

Optimal cut-off values for anthropometric indices of obesity as discriminators of cardiovascular risk factors in a Health Examinees study: a cross-sectional study

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Abstract

Background Obesity is well known as a risk factor for cardiovascular disease. We aimed to determine the performance of and the optimal cutoff value for obesity indices to discriminate the presence of cardiovascular risk factors in a Health Examinees study.

Methods The current study analyzed 134,195 participants with complete anthropometric and laboratory information in a Health Examinees study. The presence of cardiovascular risk factors was defined as having at least one of the following: hypertension, hyperglycemia or hyperlipidemia. The area under the receiver operating characteristic curve (AUC) and 95% confidence intervals were calculated for body mass index (BMI), waist to hip ratio (WHR), waist to height ratio (WHtR), waist circumference (WC) and conicity index (C index).

Results AUC of cardiovascular risk factors was the highest for WHtR (0.677 [0.672-0.683] among men; 0.691 [0.687-0.694] among women), and the lowest for the C index (0.616 [0.611-0.622] among men; 0.645 [0.641-0.649] among women) among both men and women. The optimal cutoff values were 24.3kg/m² for BMI, 0.887 for WHR, 0.499 for WHtR, 84.4cm for WC and 1.20m^{3/2} /kg^{1/2} for the C index among men, compared with 23.4kg/m² for BMI, 0.832 for WHR, 0.496 for WHtR, 77.0 cm for WC and 1.18m^{3/2} /kg^{1/2} for the C index among women.

Conclusion Obesity indices can be considered a plausible discriminator of metabolic risks.

Background

Obesity has been steadily increasing worldwide [1], referred to as the “obesity epidemic.” The Global Burden of Disease Study 2013 reported that the estimated worldwide prevalence of obesity was from 28.8–36.9% in men and from 29.8–38.0% in women between 1980 and 2013 [2]. Obesity contributed to 7.1% of the deaths from any cause, and cardiovascular diseases led to 41% of obesity-related death in 2015 [3]. The results from the Korean National Health and Nutrition Examination Survey (KNHANES), which is a cross-sectional and national representative survey, showed that the prevalence of obesity, defined as body a mass index over 25 kg/m², was increased from 25.7–37.9% in men, but it decreased from 27.2–25.9% in women between phase 1 (1998) and phase 6 (2013–2014) [4].

People with obesity are at increased risk for cardiovascular diseases, type 2 diabetes, certain cancers and premature death [5, 6]. The World Health Organization (WHO) recommended a lower cut-point of body mass index for Asian populations to reflect the realization that adverse health is associated with a lower body mass index than the WHO criteria for Western countries [7]. In this study, we aimed to determine the performance of and the optimal cutoff value for obesity indices, including body mass index, waist circumference, waist to hip ratio, waist to height ratio, and conicity index, to discriminate the presence of cardiovascular risk factors in middle-aged Koreans.

Method

Study population

The Health Examinees (HEXA) study is a part of the Korea Genome Epidemiology Study (KoGES) and is a population-based cohort study that prospectively recruited participants from 2004 to 2013 at 38 health examination centers and training hospitals located in 8 regions and included the Korean population aged 40 to 69 years [8]. Analysis was restricted to the Health Examinees-Gem (HEXA-G) participants which were defined as followed: we excluded (1) 8 sites (n = 9,370) that only participated in the pilot study years 2004–2006, (2) 8 sites (n = 12,205) that did not meet the HEXA biospecimen quality control criteria (i.e., different testing protocols), and (3) 5 sites (n = 8,799) that had participated in the study for less than 2 years. A total of 139,348 participants were included in the HEXA-G data. Among HEXA-G participants, we excluded 1,391 participants who had no information on anthropometric measurements of height, weight, waist circumference, and hip. Then, an additional 3,762 participants had no information on blood pressure or biochemical measurements of the blood specimen, such as fasting glucose, triglyceride, and high-density lipoprotein. We conducted all analyses among the 134,195 participants who remained after exclusion.

Data collection

Participants were questioned by trained interviewers and responded to a structured questionnaire on general characteristics and past medical history. Anthropometric measurements and biochemical assessments of fasting blood glucose, triglyceride and high-density lipoprotein cholesterol were also conducted for all participants. Weight and height were directly measured using electronic measuring instruments with digital scales and were read up to one decimal place. Waist and hip circumference

were obtained by a measuring tape of a horizontal plane and were read up to one decimal place. Systolic and diastolic blood pressure was measured twice using the standardized mercury sphygmomanometer on one arm in the sitting position and finally determined as the average of the two readings.

Definition of terms

Participants meeting at least one of the following criteria were considered to have multiple metabolic dysfunctions: defined hypertension [9], those who had a systolic blood pressure higher than 140 mmHg, a diastolic blood pressure higher than 90 mmHg, or those who reported taking antihypertensive medication; hyperglycemia [10], those who had a fasting blood glucose higher than 126 mg/dL or who reported taking antidiabetic medication; and hyperlipidemia, those who had a triglyceride level higher than 150 mg/mL, a high density lipoprotein cholesterol lower than 40 mg/dL, or those who reported taking medication for dyslipidemia.

Statistical analysis

We calculated the mean and standard deviation for demographic, anthropometric, blood pressure and biochemical characteristics. The inclusion of a large population in this study would reduce the meaningfulness of statistical significance for differences in the general characteristics between sexes. For this reason, we did not present a p-value in the descriptive analysis of Tables 1 and 2. Receiver operating characteristic (ROC) curves were plotted for obesity indices to identify the best obesity index that discriminates the presence of cardiovascular risk factors. The area under the receiver operating characteristic curves (AUCs) was used as a summary measure of accuracy to evaluate the performance of obesity indices for the discrimination of participants with metabolic dysfunctions. Youden's J statistics [11] was used to determine the optimal cut-off values for the obesity indices. Youden's index was calculated as sensitivity + specificity – 1 and equal to the height above the line of chance on the curves. We considered the optimal cut-off values at the corresponding value for the maximum of the Youden index. All statistical analyses were stratified by sex. We analyzed data using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) for the calculation of optimal cut-points and R software for the calculation of the AUCs and the visualization of the ROC.

Table 1

Anthropometric indices of obesity and metabolic characteristics among HEXA-G participants by sex, mean \pm standard deviation.

	Men (N = 45,052)			Women (N = 89,143)		
Age, year	53.6	\pm	8.38	52.3	\pm	7.76
Height, cm	168.8	\pm	5.74	156.5	\pm	5.26
Weight, cm	69.6	\pm	9.23	57.9	\pm	7.66
Waist circumference, cm	85.7	\pm	7.52	78.3	\pm	8.17
Hip circumference, cm	96.0	\pm	5.64	93.5	\pm	5.69
Body mass index, kg/m ²	24.4	\pm	2.75	23.6	\pm	2.94
Waist to hip ratio	0.89	\pm	0.05	0.84	\pm	0.06
Waist to height ratio	0.51	\pm	0.04	0.50	\pm	0.06
Conicity index, m ^{3/2} /kg ^{1/2}	1.23	\pm	0.06	1.18	\pm	0.08
Systolic blood pressure, mmHg	125.7	\pm	14.35	120.6	\pm	15.17
Diastolic blood pressure, mmHg	78.7	\pm	9.68	74.7	\pm	9.66
Fasting serum glucose level, mg/dL	99.3	\pm	24.28	92.7	\pm	18.47
Triglyceride, mg/dL	151.4	\pm	111.41	112.5	\pm	74.18
High-density lipoprotein cholesterol, mg/dL	49.4	\pm	12.09	56.1	\pm	12.80

Table 2

Definition and prevalence of hypertension, diabetes, hyperglycemia, hyperlipidemia and cardiovascular risk factors among HEXA-G participants by sex, n (%).

	Definition	Men	Women
Hypertension	Systolic blood pressure higher than 140 mmHg, diastolic blood pressure higher than 90 mmHg or those who reported taking antihypertensive medication	15,310 (34.0)	21,386 (24.0)
Hyperglycemia	Fasting glucose higher than 126 mg/dL or those who reported taking antidiabetic medication	5,196 (11.5)	5,319 (6.0)
Hyperlipidemia	Triglyceride higher than 150 mg/mL, high density lipoprotein cholesterol lower than 40 mg/dL or those who reported taking medication for dyslipidemia	21,794 (48.4)	39,768 (44.6)
Cardiovascular risk factors	Having at least one of the above	29,605 (65.7)	49,680 (55.7)

Results

The anthropometric indices of obesity and metabolic characteristics are presented in Table 1. The

mean age was 53.6 years for men and 52.3 years for women. Men had higher values than women for all anthropometric, blood pressure and biochemical characteristics, except for high-density lipoprotein cholesterol. The prevalence of cardiovascular risk factors was 65.7% for men and 55.7% for women. The prevalence of hypertension, hyperglycemia, hyperlipidemia, and cardiovascular risk factors was higher in men than in women. Among the components, the prevalence was lowest in hyperglycemia (11.5% for men; 6.0% for women) and highest in hyperlipidemia (48.4% for men; 44.6% for women). The AUCs of the obesity indices associated with metabolic dysfunctions and its components are shown in Table 3. Among men, the highest AUCs to discriminate cardiovascular risk factors were obtained in the waist to height ratio (AUC [95% confidence intervals], 0.677 [0.672-0.683]), followed by the waist circumference (0.671 [0.666-0.677]), body mass index (0.667 [0.661-0.672]), waist to hip ratio (0.656 [0.650-0.661]) and conicity index (0.616 [0.611-0.622]); the AUCs of the waist to hip ratio and conicity index were significantly lower than those of the waist to height ratio, waist circumference, and body mass index. Among women, the highest AUCs were obtained in the waist to height ratio (0.691 [0.687-0.694]), followed by the waist to hip ratio (0.681 [0.677-0.684]), waist circumference (0.680 [0.677-0.684]), body mass index (0.668 [0.665-0.672]) and conicity index (0.645 [0.641-0.649]). Women had higher AUCs associated with cardiovascular risk factors for all obesity indices than men.

Table 3

Area under the receiver operating characteristic curves and the corresponding 95% confidence interval of body mass index, waist-hip ratio, waist-height ratio and conicity index associated with metabolic dysfunctions and its components among HEXA-G participants by sex.

	Men	Women
Hypertension		
Body mass index	0.629 (0.624-0.635)	0.668 (0.664-0.672)
Waist circumference	0.629 (0.624-0.635)	0.671 (0.667-0.675)
Waist to hip ratio	0.617 (0.612-0.623)	0.665 (0.661-0.669)
Waist to height ratio	0.646 (0.640-0.651)	0.687 (0.683-0.691)
Conicity index	0.593 (0.587-0.598)	0.635 (0.631-0.639)
Hyperglycemia		
Body mass index	0.570 (0.562-0.579)	0.642 (0.634-0.649)
Waist circumference	0.605 (0.597-0.613)	0.683 (0.675-0.690)
Waist to hip ratio	0.636 (0.629-0.644)	0.715 (0.708-0.721)
Waist to height ratio	0.616 (0.608-0.624)	0.693 (0.686-0.700)
Conicity index	0.611 (0.603-0.619)	0.674 (0.667-0.681)
Hyperlipidemia		
Body mass index	0.645 (0.640-0.650)	0.636 (0.632-0.639)
Waist circumference	0.645 (0.640-0.651)	0.648 (0.644-0.652)
Waist to hip ratio	0.625 (0.620-0.630)	0.651 (0.647-0.654)
Waist to height ratio	0.641 (0.636-0.646)	0.653 (0.649-0.657)
Conicity index	0.587 (0.582-0.593)	0.618 (0.614-0.622)
Cardiovascular risk factors		
Body mass index	0.667 (0.661-0.672)	0.668 (0.665-0.672)
Waist circumference	0.671 (0.666-0.677)	0.680 (0.677-0.684)
Waist to hip ratio	0.656 (0.650-0.661)	0.681 (0.677-0.684)
Waist to height ratio	0.677 (0.672-0.683)	0.691 (0.687-0.694)
Conicity index	0.616 (0.611-0.622)	0.645 (0.641-0.649)

Table 4 shows the optimal cut-off values for body mass index, waist circumference, waist to hip ratio, waist to height ratio and conicity index. Optimal cut-off values to discriminate multiple dysfunctions were 24.3 km/m² of body mass index, 84.4 cm of waist circumference, 0.887 of waist to hip ratio, 0.499 of waist to height ratio and 1.20 m^{3/2}/kg^{1/2} of conicity index for men, and 23.4 km/m² of body mass index, 77.0 cm of waist circumference, 0.832 of waist to hip ratio, 0.496 of waist to height ratio and 1.18 m^{3/2}/kg^{1/2} of conicity index for women.

Table 4

Optimal cut-off value, Youden index, sensitivity and specificity of body mass index, waist-hip ratio, waist-height ratio and conicity index associated with metabolic dysfunction and its components among HEXA-G participants by sex.

	Men				Women			
	Optimal cut-off value	Youden's index	Sensitivity	Specificity	Optimal cut-off value	Youden's index	Sensitivity	Specificity
Hypertension								
Body mass index	24.5	0.189	0.596	0.593	23.5	0.246	0.670	0.576
Waist circumference	87.0	0.187	0.570	0.617	78.9	0.255	0.655	0.600
Waist to hip ratio	0.887	0.175	0.504	0.591	0.840	0.241	0.660	0.590
Waist to height ratio	0.499	0.175	0.504	0.591	0.496	0.175	0.504	0.591
Conicity index	1.20	0.175	0.504	0.591	1.18	0.175	0.504	0.591

Waist to hip ratio	0.896	0.175	0.594	0.581		0.840	0.241	0.662	0.580
Waist to height ratio	0.506	0.210	0.662	0.548		0.503	0.275	0.674	0.601
Conicity index	1.24	0.138	0.535	0.604		1.19	0.199	0.607	0.592
Hyperglycemia									
Body mass index	24.5	0.104	0.567	0.537		24.2	0.207	0.569	0.637
Waist circumference	86.3	0.150	0.591	0.559		80.0	0.272	0.672	0.600
Waist to hip ratio	0.895	0.197	0.660	0.537		0.850	0.315	0.710	0.606
Waist to height ratio	0.509	0.165	0.634	0.531		0.514	0.288	0.655	0.633
Conicity index	1.23	0.165	0.655	0.510		1.18	0.255	0.728	0.527
Hyperlipidemia									
Body mass index	24.0	0.213	0.654	0.559		23.2	0.198	0.634	0.564
Waist circumference	84.4	0.208	0.675	0.533		77.5	0.219	0.640	0.579
Waist to hip ratio	0.879	0.185	0.712	0.474		0.832	0.227	0.652	0.575
Waist to height ratio	0.502	0.204	0.661	0.542		0.497	0.228	0.636	0.592
Conicity index	1.20	0.131	0.706	0.425		1.18	0.175	0.608	0.567
Cardiovascular risk factors									
Body mass index	24.3	0.241	0.588	0.653		23.4	0.245	0.604	0.641
Waist circumference	84.4	0.248	0.653	0.595		77.0	0.266	0.676	0.590
Waist to hip ratio	0.887	0.228	0.639	0.589		0.832	0.270	0.645	0.624
Waist to height ratio	0.499	0.259	0.672	0.587		0.496	0.281	0.638	0.644
Conicity index	1.20	0.173	0.698	0.475		1.18	0.210	0.598	0.613

Discussion

We analyzed baseline data from a large population-based cohort study, and the results showed that the range of AUCs for obesity indices was between 0.570 and 0.715. Abdominal obesity referred to waist circumference, and the waist to hip ratio had good performance as a diagnostic tool for cardiovascular risk factors, rather than general obesity, referred to as body mass index. These results were similar to previous cross-sectional studies in Asian [12–16], Australian [17] and American [18] populations. Results from the studies using this directed fat measurement can support the association between abdominal obesity and cardiovascular disease. The Framingham Heart Study directly

measured visceral adipose tissue and subcutaneous adipose tissue and concluded that visceral adiposity is associated with the incident of cardiovascular disease [19]. Experimental studies explained this association using the secretion of inflammatory factors from visceral adipose tissue. Adipose inflammatory factors, including chemokines, adipokines, adipose tissue macrophages, and free fatty acids, can induce chronic inflammation and insulin resistance that contribute to cardiovascular disease [20]. Inflammatory factors, such as C-reactive protein, interleukin-6, tumor necrosis factor- α , vascular endothelial growth factor and plasminogen activator inhibitor-1, were more frequently secreted from visceral fat compared with subcutaneous fat and can also be implicated in the development of cardiovascular disease mediated by the upregulation of inflammatory cytokines in the liver and increased systemic inflammation [21].

Cut-off values from the present study were lower than previous guidelines. Our results showed that a body mass index of more than 24.3 kg/m² among men and 23.4 kg/m² among women was associated with the presence of cardiovascular risk factors, while the WHO recommended that obesity in Asian populations be defined as a body mass index of 25 kg/m² or higher [7]. We obtained waist circumference cut-offs of 84.4 cm for men and 77.0 cm for women, and the National Cholesterol Educational Program and International Diabetes Federation diagnostic criteria for metabolic syndrome defined obesity as a waist circumference of more than 90 cm for men and 80 cm for women [22].

This study had several limitations. First, there is an inherent limitation of temporality in the cross-sectional design. A prospective cohort study was conducted in the Korean population and showed that the waist to hip ratio, not body mass index, was a better predictor of developing multiple metabolic risk factors, which is similar to the results from other cross-sectional studies [23]. Second, it is difficult to generalize these results. The study participants consisted of Koreans aged 40 to 60 years who regularly attended health screening examinations; therefore, the cut-off values derived from the current study may be relevant middle-aged Korean population.

Conclusions

We demonstrated that the presence of obesity can discriminate cardiovascular risk factors, including hypertension, hyperglycemia, and dyslipidemia. Waist-related indices such as waist circumference,

waist to hip ratio and waist to height ratio might be used as a better anthropometric discriminator of cardiovascular risk factors than body mass index. We believe that these results can support the establishment of policies for the prevention and management of obesity.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Korean Health and Genomic Study of the Korean National Institute of Health and the institutional review boards of all participating hospitals (IRB No. E-1503-103-657).

Consent for publication

Not applicable.

Availability of data and materials

Since no novel datasets have been generated or analyzed during the current study, data sharing does not apply to this article. Please contact the corresponding author for data requests.

Competing interests

The authors declare no conflicts of interest.

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Authors' contributions

SC and AS designed this study. SC performed the statistical analyses and wrote the manuscript. AS edited the manuscript. AS, JYC, SMP, DK, and JKL were responsible for designs of this work. All authors read, edited and approved the final manuscript.

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Not applicable.

Abbreviations

AUC: Area under the receiver operating characteristic curve; BMI: Body mass index; WHR: Waist to hip ratio; WHtR: Waist to height ratio; WC: Waist circumference; C index: Conicity index; WHO: World Health Organization; KoGES: the Korea Genome Epidemiology Study; HEXA: Health Examinees in KoGES; HEXA-G: Health Examinees-Gem in KoGES, ROC: Receiver operating characteristic;

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