Original Article

# Waist circumference percentile criteria for the pediatric metabolic syndrome in Korean adolescents

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This study aimed to determine valid waist circumference (WC) thresholds using receiver operating characteristic (ROC) curves for pediatric metabolic syndrome (MS) prediction and to compare validities between the thresholds derived from ROC curves and the WC cut-offs defined by International Diabetes Federation (IDF). Four hundred and sixty four males and 415 females, 10–18 years, who participated in the KNHNES 2005 were included. Subjects were classified as having pediatric MS when a high WC and ≥ 2 of the risk factors defined by IDF were present. High WC was defined using either IDF criterion (≥90$^{th}$ percentile for age and sex-specific WC based on Korean reference in adolescents 10-15 years of age, ≥90cm in males and ≥80cm in females 16-18 years of age) or age-adjusted WC thresholds derived from the ROC curves predicting ≥ 2 abnormal risk factors. The AUCs were 0.71-0.81 (sensitivity 74-100%, specificity 52-65%) among males and 0.63-0.76 (sensitivity 71-90%, specificity 37-87%) among females for WC thresholds (55$^{th}$ and 32$^{th}$ percentile for males and females 10-15 years of age, 73cm and 76cm for males and females 16-18 years of age), while the AUCs were 0.65-0.66 (sensitivity 39-45%, specificity 84-93%) among males and 0.53-0.76 (sensitivity 20-57%, specificity 86-96%) among females for IDF-defined WC cut-offs. The prevalence of MS using IDF definition for WC was 4% in males and 2% in females, while those using WC thresholds were 8% and 5%, respectively. The IDF's definition of abdominal obesity may be less sensitive in screening adolescents with pediatric MS compared to WC thresholds.

**Key Words: waist circumference, metabolic syndrome, adolescents, prevalence, Korea**

## INTRODUCTION

The Metabolic syndrome (MS) in adulthood is characterized by an increased risk of type 2 diabetes[1] and high mortality associated with cardiovascular diseases.[2,3] However, the clinical importance of MS as a high risk factor for cardiovascular disease is not restricted to adults. A recent study showed that the presence of MS during childhood predicted cardiovascular disease and MS in adulthood.[4]

Several studies have reported the prevalence of MS in children and adolescents.[5-11] The components of pediatric MS are similar to those seen in adult MS and include obesity, high blood pressure (BP), high fasting glucose levels, high concentrations of triacylglycerol (TG), and low levels of high-density lipoprotein cholesterol (HDL).[12] However, criteria for pediatric MS have not been clearly defined, and thus the prevalence of MS varies depending on the definition used.[10,11] Recently, the International Diabetes Federation (IDF) published a new definition for MS in adolescents 10 years of age or older. According to the IDF definition, MS can be diagnosed when abdominal obesity and at least two of four metabolic risk factors are present. Regarding the definition for abdominal obesity, the IDF recommends the age- and sex-specific 90$^{th}$ percentile as a cut-off value for waist circumference (WC) in adolescents 10-15 years of age and ethnic-specific WC cut-off value for those 16-18 years of age.[13]

In previous studies, the threshold percentiles for WC regarding the clustering of cardio-metabolic risk factors tended to be lower than the threshold percentiles defined by the IDF.[14-17] For example, in the Bogalusa Heart Study, the optimal threshold for WC ranged from the 50$^{th}$ to 57$^{th}$ percentile in white and black adolescents.[15] Likewise, in Chinese adolescents, the optimal WC threshold for the presence of three of the ATP III components was the 74$^{th}$ percentile in females and the 80$^{th}$ percentile in males.[16] Based on these studies, the IDF's definition for abdominal obesity may underestimate the amount of individuals who are at a high risk for developing MS. The IDF has addressed this issue and stated that the defined threshold percentile will be reassessed when more data are available for review.

In the current study, we sought to develop WC threshold percentiles/values for predicting metabolic risk factors of pediatric MS in a representative sample of Korean adolescents using receiver operating characteristic (ROC) curves. We also compared the validity of threshold percentiles/values obtained with the IDF definition for WC cut-off percentiles/values in predicting metabolic risk factors. Finally, we confirmed the associations between the two WC percentiles/values and metabolic risk factors.

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## MATERIALS AND METHODS

### *Subjects*

Data were obtained from the third Korean National Health and Nutrition Examination Survey (KNHANES). The KNHANES was a community-based cross-sectional survey conducted in 2005 by the Korean Ministry of Health and Welfare that used a stratified multistage probability sampling procedure.[18] Complete data were obtained for 7597 individuals 1 year of age or older. Of the 938 adolescents (495 males, 10–18 years old) from whom anthropometric measurements were taken, 879 adolescents (464 males and 415 females) had more extensive testing performed and these data were available for analyses. The ethics committee of Inje University Busan Paik Hospital approved the study.

### *Anthropometric measurements and metabolic risk factors*

Trained research assistants measured the adolescents' height and weight according to standard procedures. Height was measured to the nearest 0.1 cm, weight to the nearest 0.1 kg and BMI was calculated as kg/m$^2$. Overweight was defined using the IOTF-recommended BMI values for each age and sex. These values corresponded to the BMI cut-offs of 25 kg/m$^2$ at 18 years of age. Since BMI cut-off values were provided for each half-year of age, and the age of the current subjects was provided at 1-year intervals, we used the BMI cut-off values for each child at the midyear value as recommended by Cole *et al*.[19] Waist circumference was measured at a level midway between the lowest lateral border of the ribs and the uppermost lateral iliac crest using a tape measure. Blood pressure measurements were performed three times with a standard manual sphygmomanometer while participants were in a sitting position. The means of the second and third BP measurements were used in all analyses. Blood samples were collected and shipped to the central laboratory within 24 hours, where they were analyzed. The participants had fasted for at least 8 hours before blood samples were obtained, and serum TG, HDL, and plasma fasting glucose levels were measured.

### *Definition of MS*

Subjects were classified as displaying pediatric MS if they had a high WC and two or more of the metabolic risk factors present. A high WC was defined using the IDF criteria (age- and sex-specific WC equal to or higher than the 90$^{th}$ percentile for adolescents 10-15 years of age, 90cm for males 16-18 years of age, and 80cm for females 16-18 years of age) or the age- and sex-specific WC threshold percentile/value derived from the ROC curves for predicting two or more abnormal metabolic risk factors. The age- and sex-specific WC cut-off values for the 90$^{th}$ percentile were based on the data recommended by Korean Ministry of Commerce, Industry, and Energy.[20] The criteria for abnormal metabolic risk factors were defined by the IDF: BP ≥ 130/85 mmHg, fasting glucose ≥ 5.6 mmol/L (100 mg/dL), HDL < 1.03 mmol/L (40 mg/dL) for children at the ages of 10-15 years and male adolescents at the ages of 16-19 years, HDL < 1.29 mmol/L (50 mg/dL) for female adolescents at the ages of 16-19 years and TG ≥ 1.7 mmol/L (150 mg/dL).[13]

### *Statistical analyses*

The data were weighted to adjust for differential response rates and variation in probabilities of selection into the sample. Post-stratification weights adjusted sample results to the July 1, 2005, Bureau of the Census population estimates by sex, age, and region of Korea. Since WC increase with age and differ by sex, age-adjusted percentiles for each sex were used in the analyses. To create age-adjusted percentiles, the predicted values for WC were obtained from a full cubic polynomial with respect to age (age 1, age 2, and age 3) using a stepwise regres-

**Table 1.** The descriptive characteristics by gender among Korean adolescents at the ages of 10-18 years

| | Males | | Females | |
|---|---|---|---|---|
| | Unweighted (n=464) mean±SD, N (%) | Weighted mean±SD, % | Unweighted (n=415) mean±SD, N (%) | Weighted mean±SD, % |
| Age (y) | 13.5 ± 2.5 | 13.5 ± 2.5 | 13.4 ± 2.5 | 13.4 ± 2.5 |
| Body mass index (kg/m2) | 21.0 ± 3.9 | 20.9 ± 3.8 | 20.2 ± 3.5* | 20.4 ± 3.5 |
| Waist circumference (cm) | 71.7 ± 10.7 | 71.4 ± 10.4 | 66.6 ± 8.5* | 66.9 ± 8.6 |
| Overweight prevalence by IOTF | 150 (32.4) | 30.6 | 83 (20.0)* | 21.3 |
| WC ≥ 90th percentile (10-15y)[1], 90 cm (males at 16-18y), 80 cm (females at 16-18y) | 79 (17.0) | 16.3 | 53 (12.8) | 14.2 |
| BP ≥ 130/85 mmHg | 29 (6.3) | 6.5 | 11 (2.7)* | 2.8 |
| Glucose ≥ 100 mg/dL | 16 (3.4) | 3.8 | 12 (2,9) | 3.0 |
| HDL < 40 mg/dL (10-15y, males at 16-18y), 50 mg/dL (females at 16-18y) | 184 (39.7) | 37.7 | 145 (34.9) | 36.4 |
| TG ≥ 150 mg/dL | 40 (8.3) | 8.5 | 36 (8.4) | 8.9 |
| Number of abnormal risk factors of MS | | | | |
| ≥ 1 | 215 (46.3) | 45.6 | 174 (41.9) | 43.8 |
| ≥ 2 | 49 (10.6) | 10.1 | 27 (6.5)* | 6.6 |
| 3 | 5 (1.1) | 0.8 | 3 (0.7) | 0.6 |

Abbreviations: WC, waist circumference; BP, blood pressure; HDL, high density lipoprotein cholesterol; TG, triacylglycerol; MS, the metabolic syndrome.

[1] Reference data from Korean Ministry of Commerce, Industry, and Energy (20)

*Significant difference ($p < 0.05$) by $\chi^2$ test between unweighted males and females.

**Table 2.** Threshold values, area under the curves, sensitivity and specificity of WC measure for predicting two or more metabolic risk factors among Korean adolescents at the ages of 10-18 years

| | Percentile (cm) | AUC (95% CI) | Sensitivity (95% CI) | Specificity (95% CI) |
|---|---|---|---|---|
| Age-adjusted WC threshold percentile at 10-15 y | | | | |
| Males | 55 | 0.71 (0.66-0.76) | 74 (55-88) | 65 (60-71) |
| Females | 32 | 0.63 (0.58-0.66) | 90 (68-98) | 37 (32-43) |
| Age-adjusted WC threshold value (cm) at 16-18 y | | | | |
| Males | 73 | 0.81 (0.73-0.88) | 100 (81-100) | 52 (42-63) |
| Females | 76 | 0.76 (0.66-0.84) | 71 (29-96) | 87 (78-93) |
| WC threshold percentile by IDF at 10-15 y | | | | |
| Males | 90 | 0.65 (0.59-0.70) | 45 (27-64) | 84 (79-88) |
| Females | 90 | 0.53 (0.48-0.59) | 20 (6-44) | 86 (82-90) |
| WC threshold value (cm) by IDF at 16-18 y | | | | |
| Males | 90 | 0.66 (0.57-0.74) | 39 (17-64) | 93 (86-97) |
| Females | 80 | 0.76 (0.67-0.84) | 57 (19-90) | 96 (89-99) |

Abbreviations: WC, waist circumference; IDF, International Diabetes Federation; AUC, area under the curve; CI, confidence interval.
[1] Reference data from Korean Ministry of Commerce, Industry, and Energy (20)

**Table 3.** The weighted prevalence of the MS using the IDF definition for WC cutoffs and WC thresholds obtained from Korean adolescent at the ages of 10-18 years

| | IDF-defined WC +2 or more MS components | WC ≥ threshold percentile (10-15y), cutoff value (16-18y) + 2 or more MS components |
|---|---|---|
| Total | 3.1 | 6.4 |
| Males | 4.3 | 7.9 |
| 10-15 years | 3.9 | 5.9 |
| 16-18 years | 5.6 | 14.1 |
| Females | 1.9 | 4.6 |
| 10-15 years | 1.2 | 4.4 |
| 16-18 years | 4.2 | 5.4 |

Abbreviations: MS, metabolic syndrome; WC, waist circumference; IDF, International Diabetes Federation; BP, blood pressure; HDL, high density lipoprotein cholesterol; TG, triacylglycerol.
IDF-defined WC: WC ≥ 90$^{th}$ percentile (adolescents at 10-15years old) [1], 90cm (males at 16-18 years old), 80cm (females at 16-18 years old)
[1] Reference data from Korean Ministry of Commerce, Industry, and Energy (20)

sion model for each sex in adolescents at the ages of 10-15 years. The predicted WC was then subtracted from the measured WC for each child. The residuals of WC for each adolescent were standardized to represent age-adjusted *z*-scores of WC and were then transformed to age-adjusted percentiles of WC. Receiver operating characteristic curves were applied to identify age-adjusted WC threshold percentiles for adolescents 10-15 years of age and WC threshold values for those 16-18 years of age that predict the presence of at least two metabolic risk factors in each sex. From the ROC curves, we calculated the sensitivity, specificity, and areas under the ROC curves (AUCs) for age-adjusted and sex-specific WC threshold percentiles and WC 90$^{th}$ percentiles as recommended by the Korean Ministry of Commerce, Industry, and Energy for adolescents 10-15 years of age,[20] and sex-specific WC cut-off values and IDF-defined WC cutoff values (90cm for males and 80cm for females) for adolescents 16-18 years of age. Multiple comparison of the ROC analyses were used to compare the two AUCs derived from the two percentiles for adolescents 10-15 years of age and the two AUCs derived from the two WC values for adolescents 16-18 years of age. Logistic regression analyses were used to calculate the odds ratios (ORs) for those WC percentiles and values with abnormal values of metabolic risk factors for MS in each sex after adjusting for age. Statistical significance was set at $p < 0.05$. All statistical analyses were conducted with the software package SPSS 12.0K for Windows (Release 12.0.1; SPSS Inc., Chicago, IL, USA) and MedCalc version 9.3.0.0 (MedCalc Software, Mariakerke, Belgium).

## RESULTS

The weighted and unweighted distribution of individual components of MS is shown in Table 1. The prevalence of overweight defined by the IOTF and abdominal obesity defined by the IDF was 31% and 16%, respectively for males, while those values were 21% and 14%, respectively for females. Likewise the percentage of children having two or more of the MS components was 10% for males, the value for female adolescents was 7%. Among individual components of MS, low HDL was the most common factor and high fasting glucose in male adolescents and high BP in female adolescents were the least common abnormalities observed.

The age-adjusted thresholds for WC derived from the ROC analysis was 55$^{th}$ and 32$^{th}$ percentiles in males and females 10-15 years of age, and 73cm and 76cm in males and females 16-18 years of age, respectively. At the threshold percentiles/values for WC, 71–100% of adolescents were correctly classified as having two or more MS components (sensitivity) and 37–87% of them were correctly classified as not having two or more MS components (specificity). However, using the IDF definition for WC, sensitivity was calculated as 20–57% and specificity was 84–96% (Table 2). There was no significant differences between two AUCs obtained using WC threshold percentiles/values in each sex and age groups (Figure 1).

Table 3 shows the weighted prevalence of pediatric MS using the two WC definitions. Three percent of adolescents (4% of males and 2% of females) were classified

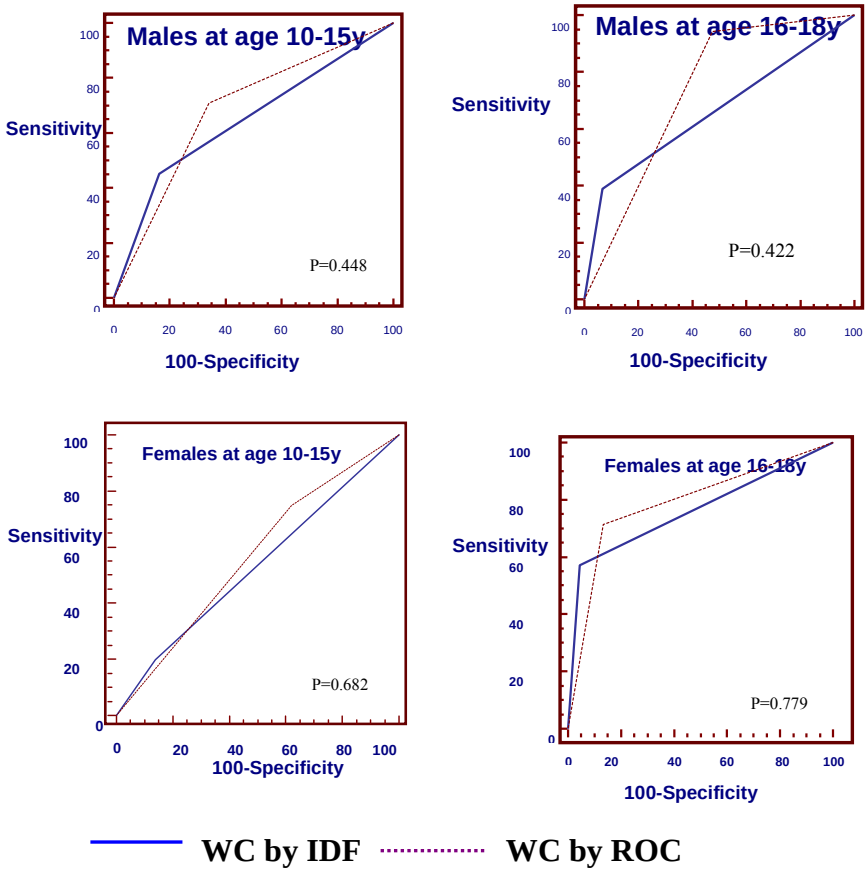


**Figure 1.** Comparison of receiver operating curves between age-adjusted waist circumference (WC) thresholds by ROC curves and WC threshold by IDF for predicting two or more metabolic risk factors among Korean adolescents.
Note: WC threshold by ROC (55 percentile for males and 32 percentile for females 10-15 years of age, 73cm and 76cm for males and females 16-18 years of age) and WC threshold by IDF (90$^{th}$ percentile based on the reference data from Korean Ministry of Commerce, Industry, and Energy for adolescents 10-15 years of age, 90cm and 80cm for males and females 16-18 years of age).
Multiple comparisons of ROC curves showed no statistical significance between the two threshold percentiles/values

as having MS using the IDF definition, while 6% (8% of males and 5% of females) were so identified using WC threshold percentiles/values. Among males 16-18 years of age, the prevalence of MS rose to 6% using the IDF definition and 14% using the WC threshold value. In contrast, that prevalence is the lowest in females 10-15 years of age regardless of the definitions.

Associations between WC threshold percentiles/values and abnormal values of metabolic risk factors are presented in Table 4. Those associations were generally stronger among male adolescents than among female adolescents. However, the magnitudes of associations between the WC threshold percentiles/values and the risk of having at least two abnormal components of MS were

**Table 4.** The weighted and age-adjusted odds ratios (95% CIs) for the presence of abnormal components of MS with WC thresholds among Korean adolescents at the ages of 10-18 years

| | Percentile cm[1] | BP ≥ 130/85mmHg | Glucose ≥ 100mg/dL | HDL < 40mg/dL | TG ≥ 150mg/dL | MS components≥ 2 |
|---|---|---|---|---|---|---|
| Males | | | | | | |
| Age-adjusted WC threshold | 55tile 73cm | 2.2 (2.22-2.26) | 3.4 (3.35-3.44) | 1.9 (1.87-1.88) | 7.5 (7.44-7.59) | 5.8 (5.73-5.84) |
| WC threshold by IDF | 90tile 90cm | 1.7 (1.67-1.71) | 4.9 (4.80-4.91) | 2.7 (2.74-2.78) | 5.6 (5.55-5.64) | 5.5 (5.42-5.51) |
| Females | | | | | | |
| Age-adjusted WC threshold | 32tile 76cm | 5.7 (5.61-5.82) | 1.7 (1.65-1.71) | 2.3 (2.27-2.30) | 3.4 (3.41-3.49) | 2.1 (2.06-2.10) |
| WC threshold by IDF | 90tile 90cm | 3.3 (3.20-3.31) | 1.1 (1.04-1.08) | 4.7 (4.70-4.77) | 2.4 (2.33-2.37) | 2.5 (2.53-2.58) |

Abbreviations: CIs, confidence intervals; MS, metabolic syndrome; WC, waist circumference; IDF, International Diabetes Federation; BP, blood pressure; HDL, high density lipoprotein cholesterol; TG, triacylglycerol.
[1]Percentile for adolescents at 10-15years old and cm for adolescents at 16-18 years old
[2] Reference data from Korean Ministry of Commerce, Industry, and Energy (20)

**Table 5.** Prevalence of the metabolic syndrome and risk factors in Korean adolescents of the Korean National Health and Nutrition Examination Survey 1998, 2001, and 2005

| Prevalence(%) | 1998* | | 2001* | | 2005* | |
|---|---|---|---|---|---|---|
| | Males (*n*= 649) | Females (*n*=668) | Males (*n*=432) | Females (*n*=416) | Males (*n*=464) | Females (*n*=415) |
| Metabolic syndrome | 6.6 | 6.9 | 12.5 | 5.8 | 10.6 | 5.6 |
| Abdominal obesity | 10.3 | 19.6 | 16.2 | 18.5 | 18.8 | 14.2 |
| High triacylglycerol | 21.9 | 24.8 | 32.4 | 28.6 | 22.6 | 23.4 |
| Low HDL cholesterol | 15.8 | 11.2 | 37.0 | 14.2 | 39.7 | 24.6 |
| High fasting glucose | 8.3 | 6.0 | 8.1 | 5.5 | 0.4 | 0 |
| Elevated blood pressure | 28.4 | 22.3 | 28.2 | 10.8 | 17.2 | 10.4 |

Note: metabolic syndrome ≥ 3 components of risk factors; abdominal obesity, waist circumference (WC) ≥ age- and gender-specific 90 percentile of WC (20); high triacylglycerol ≥ 1.24 mmol/L (110 mg/dL); low HDL cholesterol < 1.03 mmol/L (40 mg/dL); high fasting glucose ≥ 6.1 mmol/L (110 mg/dL); elevated blood pressure (BP) ≥ age-, gender-, and height-specific 90$^{th}$ percentile of systolic or diastolic BP (20, 21).
*Adolescents at the ages between 12 and 19 years in 1998 and 2001 (7) and between 10 and 18 years in 2005.

similar to those magnitudes for the IDF-defined WC cut-offs in each sex.

## DISCUSSION

This study presents the prevalence of MS among 10–18-year-old Korean adolescents obtained from the third KNHANES 2005 using two separate definitions. One definition is recommended by the IDF and the other is based on threshold percentiles/values for WC that predicts abnormal metabolic risk factors for MS. The weighted prevalence of MS using the IDF definition was 3%; however, the prevalence rose to 6% after redefining the WC threshold from the 90$^{th}$ percentile to the 55$^{th}$ percentile in male adolescents and the 32$^{th}$ percentile in female adolescents 10-15 years of age, from 90cm to 73cm in male adolescents 16-18 years of age, and from 80cm to 76cm in female adolescents 16-18 years of age.

The key finding in this cross-sectional study is that the IDF definition of age- and sex-specific WC percentiles/values for abdominal obesity is less likely to identify adolescents with abnormal levels of metabolic components as compared to age-adjusted sex-specific threshold percentiles/values for WC. Although a greater number of subjects are correctly classified as not having abnormal metabolic risk factors using the IDF definition for WC rather than the WC threshold derived from the current study, the IDF definition of WC is able to correctly identify only 20–57% of subjects as having at least two abnormal metabolic risk factors.

Direct comparisons of pediatric MS prevalence across studies are hampered due to differences in the definition of the syndrome. For example, the prevalence of MS using the definition by Cook *et al.*[5] in male adolescents between the ages of 12 and 19 from the KNHANES in 1998 and 2001 were 6.6% and 12.5%, respectively; prevalence in female adolescents were 6.9% and 5.8%, respectively.[7] According to the definition used in study by Kim et al.[7], WC was not regarded as a prerequisite component in classifying adolescents as having MS, but instead was regarded as one of the components of MS. Additionally, the cut-off values of metabolic risk factors except for low HDL were different from those values in current study. The prevalence of MS in adolescents using the same criteria[3] used in study by Kim et al. [7] across three KNHANES data was shown in Table 5 For male adolescents, the prevalence of MS in 2005 increased compared with that in 1998 but was almost the same with the prevalence in 2001. Additionally, the prevalence of MS defined by the criteria by *Cook et al.* [3] is greater compared with that prevalence defined by the IDF.[13] Our finding of 3 to 6% MS is in accordance with the prevalence of pediatric MS from Finnish data (4%),[22] U.S. data (4–6%), [5,6] and Indian data (4%).[8] However, the definitions for pediatric MS and the ages of the subjects vary among these studies.

Earlier studies regarding age- and sex-specific WC threshold percentiles for predicting cardiovascular risk factors using ROC curves found lower threshold percentiles than 90. The threshold percentiles were 74–80 using data from Chinese children[16] and 50–57 based on the Bogalusa Heart Study.[15] The AUCs ranged from 0.75 to 0.82, and the sensitivity and specificity ranged from 63% to 81%, respectively, in the Chinese data. Likewise, the AUCs ranged from 0.74 to 0.82, and the sensitivity and specificity ranged from 68% to 75% in the Bogalusa data.

Much controversy exists regarding labeling the clustering of metabolic risk factors as a syndrome.[23] However, it is important to note that the syndrome in adults is an entity associated with the risk of future morbidity and mortality due to cardiovascular disease[2,3] and the presence of the MS in childhood. Therefore, early identification of the clustering of risk factors in childhood may be valuable in targeting efforts for chronic disease prevention. Based on the need for early detection of adolescents at risk, the adoption of a WC threshold with higher sensitivity rather than the WC threshold with higher specificity may be more appropriate. Additionally, the question remains as to whether WC threshold values that are ethnic- and sex-specific are more sensitive than a single threshold value across sexes and ethnicities. The use of a uniform definition for WC may be easier to apply even though it will be less sensitive in identifying adolescents with abnormal metabolic risk factors.[23]

Although our findings and work in other populations suggest that WC threshold percentiles among pediatric MS components may be lower than WC thresholds defined by the IDF, the optimal single threshold value for WC should be established through further research. Studies must also consider whether WC threshold percen-

tiles/values used for classifying pediatric MS will predict the risk of MS and cardiovascular disease in adulthood. The strength of the present study is that subjects included in KHANES 2005 are a representative sample of adolescents in Korea. Therefore, the results of this study may be generalized to Korean adolescents. However, additional studies in other populations and longitudinal data are necessary to determine the optimal WC threshold across ethnicities and genders.

In conclusion, age- and sex-specific WC threshold percentiles/values regarding metabolic risk factors among Korean adolescents 10–18 years of age were lower compared to those values recommended by the IDF. These WC percentiles/values may be more sensitive for screening pediatric MS as compared to WC threshold values defined by the IDF. More research is necessary to establish a single optimal WC threshold percentile for pediatric MS.

**AUTHOR DISCLOSURES**

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**REFERENCES**

1. Hanson RL, Imperatore G, Bennett PH, Knowler WC. Components of the "metabolic syndrome" and incidence of type 2 diabetes. Diabetes. 2002; 51: 3120-3127.
2. Lakka HM, Laaksonen DE, Lakka TA et al. The metabolic syndrome and total and cardiovascular disease mortality in middle-aged men. JAMA. 2002; 288: 2709-2716.
3. Andreadis EA, Tsourous GI, Tzavara CK et al. Metabolic syndrome and incident cardiovascular morbidity and mortality in a Mediterranean hypertensive population. Am J Hypertens. 2007; 20(5): 558-564.
4. Morrison JA, Friedman LA, Gray-McGuire C. Metabolic syndrome in childhood predicts adult cardiovascular disease 25 years later: The Princeton Lipid Research Clinics Follow-up Study. Pediatrics. 2007; 120(2): 340-345.
5. Cook S, Weitzman M, Auinger P, Nguyen M, Dietz WH. Prevalence of a metabolic syndrome phenotype in adolescents: Findings from the third National Health and Nutrition Examination Survey, 1988-1994. Arch Pediatr Adolesc Med. 2003; 157(8): 821-827.
6. Duncan GE, Li SM, Zhou X. Prevalence and trends of a metabolic syndrome phenotype among US adolescents, 1999-2000. Diabetes Care. 2004; 27(10): 2438-2443.
7. Kim HM, Park J, Kim H, Kim DH. Prevalence of the metabolic syndrome in Korean adolescents aged 12-19 years from the Korean National Health and Nutrition Examination Survey 1998 and 2001. Diabetes Res Clin Pract. 2007; 75(1): 111-114.
8. Singh R, Bhansali A, Sialy R, Aggarwal A. Prevalence of metabolic syndrome in adolescents from a north Indian population. Diabet Med. 2007; 24(2): 195-199.
9. Vissers D, Vanroy C, De Meulenaere A, Van de Sompel A, Truijen S, Van Gaal L. Metabolic syndrome in youth: A cross-sectional school-based survey. Acta Paediatr. 2007; 96(12): 1809-1813.
10. Golley RK, Magarey AM, Steinbeck KS, Baur LA, Daniels LA. Comparison of metabolic syndrome prevalence using six different definitions in overweight pre-pubertal children enrolled in a weight management study. Int J Obes. 2006; 30(5): 853-860.
11. Reinehr T, de Sousa G, Toschke AM, Andler W. Comparison of metabolic syndrome prevalence using eight different definitions: a critical approach. Arch Dis Child. 2007; 92 (12): 1067-1072.
12. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). JAMA. 2001; 285(19): 2486-2497.
13. Zimmet P, Alberti G, Kaufman F et al. The metabolic syndrome in children and adolescents. Lancet. 2007; 369 (9579):2059-2061.
14. Moreno LA, Pineda I, Rodríguez G, Fleta J, Sarría A, Bueno M. Waist circumference for the screening of the metabolic syndrome in children. Acta Paediatr. 2002; 91 (12): 1307-1312.
15. Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, Berenson GS. Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. Pediatrics. 2004; 114(2). e198-205.
16. Sung RY, Yu CC, Choi KC et al. Waist circumference and body mass index in Chinese children: cutoff values for predicting cardiovascular risk factors. Int J Obes. 2007; 31 (3): 550-558.
17. Hirschler V, Maccallini G, Calcagno M, Aranda C, Jadzinsky M. Waist circumference identifies primary school children with metabolic syndrome abnormalities. Diabetes Technol Ther. 2007; 9(2): 149-157.
18. The third Korea National Health and Nutrition Examination Survey (KNHANES III), 2005. Ministry of Health and Welfare 2006.
19. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000; 320 (7244): 1240-1243.
20. Agency for Technology and Standards. The fifth National Anthropometric Survey of Korea. Gyeonggi-do, Korea, Ministry of Commerce, Industry and Energy, 2004.
21. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The Fourth Report of on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. Pediatrics. 2004; 114: 555–76.
22. Raitakari OT, Porkka KV, Ronnemaa T et al. The role of insulin in clustering of serum lipids and blood pressure in children and adolescents. The Cardiovascular Risk in Young Finns Study. Diabetologia. 1995; 38: 1042-1050.
23. Cruz ML, Goran MI. The metabolic syndrome in children and adolescents. Curr Diab Rep. 2004; 4(1): 53-62.

Original Article

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# 腰圍百分位標準預測韓國青少年的小兒代謝症候群

本研究的目的是用接受者操作特徵(ROC)曲線訂出腰圍閾值來做小兒代謝症候群的預測，並與國際糖尿病組織(IDF)訂出的腰圍切點之效度做比較。參與2005年KNHNES的464位男生與415位女生(年齡10-18歲)為研究對象。研究對象若有高腰圍及有兩項或以上IDF定義的危險因子則被歸為有小兒代謝症候群。高腰圍定義或根據IDF標準(10-15歲者是以韓國青少年的參考值，大於或等於同性別及同年齡90百分位為分界；16-18歲者以男生腰圍≥90 cm，女生≥80 cm為切點)或根據ROC曲線推衍的年齡校正後的腰圍閾值，此閾值能預測兩項或以上的危險因子。以腰圍閾值(10-15歲男生與女生分別為55及32百分位；16-18歲男生腰圍73 cm，女生76 cm)預測男生曲線下面積(AUC)為0.71-0.81(敏感度74-100%，特異度52-65%)，女生AUC為0.63-0.76(敏感度71-90%，特異度37-87%)。以IDF的腰圍切點預測男生AUC為0.65-0.66(敏感度39-45%，特異度84-93%)，女生AUC為0.53-0.76(敏感度20-57%，特異度86-96%)。使用IDF定義，代謝症候群的盛行率為男生4%，女生2%。但以腰圍閾值預測盛行率為男生8%，女生5%。對腹部肥胖的青少年以IDF的定義預測代謝症候群之敏感度似乎不及腰圍閾值。

**關鍵字：腰圍、代謝症候群、青少年、韓國、盛行率**