitant to visit the clinic, which makes disease prevention and management more difficult. DM is associated with several risk factors, including age, sex, obesity, and lifestyle [6-8]. Among these risk factors, obesity has various indices that can be measured anywhere. Obesity is normally defined by the body mass index (BMI); however, several other indices are also used to define obesity, including waist circumference (WC), waist-hip ratio (WHR), and a body shape index (ABSI).

Many studies have assessed the association between anthropometric indices and chronic diseases, such as hypertension, cardiovascular disease (CVD), DM, and mortality in the general population [8-10]. A previous study examined the association of obesity-related cardiometabolic risk factors in the Bangladeshi population and showed that WHR, WC, waist-to-height ratio (WHtR), and body fat percentage (BF%) were more strongly associated with cardiometabolic risk factors than was the BMI [9]. The Z-score of the log-transformed ABSI (LBSIZ) has been assessed with regard to its association with CVD in Koreans [11, 12] and the LBSIZ was shown to have a stronger association with CVD than with other indices, including BMI and WC. Several studies have compared and analyzed obesity indices to determine the mortality risk [13-15] and DM risk [9-12, 16]. As obesity is associated with a high risk of DM, obesity-related indices are strongly associated with DM [10, 17]. A cohort study in Iran showed that the WHR is a better index for type 2 diabetes mellitus (T2DM) than the body adiposity index (BAI), BMI, and WC [10]. Other studies have compared several indices, including BMI, WC, WHR, and ABSI, to assess their association with DM [18-20].

This study aimed to evaluate the association between these indices and DM according to age and sex in Korean middle-aged and older adults.

**Methods**

**Data sources and study population**

We evaluated the associations of indices with the prevalence of DM in different age groups (40–49, 50–59, and ≥60 years) based on data from the three cohorts, including the Ansan/Ansung Study, the Health Examination (HEXA) study, and Cardiovascular Disease Association Study (CAVAS), from the Korean Genome and Epidemiology Study (KoGES) [16]. The KoGES was launched to investigate the genetic and environmental etiologies of common complex diseases in Koreans. The KoGES aims to form a genome epidemiological platform for research using a health database and biobank [16]. Informed consent for data collection, including interviews and examinations, was obtained from participants and trained health workers. Core questionnaires, physical examinations, and clinical investigations, including those on sociodemographic status, lifestyle, and psychological stress were collected from all cohorts [16]. Eligible participants aged over 40 years at baseline were recruited from the National Health Examinee Registry. The Ansan and Ansung studies recruited 10,030 participants from 2001 to 2002; the HEXA study recruited 173,202 participants from 2004 to 2013; and the CAVAS study recruited 28,337 participants from 2006 to 2011. Baseline recruitment was used for each cohort in this study.

**Anthropometric indices**

This study used four anthropometric indices: BMI, WC, WHR, and ABSI. The ABSI was defined as WC/(BMI2/3\*height1/2) [21]. BMI was measured using a machine, and for participants who did not have BMI values, we calculated it using weight and height as the body weight (kg) divided by the height squared (m2). For WC and hip circumference measurements, the Ansan and Ansung study measured these three times, and we calculated the average; the HEXA study measured this parameter once; and the CAVAS measured it twice; therefore, we calculated the average. The height and weight were measured once in all the studies. We dichotomized each index with each criterion as normal and high: 25 kg/m2 for the BMI and 90 cm in male and 85 cm in female for WC according to the Korean Society for the study of obesity (KOSSO) [22], 0.9 in men and 0.85 in women for WHR according to the World Health Organization (WHO) definition [23], and 0.08 m11/6/kg2/3 in men and 0.073 m11/6/kg2/3 in women for ABSI as reported previously [24].

**Diabetes mellitus and variables**

Diabetes mellitus (DM) was defined based on a doctor's diagnosis and/or use of antidiabetes treatments and/or high fasting blood sugar (>126 mg/dL). The questionnaires for the diagnosis of DM and antidiabetic treatment included yes or no questions that were answered by the participants themselves. This study collected demographic and clinical information, including age, systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol (TC), triglycerides (TG), fasting blood sugar (FBS), high-density lipoprotein cholesterol (HDL-C), smoking, drinking, education level (less than elementary school, middle and high school, and more than college), and income level (low, middle, and high as<1,500,000, 1,500,000–4,000,000, and >4,000,000 won per month, respectively). The participants were divided into three groups: 40–49, 50–59, and ≥60 years. SBP and DBP were used to calculate the average for that it measured several times. In the present study, smoking and drinking variables were classified dichotomously as yes or no in present. The studies covered different periods of data collection, from 2 to 10 years: 2 years for the Ansan and Ansung study, 10 years for the HEXA study, and 6 years for the CAVAS. Moreover, the number of study sites varied: two sites for the Ansan and Ansung study, 39 sites for the HEXA study, and 11 sites for the CAVAS. To adjust the model, we included age, sex, year of sample collection, collection site, educational level, income level, smoking, drinking, TC, and SBP.

**Statistical analysis**

We evaluated the associations between obesity-related indices and DM for the three age groups and by sex. We analyzed categorical variables as the frequency and proportion, and continuous variables as mean and standard deviation (SD). Differences in the prevalence of DM in categorical variables were analyzed using the chi-square test whereas continuous variables were analyzed using the two-sample t-test. We compared the odds ratios (OR), with 95% confidence intervals (95% CI), of the prevalence of DM for BMI, WC, WHR, and ABSI in sex- and age-specific groups, with the normal OR as the reference. The crude model was not adjusted; Model 1 was adjusted for confounders, including age, sex, collection year, collection site, education level, income level, smoking, drinking, TC, and SBP. To demonstrate the discrimination of the model, we analyzed the integrated discrimination index (IDI) and category-free reclassification improvement (cfNRI) for each index by age group. We compared the area under the curve (AUC) of the receiver operating characteristic (ROC) curve to compare the indices according to sex and age. Data analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

**Results**

**Characteristics of the participants**

The three studies included 211,569 participants who were older than 40 years as follows: 10,030 in the Ansan and Ansung studies, 173,202 in the HEXA study, and 28,337 in the CAVAS study. Among the 211,569 participants, we excluded 50,984 participants who were older than 80 years and those with missing data for variables, such as indices, clinical information, and anthropometric values (Figure 1). A total of 160,585 participants were included in the analysis, including 57,653 men (35.90%) and 102, 932 women (64.10%). The mean age of the 211,569 participants was 53.26 (SD 8.44) years (Table 1). Table 1 shows the anthropometric, clinical, and lifestyle characteristics of the participants according to their age and prevalence of DM. Participants were divided into three age groups: 40–49 years (58,332; 36.32%), 50–59 years (60,768; 37.84%), and ≥60 years (41,485; 25.83%). With age, the number and percentage of participants with DM increased: 2,339 (4.01%) in the 40–49 years, 5,313 (8.74%) in the 50–59 years, and 6,194 (14.93%) in the ≥60 years groups. Most of the variables differed significantly across all age groups between the normal and DM groups. The drinking variable showed no significant difference between the 40–49 and ≥60 years groups. The education and income level variables in the ≥60 years group did not show any difference. Among the variables that significantly differed, participants with DM were more likely to have higher age, BMI, WC, WHR, ABSI, SBP, DBP, TG, and FBS. In contrast, HDL-C levels and nonsmoking variables were higher in participants without DM.

**Age-related association of indices with the prevalence of DM**

Figure 2 presented the adjusted odds ratios (aOR) and 95% CI for the association between each index and DM prevalence by age group. Using the normal group as a reference, every index showed a higher ORs in the high group. WHR had the highest ORs in every age group, and WC had the second highest ORs. With age, the ORs decreased for BMI, WC, and WHR, whereas ABSI showed almost steady or slightly increasing ORs with increasing age despite the lowest ORs (Figure 2 and Table S1). Even after stratification by sex, all indices showed a significantly increased risk of DM by age group in both sexes, and WHR indicated the highest increased risk for DM for all age groups, although the ORs decreased with increasing age. ABSI had the lowest risk for almost all age groups, but showed an almost steady or slightly increasing OR with age (Figure 2 and Table S2).

**AUC difference for each index between age groups**

Table 2 showed the AUC of the ROC curve for BMI, WC, WHR, and ABSI for the prevalence of DM by age group. Model 2 was added to each index of Model 1. The highest AUC in Model 2 was for the WHR in the 40–49 years group, followed by WC, BMI, and ABSI. The AUC difference between Models 1 and 2 was significant (*P*<0.0001) for all indices; between Models 1 and 2, had the largest difference in AUC (0.030) was noted for WHR in the 40–49 years group. Overall, the AUC differences decreased as age increased for all indices. In Model 2, the largest difference in the AUC (0.069) was identified in BMI between the 40–49 and ≥60 years groups; however, the WC, WHR, and ABSI showed similar differences of 0.065, 0.062, and 0.053, respectively. In men, the AUCs were slightly lower than the overall values for all age groups; however, the AUCs for women were higher than the overall values for all age groups. The trends in both men and women were similar, with AUCs decreasing with increasing age. For both sexes, the WHR in the 40–49 years group had the highest AUC (male: 0.668, female: 0.727). The AUC values between models 1 and 2 significantly differed in most groups, except for the ABSI in the 40–49 and 50–59 years groups in men (P: 0.212 and 0.069; additional file Table S3).

**Reclassification of each index by age group**

The IDI showed positive values for all age groups (p<0.05), indicating that adding each index Model 1 was significantly better than the model without the index. Unlike the OR and AUC results, the IDIs in the 40–49 year group did not have the highest values for all indices. The WHR had a higher IDI in each age group than the other indices, and the WHR in the 50–59 year group had the highest IDI (0.013; Table 3). After sex-specific stratification, the trend was similar to the overall trend, with positive values and lower p-values for all age groups. In both sexes, WHR had the highest IDI in all age groups, and between men and women, men had a lower IDIs in the 40–49 and 50–59 year groups than women; however, the IDIs of men ≥60 years were higher than those of women (additional file Table S4). The cfNRI showed a trend similar to that of the ORs, and decreased as age increased. Similar to that in the OR and IDI, the WHR had the highest cfNRI among the indices in every age group, whereas ABSI showed similar and increased cfNRI values with age. BMI in the 40–49 year group had a higher cfNRI than the WC; however, the cfNRI of BMI and WC in the ≥60 year group crossed over because the cfNRI of the BMI decreased sharply as age increased (Table 3). Overall, the WHR group had the highest cfNRI among all age groups for both sexes. Women generally had higher cfNRIs than men in all age groups, except for the ABSI in those >60 years. In the 40–49 year group, women had a much higher cfNRI than men; however, the cfNRI was similar between men and women in the ≥60 year group because the cfNRI of women decreased sharply as age increased (additional file Table S4).

**Discussion**

In this study of 160,585 participants (DM: 13,846 and normal: 146,739), we compared the associations between the four indices, BMI, WC, WHR, and ABSI, and the prevalence of DM by age- and sex-specific groups (Figure 2). We found that the WHR had the strongest association with the prevalence of DM in every age- and sex-specific group. However, as age increased, the associations weakened for most indices, including BMI, WC, and WHR. A subgroup analysis was conducted to analyze the association between the indices and the prevalence of DM by sex. Although women showed higher ORs than men in most age groups, the ORs in both men and women decreased sharply with age.

This cross-sectional study aimed to compare the association between obesity-related indices, including BMI, WC, WHR, and ABSI, and the prevalence of DM by age- and sex-specific groups in South Korea. The key findings were as follows: First, overall, both males and females showed that indices with a waist circumference factor, such as WC and WHR, had higher ORs for DM in all age groups than did the other indices. Second, WC, WHR, and BMI showed decreasing ORs for DM as age increased in both sexes. However, the ABSI showed low but steady ORs in all age groups for both sexes. Finally, for an in-depth analysis, we compared the association between each index and DM using the AUC of the ROC curve and reclassifications, including IDI and cfNRI. The results showed that WHR had the highest value for DM overall and in both sexes by age group. The difference in AUCs between the models with and without each index showed that WHR had the greatest increase after adding the WHR variable in all age groups (Table 2), and the IDI and cfNRI showed that the WHR had the highest value in all age and sex groups (Tables 3 and additional file Table S4). For the AUC, as the ABSI showed the lowest difference between the 40–49 and ≥60 year groups, the ABSI would constitute a consistent method in terms of age; however, as the AUC value for each age group was the lowest among the indices, the ABSI is not a good index for DM (Table 3).

Several studies had compared the association between these indices and mortality or chronic diseases. The ABSI had a stronger association with all-cause mortality in type 2 diabetes than BMI or WHR [15]. Few studies had compared the associations between these indices and DM. In a rural Chinese population, increasing ABSI and body adiposity estimator (BAE) showed an increased risk of T2DM in a comparison of ABSI, BAE, BMI, WC, and WHtR [19]. A study showed an association between obesity-related indicators and the prevalence of chronic diseases, including DM, hypertension, and dyslipidemia, using data from the sixth Korea National Health and Nutrition Examination Survey (Sixth KNHANES), wherein BMI was found to be a better index of chronic disease [25]. As the study included participants older than 19 years, the results would differ from those of our study, which included participants older than 40 years. Our study showed that WHR and WC, which had a waist circumference factor, had stronger associations with the prevalence of DM than the other indices (ABSI and BMI).

In addition, our study showed that WHR has the strongest association with the prevalence of DM, and the result persists even in sex- and age-specific stratified analyses. Some studies had reported differences in the associations between anthropometric indices and diseases by age and sex [8, 26, 27]. A cross-sectional study based on the Korean National Health and Nutrition Examination Survey (KNHANES IV and V, 2008–2011) showed an association between body composition and DM in age- and sex-specific groups. The findings of the study indicated that fat mass index (FMI) is independently linked to DM in women older than 50 years, whereas both FMI and muscle mass index (MMI) were independently linked to DM in men older than 70 years [8]. Another previous study with participants over 60 years of age showed that WC had the strongest association with DM in male and BMI had the strongest association with DM in female participants [26]. Another study reported the effects of major metabolic risk factors on CVD and DM according to age groups [27]. Unlike previous studies, we had different results: WC and WHR had similar ORs in 40-49 years old, but the ORs with WC fell sharper with increasing age than ORs with WHR, especially in female. Although the ORs of women were higher than those of men for all indices and age groups, except the OR for BMI in the ≥60 year group, the WHR had the highest ORs in every age group in both men and women.

Except for the ABSI, the other three indices decreased with increasing age in both male and female participants. These results indicated that the indices are not sufficiently associated with DM in older adults. In the 40–49 year group, men had markedly lower ORs than women; however, the ORs of women decreased sharply with age in terms of BMI, WC, and WHR. Unlike the other three indices, the ABSI had a different pattern in both men and women, with a steady or slight increase with age. The association between age and the ABSI could explain these different patterns as shown in additional file Figure S1, which indicated that all index trends displayed that men had higher values than women from the 40th to 60th age groups; however, the differences became smaller and women had higher values after the 70th age group. BMI showed a half-parabola (upside-down U-shape) in both sexes. Men had the highest point at approximately 50 years of age, and BMI decreased with age. Females had the highest point at approximately the mid-70s and then BMI decreased as in men; therefore, BMI values in men and women crossed over at approximately 60 years. This association created the BMI paradox, in which a higher BMI was better than a low BMI for chronic diseases and mortality in older people [26]. WC and WHR showed similar associations with a half-parabolic pattern in men but increased continuously in women. Furthermore, these three indices showed decreasing trends with age in male. On the other hand, although ABSI also showed a cross between males and females at approximately 70 years, the values in both sexes increased continuously with age (additional file Figure S1).

The AUC of the ROC curve indicated the accuracy of each index for predicting the prevalence of DM. A comparison of the AUC of the models with and without the index indicated an improvement in the predictive accuracy. WHR showed the highest improvement after adding the index in all age groups, and WC had the second-highest AUC. This result indicated that WHR had the strongest association with DM. Even after stratification by sex, the WHR had the highest AUC in both sexes IDI and cfNRI. By comparing the models with and without the index to show discrimination, we analyzed the improvement in model performance. The IDI was generally smaller than the cfNRI; however, both show that WHR is the highest in every age group. cfNRI decreases with increasing age similar to the ORs; however, the IDI showed that the 50–59 year group had higher values than that of the 40–49 year group for every index. The IDIs of BMI and WHR decreased in participants ≥60 years whereas the IDI of WC in this group was the same as that in the 50–59 year group; however, the ABSI increased more in the ≥60 year group. Similar to the OR, the IDI and cfNRI were higher in women than in men. The WHR group had the highest IDI and cfNRI in both sexes among all the age groups. Men had a trend similar to that of the overall IDI, whereas women had a decreasing IDI for BMI and WC. In the cfNRI in men, the BMI, WC, and WHR decreased with age whereas the ABSI showed an increasing cfNRI, even with age.

This study had several strengths. First, we had a large sample size of middle-aged and older people (160,585 from three cohorts), which could be stratified by several subgroups, including age and sex. This study possibly had the largest sample size to show sex- and age-specific associations between obesity-related indices and the prevalence of DM in South Korea. Second, we stratified the patients into three groups and stratified age group-specific analyses showed that the associations between the indices and the prevalence of DM changed with age. Finally, we analyzed the IDI and cfNRI to compare the models with and without each index. Several studies had compared the AUC of the ROC curve; moreover, we analyzed the practical value of discrimination to improve by comparing the IDI and cfNRI. Despite these strengths, this study had some limitations. First, because we used three cohorts, the research periods were different and long. The Ansan/Ansung cohort study was performed between 2001 and 2002 (2 years), the CAVAS study between 2007 and 2014 (8 years), and the HEXA study had been performed between 2004 and 2013 (10 years). The CAVAS and HEXA had some overlapping periods, but the Ansan and Ansung cohorts had been assessed in many different years. Second, because this study was cross-sectional, we could not conclude whether the indices and DM are causally related. Future studies should address these limitations. Third, older participants were not included. Due to limited participants, we excluded those aged >80 years. Therefore, the age of the oldest group in this study was 60–79 years. However, the cohorts had been followed up until now, and the participants were older at follow-up. Further studies should be performed with a more recent follow-up to evaluate the association or causality between the indices and diseases in the old-old group, aged >80 years.

**Conclusions**

This study showed that, among the four anthropometric indices of BMI, WC, WHR and ABSI, the indices with a waist circumference factor, which included the WHR and WC, had strong associations with the precedence of DM in general. However, the association weakened with increasing age in both men and women, but especially so in women. These findings suggested that age-dependent cutoff points and a proper index for DM in older adults need to be developed.

**List of Abbreviations**

BMI, body mass index; WC, waist circumference; WHR, waist-to-hip circumference ratio; ABSI, a body shape index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; FBS, fasting blood sugar; TG, triglyceride

**Additional Files**

**Additional File Figure S1.** Sex-specific associations of age (years) with (a) BMI, (b) WC, (c) WHR, and (d) ABSI. Units are kg/m2 for BMI, cm for WC, and m11/6/kg2/3 for ABSI.

**Additional File Table S1, docx**. Age group-stratified ratios (95% CI) for the prevalence of DM with regard to BMI, WC, WHR, and ABSI according to the cutoff point of each index

**Additional File Table S2, docx.** Sex-specific and age group-specific odd ratios (95% CI) of the prevalence of DM for BMI, WC, WHR, and ABSI according to the cutoff point of each index

**Additional File Table S3, docx.** Difference in AUC among indices for DM in sex-specific and age-specific analyses

**Additional File Table S4, docx.** Reclassification of indices based on sex-specific and age-specific stratification

**DECLARATIONS**

**Ethics approval and consent to participate**

This study was approved by the Institutional Review Board Committee of the Korean National Institute of Health, Korea Disease Control and Prevention Agency (Approval No. 2021-04-02-P-A). The patients/participants provided their written informed consent to participate in this study.

**Consent for publication**

Not applicable .

**Availability of data and materials**

Data in this study were from the Korean Genome and Epidemiology Study (KoGES; 6635-302). National Institute of Health, Korea Disease Control and Prevention Agency, Republic of Korea. The data can be obtained upon reasonable request from the NIH, KDCA.

**Competing interests**

The authors declare that there are no potential conflicts of interest.

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**Author Contributions**

Conceptualization and writing-review and editing: YL and H-YP; Methodology and resources: YL and N-KL; software, validation and formal analysis: YL and N-KL; writing—original draft preparation: YL; writing—review and editing: YL and H-YP; supervision, project administration and funding acquisition: H-YP. All authors have read and agreed to the published version of the manuscript.

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**Table 1.** Stratification of the participants’ general characteristics by age group and DM prevalence

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|  | **40–49 years** | | | **50–59 years** | | | **60–79 years** | | |
| **Variables** | **Normal (n=55,993)** | **DM (n=2,339)** | ***p*-value** | **Normal (n=55,455)** | **DM (n=5,313)** | ***p*-value** | **Normal (n=35,291)** | **DM (n=6,194)** | ***p*-value** |
| Age (years) | 44.30±3.08 | 45.17±3.00 | <.0001 | 54.13±2.83 | 54.78±2.84 | <.0001 | 64.40±3.38 | 64.80±3.44 | <.0001 |
| Sex (female) | 37,694 (67.32) | 1,138 (48.65) | <.0001 | 37,703 (67.99) | 2,748 (51.72) | <.0001 | 20,526 (58.16) | 3,123 (50.42) | <.0001 |
| **Anthropometric Indices** | | | | | | | | | |
| BMI (kg/m2) | 23.55±2.98 | 25.37±3.56 | <.0001 | 24.01±2.82 | 25.13±3.06 | <.0001 | 24.19±2.88 | 24.80±3.03 | <.0001 |
| WC (cm) | 79.01±8.76 | 85.13±9.21 | <.0001 | 81.14±8.32 | 85.59±8.31 | <.0001 | 83.49±8.16 | 86.21±8.16 | <.0001 |
| WHR | 0.84±0.07 | 0.88±0.06 | <.0001 | 0.86±0.06 | 0.90±0.06 | <.0001 | 0.89±0.06 | 0.91±0.06 | <.0001 |
| ABSI | 0.076±0.00 | 0.078±0.00 | <.0001 | 0.077±0.00 | 0.079±0.00 | <.0001 | 0.079±0.00 | 0.080±0.00 | <.0001 |
| **Blood Pressure (mmHg)** | | | | | | | | | |
| Systolic BP | 118.34±14.52 | 124.73±15.47 | <.0001 | 122.97±15.24 | 127.44±15.64 | <.0001 | 127.76±16.09 | 129.48±16.28 | <.0001 |
| Diastolic BP | 74.74±10.41 | 78.90±10.46 | <.0001 | 77.09±10.16 | 78.83±9.67 | <.0001 | 78.32±10.03 | 77.52±9.97 | <.0001 |
| **Laboratory parameters, mg/dL** | | | | | | | | | |
| TC | 191.41±32.63 | 195.37±38.90 | <.0001 | 202.89±35.28 | 192.71±40.55 | <.0001 | 199.76±36.0 | 186.87±39.33 | <.0001 |
| TG | 112.24±66.01 | 153.35±80.15 | <.0001 | 122.77±65.80 | 151.60±77.32 | <.0001 | 128.44±65.05 | 141.80±71.69 | <.0001 |
| HDL-C | 54.62±12.96 | 49.28±12.14 | <.0001 | 53.73±13.13 | 48.94±11.50 | <.0001 | 51.40±12.49 | 48.50±12.06 | <.0001 |
| FBS | 89.35±9.67 | 148.34±50.83 | <.0001 | 91.48±10.20 | 139.96±45.46 | <.0001 | 92.58±10.46 | 131.83±41.04 | <.0001 |
| **Education** | | | | | | | | | |
| ≤Elementary school | 3,015 (5.38) | 207 (8.85) | <.0001 | 11,504 (20.74) | 1,309 (24.64) | <.0001 | 14,359 (40.69) | 2,440 (39.39) | 0.1030 |
| Middle & high school | 30,386 (54.27) | 1,315 (56.22) |  | 31,470 (58.55) | 3,008 (56.62) |  | 15,552 (44.07) | 2,762 (44.59) |  |
| ≥College | 22,592 (40.35) | 817 (34.93) |  | 11,481 (20.70) | 996 (18.75) |  | 5,380 (15.24) | 992 (16.02) |  |
| **Income (million won/month)** | | | | | | | | | |
| Low (<1.5) | 6,508 (11.62) | 369 (15.78) | <.0001 | 13,244 (23.88) | 1,478 (27.82) | <.0001 | 18,607 (52.72) | 3,268 (52.76) | 0.7500 |
| Middle (1.5-4) | 31,904 (56.98) | 1,324 (56.61) |  | 19,664 (53.49) | 2,773 (52.19) |  | 13,764 (39.00) | 2,397 (38.70) |  |
| High (≥4) | 17,581 (31.40) | 646 (27.62) |  | 12,547 (22.63) | 1,062 (19.99) |  | 2,920 (8.27) | 529 (8.54) |  |
| Smoking (Yes) | 8,923 (15.94) | 604 (25.82) | <.0001 | 6,390 (11.52) | 974 (18.33) | <.0001 | 3,776 (10.70) | 741 (11.96) | <.0001 |
| Drinking (Yes) | 30,370 (54.24) | 1,305 (55.79) | 0.1393 | 24,079 (43.42) | 2,447 (46.06) | 0.0002 | 12,886 (36.51) | 2,293 (37.02) | 0.0032 |

Data was expressed mean ± standard deviation or number(%).

DM, diabetes mellitus; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; ABSI, a body shape index; BP, blood pressure; TC, total cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; FBS, fasting blood sugar

**Table 2**. Difference in AUC among age group-stratified indices for DM

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | Age group (years) | Model 1\* | Model 2\*\* | Difference\*\*\* |
| BMI | 40–49 | 0.690 | 0.712 | 0.022 |
|  | 50–59 | 0.667 | 0.678 | 0.011 |
|  | 60–79 | 0.638 | 0.643 | 0.005 |
| WC | 40–49 | 0.690 | 0.715 | 0.025 |
|  | 50–59 | 0.667 | 0.681 | 0.014 |
|  | 60–79 | 0.638 | 0.650 | 0.012 |
| WHR | 40–49 | 0.690 | 0.720 | 0.030 |
|  | 50–59 | 0.667 | 0.694 | 0.027 |
|  | 60–79 | 0.638 | 0.658 | 0.020 |
| ABSI | 40–49 | 0.690 | 0.696 | 0.006 |
|  | 50–59 | 0.667 | 0.671 | 0.004 |
|  | 60–79 | 0.638 | 0.643 | 0.005 |

All *p*-values were <.0001

\*Model 1 was adjusted for age, sex, year, site, education, income, smoke, drink, total cholesterol, and systolic blood pressure; \*\*Model 2 was adjusted for variables in Model 1 + BMI, WC, WHR, or ABSI; \*\*\*Difference between Model 1 and Model 2. BMI, body mass index; WC, waist circumference; WHR, waist-to-hip circumference ratio; ABSI, a body shape index

**Table 3.** Reclassification of indices by age group

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Index** | **Age group (years)** | **IDI\*** | ***p*-value** | **cfNRI\*\*** | ***p*-value** |
| BMI | 40–49 | 0.0049 | <.0001 | 0.446 | <.0001 |
|  | 50–59 | 0.0053 | <.0001 | 0.302 | <.0001 |
|  | 60–79 | 0.0034 | <.0001 | 0.152 | <.0001 |
| WC | 40–49 | 0.0074 | <.0001 | 0.395 | <.0001 |
|  | 50–59 | 0.0080 | <.0001 | 0.316 | <.0001 |
|  | 60–79 | 0.0080 | <.0001 | 0.222 | <.0001 |
| WHR | 40–49 | 0.0085 | <.0001 | 0.482 | <.0001 |
|  | 50–59 | 0.0130 | <.0001 | 0.416 | <.0001 |
|  | 60–79 | 0.0111 | <.0001 | 0.252 | <.0001 |
| ABSI | 40–49 | 0.0012 | <.0001 | 0.011 | <.0001 |
|  | 50–59 | 0.0022 | <.0001 | 0.014 | <.0001 |
|  | 60–79 | 0.0026 | <.0001 | 0.062 | <.0001 |

\* Integrated discrimination index; \*\*Category-free net reclassification improvement BMI, body mass index; WC, waist circumference; WHR, waist-to-hip circumference ratio; ABSI, a body shape index

**Figure Legends**

**Figure 1.** Flowchart depicting participant screening and enrolment in the study.

BMI, body mass index; WC, waist circumference; WHR, waist-to-hip circumference ratio; ABSI, a body shape index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; FBS, fasting blood sugar; TG, triglyceride

**Figure 2.** ORs (95% CI) for the prevalence of DM according to the cutoff of each index. (A) Total. (B) Male. (C) Female. \* BMI cutoff point: 25 kg/m2, WC cutoff point: 90 and 85 cm for male and female participants, respectively, WHR cutoff point: 0.9 and 0.85 for male and female participants, respectively, and ABSI cutoff point: 0.08 and 0.073 m11/6/kg2/3 for male and female participants, respectively.