

Sex Difference of Type 2 Diabetes Affected by Abdominal Obesity versus Overall Obesity

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Purpose: This research compares the predictive value of the abdominal obesity indicator, waist circumference (WC), and the overall obesity indicator, body mass index (BMI), among men and women with regard to type 2 diabetes. **Materials and Methods:** This study used data collected from 4,400 households selected by a stratified multistage probability sampling method during the 2001 Korea National Health and Nutrition Examination Survey (KNHANES). The final study sample included 4,684 subjects over 30 years of age who had completed the health examination required for the analysis of the health interview and health behavior surveys. **Results:** Both men and women showed significant differences in fasting blood glucose (FBG) or HbA1c levels based on abdominal obesity irrespective of BMI. However, the presence of overall obesity among men with abdominal obesity was not significantly correlated with FBG or HbA1c levels, while the presence of overall obesity among women with abdominal obesity was significantly different in regard to FBG or HbA1c levels. **Conclusion:** Both WC and BMI emerged as a measures of risk factors for type 2 diabetes among women while only WC emerged as a risk factor for diabetes among men.

Key Words: Abdominal obesity, obesity, type 2 diabetes

INTRODUCTION

As the global prevalence of obesity continues to rise, this condition has been identified as a leading contributor to such fatal illnesses as cardiometabolic disease. Although a high correlation among obesity and cardiovascular diseases¹ and type 2 diabetes^{2,3} has been reported, such results have not included categorical analyses of obesity. The inclusion of abdominal obesity in the adult treatment plan III (ATP III) diagnostic criteria for metabolic syndrome also emphasizes the importance of this condition.⁴ In addition, a growing consensus has identified waist circumference as the most useful anthropometric measurement parameter for predicting the health risks related to obesity.^{5,6} Body mass index (BMI), gauging the overall obesity level of the body, is also an excellent predictor for cardiovascular disease (CVD) and type 2 diabetes.⁷ The overall obesity indicator, BMI, and the abdominal obesity indicator, waist circumference (WC), are intimately related, with correlation coefficients between BMI and WC consistently exceeding, across ages, sexes, and races.^{8,9} However, much debate remains about whether overall obesity or abdominal obesity represents the better predictor of

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chronic diseases and death. It has been well-established that men and women exhibit different styles of obesity; upper body obesity is more prevalent among men while lower body obesity is more prevalent among women. Therefore, the influence of obesity type on chronic diseases may differ between the sexes. This research compares the predictive value of the abdominal obesity indicator, WC, and the overall obesity indicator, BMI, among men and women in regard to type 2 diabetes in Korea.

MATERIALS AND METHODS

Research subjects

This study was based on the data obtained from the second Korean National Health and Nutrition Examination Survey (KNHNES II) among non-institutionalized civilians in the Republic of Korea, which was conducted by the Korean Ministry of Health and Welfare. The KNHANES consisted of four types of surveys: a health interview survey, a health behavior survey, a health examination survey, and a nutrition survey. Some types of data were obtained by personal interview, and others, by self-report or health examination; health behavior data were recorded by self-reports. A stratified, multistage probability sampling design was used, and sampling units were based on geographical area, sex, and age using household registries. There were 246,097 primary sampling units, each of which contained about 60 households. 200 sampling frames (12,180 households) from primary sampling units were randomly sampled throughout Korea and 4,400 households surveyed in the KNHANES II were selected. An average of 20 households were randomly chosen in the selected areas, and all members of each household were interviewed. The final study sample was composed of 4,684 respondents older than 30 years of age who had completed the health examination required for the analysis of the health interview and health behavior surveys. Subjects who were diagnosed with such chronic diseases as diabetes, cardiovascular disease, and cancer were excluded due to possible changes in health-related habits.

Research parameters and methodology

Surveys other than the health examination survey were conducted via questionnaire completed by the subjects. The risk of type 2 diabetes was determined through measurement of fasting blood glucose and HbA1c levels. Fasting blood samples were taken in the morning after at least an 8-h fast, and were centrifuged, refrigerated at the examination site. Blood samples were transferred in iceboxes to a central laboratory in Seoul on the day taken. A fasting glucose concentration of 126 mg/dL determined the threshold for the diagnosis of diabetes. Abdominal obesity was deter-

mined using waist circumference measurements, where WCs greater than 90 cm for men and greater than 80 cm for women defined abdominal obesity, as per the Asian region standards outlined in ATP III. Waist circumference was measured from the narrowest point between the lower borders of the rib cage and the iliac crest. Overall obesity was determined by BMI, where scores greater than 25 represented obesity and those lower than 25 represented normal weight irrespective of sex. BMI was calculated as weight in kilograms divided by the square of the height in meters, and body weight and height were measured with subjects wearing light clothing without shoes. A family history of diabetes was obtained through a review of the diabetes history of parents, siblings, and both paternal and maternal grandparents, where the presence of a single relative with a history of diabetes was considered an indication of such a family history. Health behaviors that affect diabetes included smoking, obesity, and overweight status due to lack of physical activity, exercise, etc.⁹ Smoking and exercise were based on current behaviors.

Statistical analysis

The receiver operating characteristics (ROC) curve was used to compare the ability of WC and BMI to predict type 2 diabetes. The ROC curve is commonly used to establish the usefulness of a particular anthropometric measurement for distinguishing populations with particular diseases.

Sensitivity and specificity are computed under the assumption that each variable is positively correlated with the incidence of diabetes. The ROC curve tests the ability of a variable to predict an outcome by plotting sensitivity against 1-specificity. Screening methods producing curves that are more skewed to the left are more accurate, where 1.0 represents perfect prediction. Scores of 0.5 indicate a screening method with no predictive value and scores < 0.5 indicate that the variable under examination is negatively predictive. The differences in the BMI and WC groups in fasting blood glucose (FBG) and HbA1c levels were analyzed by using t-tests.

RESULTS

Overall obesity (high BMI) was significantly more prevalent among men in younger age groups, and the age distribution for abdominal obesity (high WC) was not different from that of normal WC subjects. High WC, compared with normal WC, was significantly related to the prevalence of diabetes, whereas high BMI, compared with normal BMI, was not significantly related with such prevalence. Among women, both the overall and abdominal obesity groups were older than the normal BMI and WC

groups, respectively. Both abdominal and overall obesity had significant differences in FBS and HbA1c levels among men and women. Women showed statistically significant differences with regard to how obese versus normal WC and how obese versus normal BMI affected the prevalence of diabetes (Table 1).

The ROC curves showed that areas under the curve (AUCs) of WC and BMI among both men [BMI = 0.556 (95% CI: 0.512-0.601); *p* value: 0.011, WC = 0.598 (95% CI: 0.553-0.644); *p* value: 0.000] and women [BMI = 0.623 (95% CI: 0.582-0.665); *p* value: 0.000, WC = 0.665 (95% CI: 0.628-0.702); *p* value: 0.000] were statistically significant to predict diabetes, but there was no statistically significant difference in AUCs between BMI and WC (Fig. 1). The true positive rate (sensitivity, Y axis) of WC among women, however, is statistically significantly higher than both that of WC among men (*p* value: 0.001) and that of BMI among women (*p* value: 0.001), while there was no significant difference in the true positive rate between WC and BMI among men.

First, differences in FBG levels between those with abdominal obesity and those with overall obesity were compared by sex (shown on the left side of Fig. 2). Both men and women, irrespective of BMI, showed significant differences in FBG levels based on abdominal obesity. This difference was observable even upon visual inspection of the data. However, data showing the impact of abdominal and overall obesity on FBG levels (right side of Fig. 2) indicated that the presence of overall obesity among men with abdominal obesity was not significantly related with FBG levels. In contrast, the presence of overall obesity among women with abdominal obesity was significantly different in regard to FBG levels.

These results are consistent with those in regard to HbA1c levels (Fig.

Table 1. General Characteristics by Obesity Type among Study Subjects

	Men (n = 2,069)				Women (n = 2,615)			
	Overall obesity		Abdominal obesity		Overall obesity		Abdominal obesity	
	BMI < 25	BMI ≥ 25	WC < 90 cm	WC ≥ 90 cm	BMI < 25	BMI ≥ 25	WC < 90 cm	WC ≥ 90 cm
Age (yr)*	48 ± 13.4	45.5 ± 11.4	47.1 ± 12.9	47.6 ± 13	46.6 ± 13.9	48.8 ± 12.0	44.3 ± 12.7	51.4 ± 13.5
<i>p</i> value	< 0.001	< 0.001	ns	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
BMI (kg/m ²)*	22.1 ± 1.9	27.1 ± 1.8	22.6 ± 2.3	27 ± 2.2	21.9 ± 2.0	27.4 ± 2.1	21.8 ± 2.2	25.9 ± 2.8
<i>p</i> value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Overall obesity (%)	-	-	16.1	80.2	-	-	5.4	59.8
<i>p</i> value			< 0.001	< 0.001			< 0.001	< 0.001
Family history of diabetes (%)	8.0	12.5	8.3	13.0	10.4	10.9	5.4	59.8
<i>p</i> value	0.001	< 0.001	< 0.001	< 0.001	ns	< 0.001	< 0.001	< 0.001
Waist circumference (cm)*	81.3 ± 6.4	92.0 ± 5.7	81.4 ± 5.9	94.8 ± 4.2	75.1 ± 6.9	87.5 ± 7.0	72.6 ± 4.9	87.1 ± 5.7
<i>p</i> value	< 0.001	< 0.001	0.002	< 0.001	< 0.001	< 0.001	ns	ns
Abdominal obesity (%)	7.0	61.5	-	-	22.8	88.4	-	-
<i>p</i> value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Fasting blood glucose (mg/dL)*	96.8 ± 16.4	101.3 ± 17.4	96.8 ± 16	102.7 ± 18.8	94.5 ± 14.7	100.4 ± 16.5	93.5 ± 13.4	100.1 ± 17.2
<i>p</i> value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
HbA1c (%)*	5.6 ± .6	5.8 ± .7	5.6 ± .6	5.8 ± .7	5.6 ± .6	5.8 ± .6	5.5 ± .6	5.8 ± .6
<i>p</i> value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Diabetes (%)	5.4	6.7	5	8.4	3.3	6.2	2.5	6.4
<i>p</i> value	ns	ns	0.006	0.006	< 0.001	< 0.001	< 0.001	< 0.001

BMI, body mass index; WC, waist circumference.
*all values are mean ± S.D.

3). In summary, Figs. 2 and 3 show that, irrespective of BMI, the presence of abdominal obesity is correlated with FBG and HbA1C levels among both men and women. In the presence of abdominal obesity, overall obesity is related to FBG or HbA1c levels only among women.

DISCUSSION

Although both overall obesity and abdominal obesity have been identified as causal factors for diabetes and are known

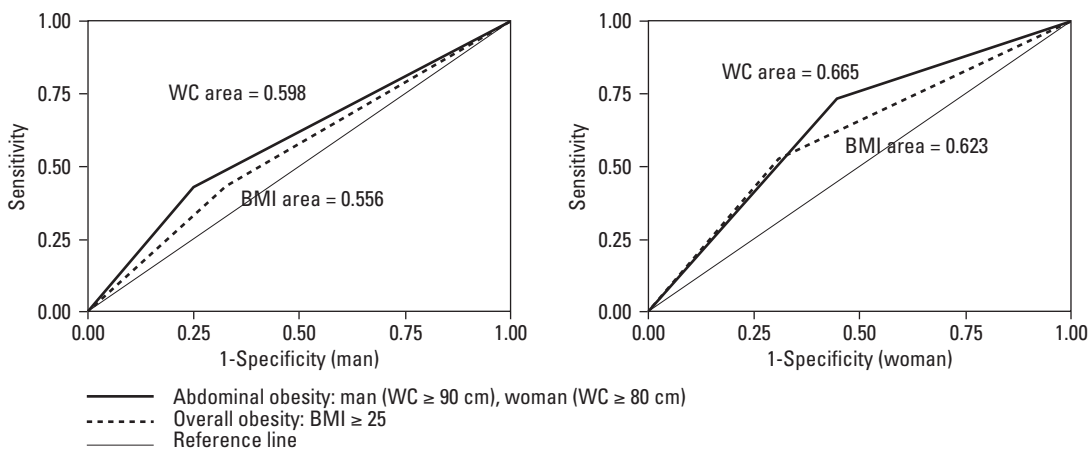


Fig. 1. Comparison of the ROCs for WC and BMI by predictive value for diabetes according to sex. WC, waist circumference; BMI, body mass index; ROCs, receiver operating characteristics.

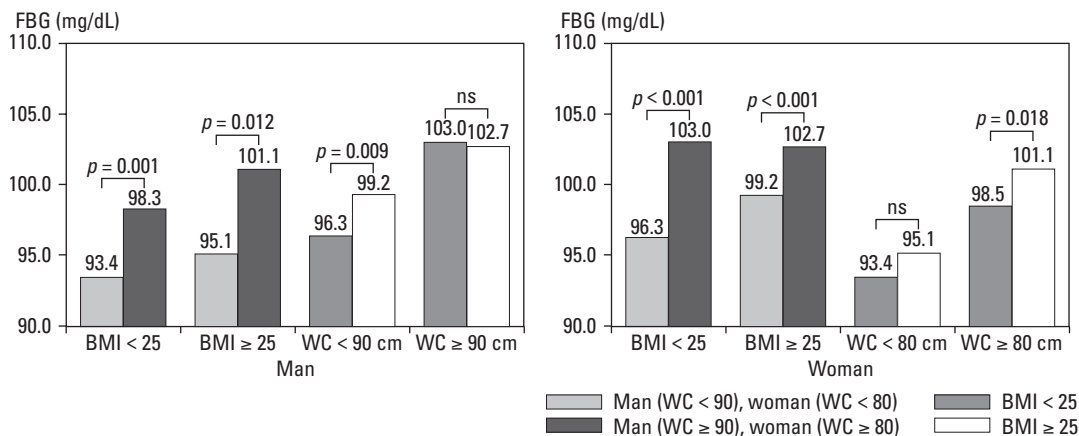


Fig. 2. Comparison of FBG levels in abdominal and overall obesity by presence of overall and abdominal obesity. WC, waist circumference; BMI, body mass index; FBG, fasting blood glucose.

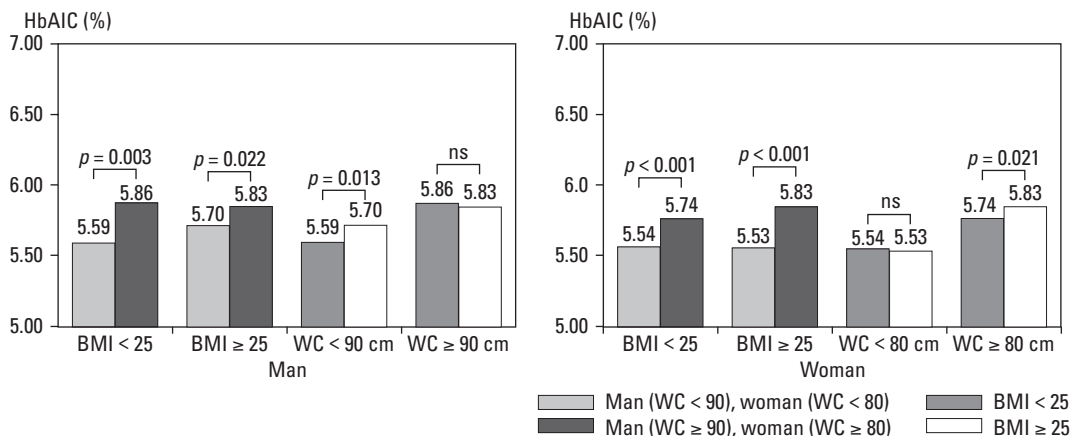


Fig. 3. Comparison of Hb1Ac levels in abdominal and overall obesity by presence of overall and abdominal obesity. WC, waist circumference; BMI, body mass index.

to act as independent parameters, the relative usefulness of each measure in the prediction of type 2 diabetes remains controversial. This research focused on sex differences in obesity by examining the differential effects of different types of obesity on men and women. Unlike previous research, this study focused on analyzing the relationships among sex, overall obesity, abdominal obesity, and risk for diabetes.

Predictive value of overall versus abdominal obesity for diabetes

The ROC analysis demonstrated that there was no statistically significant difference in AUCs between BMI and WC among both men and women, but the true positive rate (sensitivity) of WC among women was statistically significantly higher than both that of WC among men and that of BMI among women. No statistically significant difference may be caused by the reduced AUCs due to a high false positive rate of WC among women. Therefore, since it is one of the most fundamental anthropometric measurement parameters, WC is a valuable factor to predict diabetes due to a high true positive rate despite the high false positive rate.

Indeed, the San Antonio Heart Study found that WC was superior to other factors (e.g., BMI, waist-to-hip ratio, hip circumference, and sum of skinfold thickness) in predicting the development of diabetes.³ Cohort research conducted by Wang, et al.¹⁰ also reported similar ROC curves for the predictive values of WC and BMI for type 2 diabetes. The AUCs ratios for type II diabetes were: 82.5%, 83.6%, and 74.1% for BMI = 24.8, WC = 94 cm, and WHR = 0.94, respectively.

In contrast, research among Pima Indian subjects found that BMI represented the best predictor of type 2 diabetes in both men and women.⁷ The same results emerged from a Jamaican study with predominantly black participants, using a cohort design; although BMI, WC, waist-to-hip ratio, and waist-hip-ratio (WHR) represented predictors of diabetes, additional measures of body fat distribution did not affect the predictive value of general obesity for diabetes.⁹ Although WHR can be used instead of WC to measure abdominal obesity, we used WC for the following reasons. First, numerous studies have reported that WC showed higher predictive value than WHR or BMI in regard to health risk.¹¹ Second, WC can robustly account for the risk of CVD or type 2 diabetes.^{3,12,13} Third, WC measurements are simpler than WHR measurements and have relatively smaller measurement errors.³ In addition, WC has been validated as more representative than WHR of visceral fat levels.^{14,15} It has also been reported that the biological mechanisms involved in the relationship between WHR and health risk are more difficult to understand

than those involved in the relationship between WC and health risk.¹⁶ Moreover, it has been reported that WC demonstrated better predictive ability for type 2 diabetes than for cardiovascular diseases because visceral fat provided a better explanation of the risk of type 2 diabetes.²

In addition, although WC levels rapidly increased the possibility of health risk, the WC values that best predicted the risk levels for type 2 diabetes remain unclear. Within a population having homogeneous BMIs, subjects with high WC have shown greater levels of health-related risk compared to those with low WC. However, the WC value at which the health risk increases remains debatable. Furthermore, since the relationship between WC and visceral fat is influenced by race¹⁷ and age,¹⁵ this threshold value will vary according to race and age.

The American Heart Association¹⁸ and the US Department of Agriculture¹⁹ recommend a WC threshold of 102 cm and 88 cm for men and women, respectively, and a WHR threshold of 95 cm and 88 cm for men and women, respectively. WHO has accepted the proposed lowest health risk WC values of below 94 cm and below 88 cm for men and women, respectively.²⁰ Analyses of the data obtained from the American NHANES III and the Canadian Health Surveys have shown that a BMI of ≥ 30 kg/m² represents the standard of obesity used in western countries.²¹ According to this standard, the prevalence of obesity was 10% to 15% in Canada, Germany, and France, 20% to 30% in the US and England, and below 5% in East Asian countries such as Korea and Japan. The western standard of obesity is not applicable to Korea. Some scholars suggest that a BMI of ≥ 25 represents the appropriate standard for obesity in Asian countries.¹¹⁻¹⁴ Therefore, in accordance with the ATP III Asian standards, we defined overall obesity as a BMI greater than 25 and abdominal obesity as a WC greater than 90 cm and 80 cm for men and women, respectively.

Differences in blood glucose levels based on relationships between overall and abdominal obesity according to sex

Table 1 shows that abdominal and overall obesity significantly affected FBS and HbA1c levels. Figs. 2 and 3 illustrate that abdominal obesity correlated with significant differences in FBS and HbA1c levels among both men and women, regardless of overall obesity. However, in the context of abdominal obesity, only the men with normal WC scores showed significant differences based on presence of overall obesity, while those with WC scores indicating abdominal obesity showed no differences in this regard. In other words, there were no significant differences in FBS and HbA1c levels according to BMI in the abdominal obesity group. Thus, it is necessary to include

WC in all considerations of the differences between BMI and FBS or HbA1c levels among men. Among women, however, relationships involving FBS or HbA1c levels and BMI were statistically significant only among those with abdominal obesity and high blood sugar.

This finding was identical to results demonstrated by the ROC curve, presented in Fig. 1, which shows that WC was a more important predictor for diabetes than BMI among men and women. Consequently, abdominal obesity represented a very useful predictive factor for diabetes in women, whereas overall obesity was not closely related to diabetes in men.

In other words, both WC and BMI emerged as measures of risk factors for diabetes among women; for men, only WC emerged as a risk factor for diabetes and BMI did not predict diabetes. Furthermore, WC emerged as a more important factor for the development of diabetes among women than BMI.

These results derived from the differences characterizing obesity in men and women. Table 1, showing differences in the WC and BMI obesity groups according to sex, support this result. Therefore, measuring obesity using BMI is not an appropriate method for predicting diabetes for men. Moreover, 88.4% of women with overall obesity also had abdominal obesity, while 61.5% of men with overall obesity had abdominal obesity. Furthermore, 80.2% of men with abdominal obesity had overall obesity, while 59.4% of women with abdominal obesity had overall obesity. These results indicate that most men with abdominal obesity also had overall obesity, while a substantial number of men with overall obesity did not have abdominal obesity. In contrast, most women with overall obesity also had abdominal obesity, while a substantial number of women had abdominal obesity but not overall obesity. In conclusion, abdominal obesity alone was a good predictor of diabetes for men, while both abdominal obesity and overall obesity were useful predictors for women. Furthermore, WC emerged as a more important factor for the development of diabetes among women than BMI.

Similar research compared the health risk for those with overall versus abdominal obesity, which categorized the NHANES subjects in a large-scale American cross-sectional study into six BMI levels (underweight; normal weight; overweight, class I, class II, and class III) and two WC levels (normal and high). The BMI and WC obesity groups were combined to measure the effect of such health risk factors as high blood pressure, diabetes, dyslipidemia, and metabolic syndrome. We found that a greater proportion of subjects with abdominal obesity (i.e., high WC) than those with normal WC (as per NIH standards) and those in the three non-obese BMI groups (normal weight, overweight, and class I) suffered from high blood pressure,

diabetes, dyslipidemia, and metabolic syndrome.²² Most subjects met the criteria for the three non-obese BMI groups and each BMI group contained both normal and high WC subjects. Therefore, the addition of the WC measure to the BMI measure contributed important and new information about the health risks faced by patients.

This research found that the risk of diabetes increased significantly as WC increased within the high BMI group. A similar prospective study found that increases in central fat increased the risk of diabetes within the high BMI group and underscored both BMI and WC as important factors in predicting the risk of diabetes, thereby supporting the results of the current research.^{2,3,23} Studies conducted with subjects including Mexican-Americans,³ US nurses,² and elderly women in Iowa²³ have all reported that high WC and high waist-hip ratios significantly increase the risk of type 2 diabetes within the high BMI group. Hence, measures of both general obesity and distribution of body fat are proposed as important factors in predicting type 2 diabetes.

However, analyses of the predictive value of WC and BMI for diabetes according to sex remain scarce. This research revealed that WC and BMI carried different predictive values for the development of diabetes among men and women. Therefore, sex must be considered by methods screening for diabetes risk.

This research showed that increases in BMI were associated with different outcomes among men and women and within each WC group. Moreover, WC emerged as a more important factor than BMI in predicting diabetes among Koreans. However, since this research used as a cross-sectional design, casual relationships cannot be inferred. Nevertheless, numerous studies have shown that high BMI and WC can predate morbidity and mortality.^{24,25} Therefore, the results of this study can provide a foundation for developing hypotheses for longitudinal studies.

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