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Cutoff Values of Body Mass Index and Body Fat Measures for Metabolic Syndrome in Korean Population

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This study investigated cut-off values of body mass index (BMI) and body fat measures for metabolic syndrome (MS) in elderly Koreas. Questionnaire surveys, anthropometric measurements, medical examinations, and body composition analyses were conducted for 10,077 subjects aged 40-65 years in the health examinee cohort in Korea between 2004 and 2006. Cut-off values were identified using receiver-operating characteristic (ROC) curve analysis for both men and women. Stratified analyses by weight range (<60, 60-69, 70-79, and 80-89, ≥90 kg for men; <50, 50-59, 60-69, 70-79, ≥80 kg for women) were conducted. Among male subjects, the cut-off points were 25.5 kg/m^2 for BMI with a sensitivity of 70.0% and a specificity of 72.0%, and 26.1% for body fat percentage with a sensitivity of 60.6% and a specificity of 76.4%. Among female subjects, the cutoff points were 24.1 kg/m^2 for BMI with a sensitivity of 73.3% and a specificity of 68.8%, and 31.5% for body fat percentage with a sensitivity of 76.7% and a specificity of 65.6%. Stratified analysis by weight range showed that the cutoff points of BMI and body fat measures tended to higher as weight level increased. The results of our study suggest cut-off values of BMI and body fat measure for MS were similar to the general obesity criteria in Korea.

Key words : Metabolic syndrome, body mass index, body fat, cut-off

Introduction

Metabolic syndrome is a group of diseases including obesity, abnormal lipid metabolism, diabetes or glucose intolerance, and hypertension. With the common characteristic of insulin resistance, they are closely associated with the occurrence of cardiovascular diseases [5,8,19]. Third Report of the National Cholesterol Education Program Adults Treatment Panel (NCEP-ATP III) [16] states that in order to treat hyperlipidemia for the prevention of cardiovascular diseases, the first goal is to lower LDL (Low-density lipoprotein)-cholesterol and the second goal is to treat metabolic syndrome.

Obesity is an independent risk factor of cardiovascular diseases. In particular, abdominal obesity is a component of criteria in diagnosing metabolic syndrome. Obesity is defined as a state of excessive body fat, and is diagnosed when body fat percentage is 25% and higher for males and 30% and higher for females [4]. In practice, BMI is primarily used to diagnose obesity. But, many studies [6,11,20], have revealed that the prevalence of risk factors for cardiovascular diseases increases for Asians who are not categorized as obese on the basis of BMI criteria. One of the methods to analyze body composition, body impedance analysis (BIA), is also a means of diagnosing obesity. It is possible to use BIA to measure fat-free mass and body fat is can be measured by subtracting the fat-free mass from the weight [22]. BIA uses a simple device and quickly produces objective; hence, it is used in a range of areas. However, it has not been used as a standard measurement of obesity due to controversial opinions regarding its clinical significance for body fat measurement.

This study presents cut-offs for the BMI and body composition by BIA according to weight range to identify the metabolic syndrome compared with the general obesity criteria in 10,077 subjects aged 40-65 years old using a ROC curve. The study attempts to contribute to the establishment of clinical indexes for identifying metabolic syndrome for many Asians, especially Koreans who are not categorized as obese on the basis of as BMI and body composition criteria having

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risk factors of cardiovascular disease.

Materials and Methods

Study subjects

Adults aged 40 and older who had health examinations in the 10 hospitals in Korea from 2004 to 2006. A total of 13,910 subjects were recruited into the study after obtaining informed consent. Data that was missing one out of the five diagnostic criteria of metabolic syndrome were excluded and also subjects who have over 65 years old were excluded, leaving the 10,077 subjects that were included in the final analysis. The study design was approved by the committee on human research of the participating hospital.

Questionnaire

Questionnaires included basic demographic characteristics regarding the age, sex, marital status, and educational attainments of the subjects. Marital status was divided into married and not married; and educational attainment was divided according to the level of higher education. A history of alcohol consumption was divided according to current, past, and none. Classification and definition of smokers were 'non-smokers' who have never smoked cigarettes, 'ex-smokers' who smoked sometimes or regularly in the past but no longer smoked at the time of the survey, and 'current smokers' who smoked sometimes or regularly at the time of survey. In terms of exercise, people were divided into those who exercise regularly and those who do not.

Anthropometric measurement

Height and weight were measured by using a height-weight automatic scale; height was measured in units of 0.1 cm, and weight in units of 0.1 Kg. BMI was calculated by dividing subject's weight (kg) by the square of their height (m^2).

Waist circumference measurements were made when subject is stood erect with his or her arms on either side with the feet together. A measuring tape was wrapped horizontally around the waist, and the narrowest part of the upper body was measured when the subject exhaled while breathing normally with no excess pressure on the skin, in units of 0.1 cm. Occasionally in the case of obese subjects whose narrowest part of the waist was difficult to discriminate, the smallest girth was measured between the ribs and the iliac crest. The waist circumferences defining abdominal obesity were 90 cm for men and 80 cm for women [22].

Clinical examination

Blood pressure was measured twice while a subject sat after a 10-minute rest by a mercury sphygmomanometer (Baumanometer, USA). The appearance of the first sound (phase 1 Korotkoff sound) was used to define systolic pressure and the disappearance of sound (phase 5 Korotkoff sound) was used to define diastolic blood pressure. When the two measures differed by more than 5 mmHg, another measurement was taken. Subjects were instructed not to smoke and to limit caffeine intake prior to the measurements.

Blood was drawn from a vein after subjects had fasted for more than 12 hours. After centrifugation, triglycerides, HDL (High-density lipoprotein)-cholesterol, and fasting glucose were measured by an auto-analyzer (Hitachi 7600-020 auto-analyzer, Japan).

Body composition analysis

Body composition analysis was done with a body composition analyzer (Zeus 9.9, Jawon, Korea) using bioelectrical impedance analysis. Subjects were instructed to urinate prior to the measurements, and body fat weight (kg), body fat percentage (%), visceral fat (kg), and muscle mass (kg) were measured.

Diagnostic criteria of metabolic syndrome

Diagnostic criteria of metabolic syndrome were defined based on NCEP-ATP III. When three out of five items in the diagnostic criteria were positive, metabolic syndrome was diagnosed. The cut-off of waist circumference was based not on NCEP-ATP III which is the western criteria but on that of the WHO Western Pacific Region. Thus when the waist circumference for a man was more than 90 cm and that for a woman was more than 80 cm, subjects were considered abdominally obese.

(a) Abdominal obesity: waist circumference - man $\geq$90 cm,
waist circumference - woman $\geq$80 cm
(b) Triglyceride: $\geq$150 mg/dl
(c) HDL-cholesterol: men $<$40 mg/dl, women $<$50 mg/dl
(d) Blood pressure: systolic $\geq$130 mmHg or diastolic $\geq$85 mmHg or anti-hypertensive medication
(e) Fasting glucose: $>$110 mg/dl

Statistical analysis

The data for this study was analyzed by using the statistical software program SPSS Version 12.0. Frequency, mean, and the standard deviation of subjects' general characteristics, lifestyles, and anthropometric measurements were obtained by using descriptive statistics. From the result of the body composition analysis, the mean differences between men and women were analyzed by using the Student's t-test, and the mean differences in the weight of men and women were analyzed by using ANOVA. For all men and women subjects by weight, when the area under the curve on a coordinate with the x-axis as '1- specificity' and the y-axis as 'sensitivity' was more than 0.5, the results of BMI and body composition analysis were considered to have diagnostic value. Of those with diagnostic value, the points with the largest sum of sensitivity and specificity were identified as cut-off points. Age, sex, height, weight and lifestyle variables that could affect the results of the BMI and body composition were analyzed in terms of their degree of contribution through multiple logistic regression analysis.

Results

Demographic characteristics

The 10,077 subjects included 2,935 men and 7,142 women. The mean ages for the men and women were 51.15±6.9 and 49.34±6.3, respectively, and the percentages of married subjects were 92.7% for men and 87.4% for women. The percentages of men and women who had attained a higher level of education were 38.3% and 20.9%, respectively.

72.1% of male participants and 29.0% of female participants reported that they consumed alcohol at the time of the study, showing a percentage for men that was 2.5 times that for women. Additionally, 33.6% of men and 2.0% of women were current smokers with the percentage of men nearly 15 times that of women. It was found that similar percentages of men (55.3%) and women (55.4%) exercised regularly (Table 1).

Anthropometric measurement

The average height of the male subjects was 168.5±5.6 cm and their distribution by weight was in the order of 39.6% between 60-69 kg, 35.4% between 70-79 kg. The average height of the women was 156.7±5.1 cm and their distribution by weight was 50.9% between 50-59 kg, 30.4% between 60-69 kg. With a cut-off of 25 kg/m^2 BMI, prevalence rates of obesity were 42.9% for men and 27.9% for women (Table 2)

Table 1. Demographic characteristics of study subjects

Variables	Male (n=2,935)	Female (n=7,142)
Age (years)	51.1±6.9	49.3±6.3
Marital status		
Married	2,722(92.7)	6,241(87.4)
Others	195(6.7)	859(12.0)
Unknown	18(0.6)	42(0.6)
Education		
< 12 years	1,745(59.5)	5,495(77.0)
≥ 12 years	1,115(38.3)	1,495(20.9)
Unchecked	65(2.2)	152(2.1)
Alcohol drinking		
Current	2,115(72.0)	2,074(29.0)
Past	281(9.6)	289(4.1)
Non	527(18.0)	4,620(64.7)
Unchecked	12(0.4)	159(2.2)
Smoking		
Current smoker	987(33.6)	144(2.0)
Ex-smoker	1,146(39.0)	116(1.6)
Non-smoker	785(26.8)	6,640(93.0)
Unchecked	17(0.6)	242(3.4)
Exercise, regularly		
Yes	1,624(55.3)	3,959(55.4)
No	1,288(43.9)	3,124(43.8)
Unchecked	23(0.8)	59(0.8)

(Mean±SD, N (%)) SD: standard deviation; N: numbers

Prevalence of metabolic syndrome

For both male and female subjects, as their weight increased, the prevalence of metabolic syndrome increase significantly (Table 3).

Table 2. Anthropometric measurements in study subjects (Mean±S.D., N (%))

Variables	Male (n=2,935)	Variables	Female (n=7,142)
Height (cm)	168.5±5.6	Height (cm)	156.7±5.1
Body Weight (kg)		Body weight (kg)	
		< 50	844(11.8)
< 60	350(11.9)	50 - 59	3,636(50.9)
60 - 69	1,163(39.6)	60 - 69	2,171(30.4)
70 - 79	1,038(35.4)	70 - 79	411(5.8)
80 - 89	331(11.3)	≥ 80	80(1.1)
≥ 90	53(1.8)		
BMI (kg/m^2)		BMI (kg/m^2)	
< 25	1,676(57.1)	< 25	5,151(72.1)
≥ 25	1,259(42.9)	≥ 25	1,991(27.9)

Table 3. Prevalence of metabolic syndrome in study subjects according to body weight (kg) by sex

Variables	N (%)
Male* (n=2,935)	
< 60	17(4.9%)
60 - 69	113(9.7%)
70 - 79	284(27.4%)
80 - 89	153(46.2%)
≥ 90	42(79.3%)
total	609(20.8%)
Female* (n=7,141)	
< 50	17(2.0%)
50 - 59	341(9.4%)
60 - 69	526(24.2%)
70 - 79	156(38.0%)
≥ 80	47(58.8%)
total	1,087(15.2%)

*: $p < 0.05$

Validity of body composition analysis and BMI in diagnosis of metabolic syndrome

When obesity was diagnosed with the western criteria of body fat percentage, the percentages of men and women were 44.9% and 57.2%, respectively.

For the male subjects, the areas under the ROC curves of the BMI and body fat percentage for metabolic syndrome were 0.78 and 0.74, respectively. The cut-off point of BMI with the largest sum of sensitivity and specificity was 25.5 kg/m^2 with sensitivity of 70.0% and specificity of 72.0% similar to the obesity criteria. The cut-off point of body fat percentage was 26.1% with sensitivity of 60.6% and specificity of 76.4% similar to the general obesity criteria. When they were analyzed by weight groups, it was found that the critical points of the body composition analysis and BMI increased as the weight increased. The BMI and body fat percentage of the 70-79 kg group was 25.5 kg/m^2 and 26.2%, which is similar to the general obesity criteria (Fig. 1).

For the female subjects, the areas below the ROC curves of the BMI and body fat percentage for metabolic syndrome were 0.77 and 0.77, respectively, with diagnostic values in the order of BMI and body fat percentage. The critical point of BMI with the largest sum of sensitivity and specificity was 24.1 kg/m^2 with sensitivity of 73.3% and specificity of 68.8% similar to the general obesity criteria. The critical point of body fat percentage was 31.5% with sensitivity of 76.7% and specificity of 65.6% similar to the general obesity criteria. When they were analyzed by weight groups, it was found that the critical points of the body fat percentage and BMI increased as the weight increased. The BMI values and body fat percentages of the 60-69 kg groups were 25.6 kg/m^2 and 31.5% respectively, which is similar to the general obesity criteria (Fig. 2).

After adjusting all variables including sex, age and life-style variables including alcohol consumption, smoking, and regular exercise, multivariate logistic regression analysis was performed with metabolic syndrome as a dependent variable. The results showed that as the body fat percentage, muscle mass, and BMI increase, the risk of metabolic syndrome increase significantly (Table 4).

Discussion

BMI is widely accepted as it is easy to measure and it has a high correlation with risk factors of cardiovascular

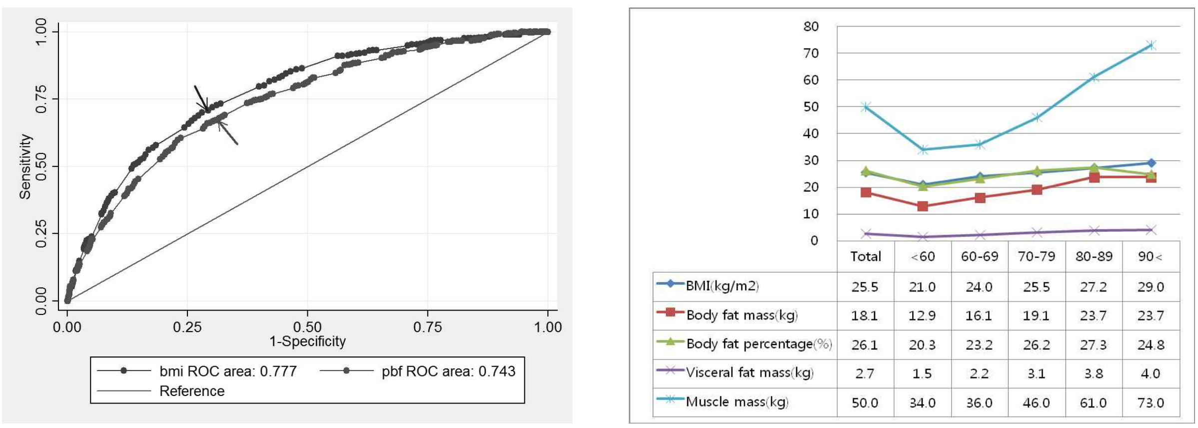

Fig. 1. ROC curve of metabolic syndrome in men: The arrow shows the obtained body mass index and body fat percentage corresponding to the highest sensitivity and specificity values. The cut-off point for the body composition analysis and body mass index that have diagnostic value in men's metabolic syndrome according to body weight is shown.

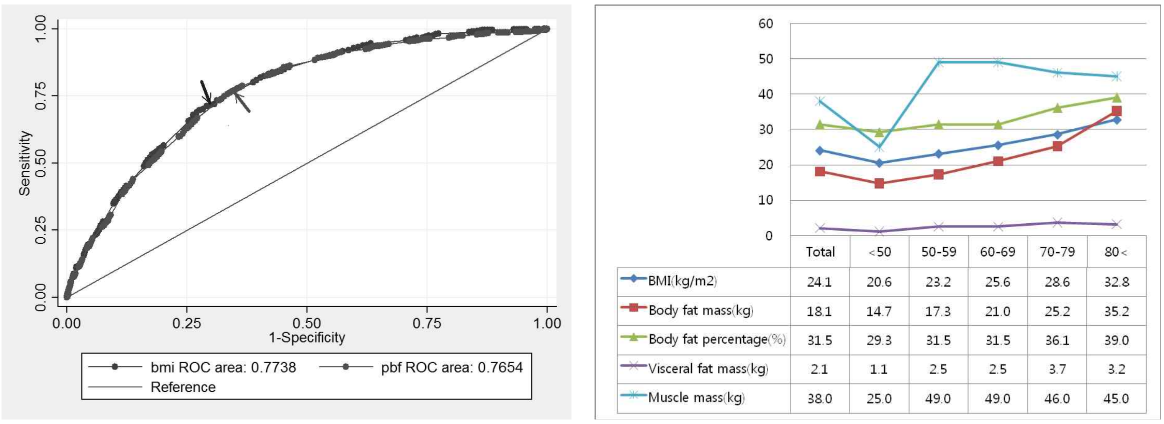

Fig. 2. ROC curve of metabolic syndrome in women: The arrow shows the obtained body mass index and body fat percentage corresponding to the highest sensitivity and specificity cut-off point for the body composition analysis and body mass index that have diagnostic value in women's metabolic syndrome according to body weight is shown.

Table 4. Multivariate logistic analysis of body composition to metabolic syndrome after adjusting for sex, age and life habit factors

Variables	Odd ratio [95% Confidence interval]	
	Male (n=2,935)	Female (n=7,142)
BMI (kg/m^2)	6.34 [5.14 - 7.82]	4.53 [3.93 - 5.23]
Body fat percentage (%)	1.28 [1.24 - 1.32]	1.22 [1.20 - 1.25]
Visceral fat mass (kg)	1.17 [1.07 - 1.27]	1.05 [1.03 - 1.07]
Muscle mass (kg)	1.14 [1.12 - 1.16]	1.15 [1.13 - 1.17]
Age (year)*	1.01 [1.00 - 1.03]	1.11 [1.10 - 1.12]
Alcohol drinking*		
None	1.0	1.0
Past	1.11 [0.77 - 1.60]	0.88 [0.63 - 1.22]
Current	1.26 [0.98 - 1.61]	0.64 [0.55 - 0.74]
Smoking*		
non-smoker	1.0	1.0
ex-smoker	1.09 [0.87 - 1.37]	0.58 [0.31 - 1.08]
current smoker	1.28 [1.01 - 1.61]	1.39 [0.92 - 2.10]
Exercise, regularly*		
Yes	1.0	1.0
No	1.17 [0.98 - 1.41]	1.32 [1.16 − 1.50]

BMI: Body mass index; * resulted by simple logistic regression

diseases. According to the WHO Western Pacific Region criteria which was based for Asians, a person with a BMI of over 23 and less 25 kg/m^2 is considered as overweight and someone with a BMI of 25 kg/m^2 or higher is considered as obese; this diagnostic criteria of obesity is used in Korea as well.

Body fat can cause an increase of total cholesterol, triglycerides, and LDL-cholesterol, increasing the risk of cardiovascular diseases. It is necessary to directly measure body fat in order to assess and treat obesity more accurately. BIA, which is used in this study, has advantages in that it is simple to obtain by measurements and is relatively inexpensive. Thus, it is popular in practice. Moreover, it has a high correlation with Dual Energy X-ray Absorptiometry (DXA) that is a well-known standard method of body fat measurement and is considered a tool that can measure body fat percentage relatively accurately [10]. In Korea, the use of a body composition analyzer using BIA has been increased, but the criteria of obesity suggested by western research [2,7] - 25% for men and 30% for women - are applied with adjustments. Unlike the diagnoses based on BMI, this result based on body fat percentage showed more women who were obese than men; while the number of men slightly declined, the number of women doubled.

Diagnostic criteria of metabolic syndrome which are currently used have been suggested by the WHO, the European Group for Study of Insulin Resistance (EGIR), the American Association of Clinical Endocrinologists and NCEP-ATP III. Of these many diagnostic criteria, the WHO and the NCEP-ATP III criteria are well known; but due to its convenience, the NCEP-ATP III criteria were used in this study. It was reported that Asians in general can have relatively more severe visceral obesity when they have the same waist circumference as Westerners [1,21]; thus, the waist circumference cut-offs of the NCEP-ATP III diagnostic criteria for abdominal obesity - 102 cm for men and 90 cm for women - were considered inappropriate for Asians. Thus, since 2001, it has been recommended that the waist circumference cut-offs for abdominal obesity for Asians recommended by the WHO Western Pacific Region should be used - 90 cm for men and 80 cm for women. Therefore, the NCEP-ATP

III criteria revised by the WHO Western Pacific Region were used for the criteria of abdominal obesity in this study.

When the criteria of obesity reflects metabolic syndrome which is a risk factor of cardiovascular diseases, an obesity-related diseases, obesity diagnoses based on general obesity criteria of BMI and body fat percentage do not reflect the result of this study that found that the prevalence of metabolic syndrome was 20.8% for men and 15.2% for women; the actual danger of cardiovascular diseases is not reflected. Therefore, in this study, validity was analyzed for the diagnosis of metabolic syndrome, which is a main risk factor of cardiovascular diseases, on the basis of a BMI and body composition analysis including age, sex, and weight. By identifying cut-off points, the results of BMI and body composition analysis may reflect the real risk of cardiovascular diseases.

In this study, in identifying metabolic syndrome for all study subjects, cut-off points of BMI were 25.5 kg/m^2 for men and 24.1 kg/m^2 for women, showing a similar trend with the general obesity criteria, at 25 kg/m^2. The cut-offs of BMI for men and women were increased according to weight range. The general obesity criteria for BMI of 25 kg/m^2 are similar to the cut-off point of the 70-79 kg group for men and the 60-69 kg group for women. For lighter individuals, BMI should be more strictly applied than the general obesity criteria when diagnosing metabolic syndrome. For heavier individuals, it may be applied with more flexibility.

Nagaya *et al.* [14], reported that compared to BMI, body fat percentage measures using BIA has higher correlations with total cholesterol, triglyceride, and LDL-cholesterol levels. A study by Ito *et al.* [9], and Nakanishi *et al.* [15], on the Japanese population showed a significant relationship between body fat percentage and risk factors of cardiovascular diseases. Among male research subjects, body fat percentage had diagnostic values for metabolic syndrome in all weight groups. For all study subjects, men and women showed the cut-off points for metabolic syndrome diagnosis similar to the body fat percentile of the general obesity criteria. For men and women who weigh less than 70 kg and 50 kg, respectively, body fat percentage should be more strictly applied in the identification of metabolic syndrome, while for those who are heavier it can be applied with more flexibility.

Unlike men, women showed body fat percentages exceeding the obesity criteria in the weight group with BMI lower than the obesity criteria. This demonstrates that in the diagnosis of metabolic syndrome for women, body fat percentage may be a more valid indicator than BMI. This can assist with understanding why there are a large number of metabolic syndrome patients who are not obese. The reasons why men, unlike women, have a lower critical point than those with lower weight are that estimated formulas of BIA overestimate the fat-free mass of obese populations, decreasing the accuracy of the body fat percentage measurements [13,17]. Another reason is that there were lesser subjects in the higher weight than in the lower weight group.

In particular Asians with the same degree of obesity have more accumulated visceral fat [12]. Unlike subcutaneous fat tissue, visceral fat can be easily disintegrated, increasing the concentration of free fatty acid in the hepatic portal system, which decreases insulin sensitivity in the liver. In addition to the decline in the insulin removal rate, the synthesis and secretion of glucose and triglyceride, and the use of glucose by skeletal muscle is decrease, leading to insulin resistance [3,18]. In this study, visceral fat has diagnostic value in all weight groups for men. This study shows that visceral fat in a lower weight group for women rather than men can reflect the risk of cardiovascular diseases, and through a follow-up observation, this can serve as a clue in the diagnosis of metabolic syndrome among women who appear to be thin. Visceral fat was found to have diagnostic values in all weight groups for both men and women; consequently, it is assumed to be the most useful criterion for body composition analyses when diagnosing metabolic syndrome. It is necessary to confirm the validity by comparing the results from the BIA and CT and MRI findings. Muscle mass had diagnostic value only for women with weights of 80 kg or more; however, considering the fact that the number of subjects in this group was smaller than that of the other weight groups, it is necessary to confirm its clinical usefulness through a study with more subjects.

The limitations of this study are as follows: First, it is difficult to generalize the findings of the higher weight groups for both men and women due to the relatively small number of research subjects; Second, although the revised NCEP-ATP III criteria used here as the diagnostic criteria of metabolic syndrome is the most commonly used diagnostic criteria, using other criteria of metabolic syndrome may produce different results. Finally, body composition analysis cannot be conducted with greater precision by means of CT. These limitations should be assessed and addressed in future studies.

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초록 : 한국인에서 대사증후군의 선별검사로서 체성분 분석 및 체질량지수의 타당성연구

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본 연구는 단면조사 연구로 건강검진 수진자 코호트 연구에 참여하는 전국의 10개 의료기관에서 수진한 40세에서 65세 사이의 성인 남녀 10,077명을 대상으로 수행하였다. 연구대상자들에 대해 설문조사, 신체계측, 임상검사 및 체성분 분석을 시행하였고, 대사증후군의 진단에서 ROC 곡선을 이용하여 각 남녀의 체중별 체질량지수와 체성분 분석 결과의 진단적 가치를 비교하였다. 남성 대상자의 대사증후군 진단은 체질량지수 25.5 kg/m^2 임계점에서 민감도 70.0%, 특이도 72.0%로 나타났으며 26.1%의 비만기준에서는 민감도 60.6%, 특이도 76.4%였다. 여성 대상자의 경우는 체질량지수 24.1 kg/m^2 기준으로 민감도 73.3%, 특이도 68.8%였고 31.5%의 비만기준에서는 민감도 76.7%, 특이도 65.6%로 나왔다. 본 연구를 통해 전체 남녀 연구대상자의 대사증후군 진단에서 체중 증가에 따른 체질량지수와 체성분 분석결과의 임계점이 증가하는 양상을 확인하였고, 한국의 일반적 비만기준과 유사한 결과를 보였다. 이러한 결과들은 대사증후군의 진단에서 체성분 분석 결과, 체질량지수의 성별, 체중별 진단적 가치 비교와 대사증후군의 진단에 따른 각각의 임계점은 대사증후군 선별검사의 임상적인 지표로 활용될 수 있을 것으로 사료된다.