Optimal cut-off values for anthropometric indices of obesity as discriminators of metabolic abnormality in Korea: Results from a Health Examinees study

Sooyoung Cho
Seoul National University College of Medicine
Aesun Shin (shinaesun@snu.ac.kr)
Seoul National University College of Medicine https://orcid.org/0000-0002-6426-1969
Ji-Yeob Choi
Seoul National University College of Medicine
Sang Min Park
Seoul National University College of Medicine
Daehee Kang
Seoul National University College of Medicine
Jong-Koo Lee
Seoul National University College of Medicine

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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 cut-off value for obesity indices to discriminate the presence of a metabolic abnormality as a primary risk for cardiovascular diseases in a Health Examinees study (HEXA).

Methods: The current study analyzed 134,195 participants with complete anthropometric and laboratory information in a Health Examinees study, consisting of the Korean population aged 40 to 69 years. The presence of metabolic abnormality was defined as having at least one of the following: hypertension, hyperglycemia, or dyslipidemia. The area under the receiver operating characteristic curve (AUC) and 95% confidence intervals (CIs) 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 metabolic abnormality was the highest for WHtR (AUC [95% CIs], 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/m^2 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, and 23.4kg/m^2 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: Our findings are implicated that the primary prevention of cardiovascular disease can be approached via appropriate recommendations for abdominal obesity in Korea.

Background

Obesity has been raised as public concerns worldwide, as it has been steadily increasing [1]. The Global Burden of Disease Study has reported that the estimated worldwide prevalence of obesity was 28.8% to 36.9% in men and 29.8% to 38.0% in women between 1980 and 2013 [2], and global death attributable to obesity has rapidly increased more than doubled between 1990 and 2017 [3]. People with obesity are at increased risk for cardiovascular diseases, type 2 diabetes, certain cancers, and premature death [4, 5]. The World Health Organization (WHO) recommended a lower cut-point of body mass index for Asian populations [6], reflecting the realization that adverse health is associated with a lower body mass index than the WHO criteria for Western countries [7].

Cardiovascular disease is the leading cause of death [8]. Hypertension, hyperglycemia, and dyslipidemia are the components of metabolic syndrome [9], referring to the risk factors for cardiovascular disease [10]. We aimed to evaluate the ability of obesity to discriminate for metabolic abnormalities before the onset of heart disease. In this study, we evaluated the performance of and the optimal cut-off 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 a metabolic abnormality in middle-aged Koreans.

Method

Study population

The Health Examinees (HEXA) study is a part of the Korea Genome Epidemiology Study (KoGES) funded by Korea Centers for Disease Control and Prevention [11]. National Health Insurance Corporation (NHIC) covered the entire Korean population for general health screening, and beneficiaries aged over 40 years can biannually receive the national health examination program [12]. Participants of the HEXA study were prospectively recruited at the 38 health examination centers from 2004 to 2013 at 38 health examination centers and training hospitals located in 8 regions based on the infrastructural advantage of the national health checkup services funded by Korea Centers for Disease Control and Prevention [13].

Figure 1 shows the flow chart of the study population. We included HEXA participants aged 40 to 69 years in the analyses and restricted to the Health Examinees-Gem (HEXA-G) participants who were defined as follows: 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 two 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 circumference. 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 interviewed by trained interviewers and responded to a structured questionnaire on general characteristics and past medical history. Biochemical assessments and anthropometric measurements were also conducted for all participants. Blood specimens were taken after 8 hours of fasting at enrollment and transported to the clinical laboratory for blood tests using plasma to examine the levels of glucose, triglyceride, and high-density lipoprotein. Height was measured using digital freestanding stadiometers (BSM, InBody Co, Seoul, Korea) with the participants' head in the Frankfort horizontal plane and read up to one decimal place. Weight was measured using digital scales (BSM, InBody Co, Seoul, Korea) in units of 10g. Waist and hip circumferences were obtained by a measuring tape of a horizontal plane and were read up to one decimal place. In detail, waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, and hip circumference was measured around the widest part of the buttocks.

Systolic and diastolic blood pressure was manually measured using the stethoscope and mercury sphygmomanometer on one arm in the sitting position according to the standard operating procedure by trained medical staff. Blood pressure was measured at least twice, and the second blood pressure measurement should be taken at least 1 minute after the first measurement. If the difference between the two records of blood pressure was more than five mmHg, additional measurements were taken until the last two records of blood pressure are similar. Then, the last two records of blood pressures were recorded.

Blood pressure was measured in both arms and re-measured if the difference of blood pressure between both arms was more than ten mmHg. Blood pressure was measured on the other arm only if there were arm injury, previous breast surgery, the venous or arterial tube, or plaster bandage. We determined blood pressure as the average of the two readings.

Definition of terms

Body mass index, waist circumference, waist to hip ratio, and waist to height ratio were calculated using directly measured anthropometric values. Additionally, we considered the conicity index as a measure of central adiposity with the below equation [14].

$$Conicity\ index = \frac{waist\ circumference\ (m)}{0.109 \times \sqrt{\frac{weight\ (kg)}{height\ (m)}}}$$

Participants meeting at least one of the following criteria were considered to have the metabolic abnormality: defined hypertension [15], those who had systolic blood pressure higher than 140 mmHg, diastolic blood pressure higher than 90 mmHg, or those who reported taking antihypertensive medication; hyperglycemia [16], those who had a fasting blood glucose higher than 126 mg/dL or who reported taking antidiabetic medication; and dyslipidemia, those who had a triglyceride level higher than 150 mg/mL, high-density lipoprotein cholesterol lower than 40 mg/dL, or those who reported taking medication for dyslipidemia. Low-density lipoprotein cholesterol is commonly used for diagnoses of hyperglycemia, but low-density lipoprotein was not examined from blood samples. Therefore, we defined dyslipidemia using the level of triglyceride and high-density lipoprotein cholesterol.

Statistical analyses

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 metabolic abnormality. 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 [17] was used to determine the optimal cut-off values for the obesity indices. Youden's index was calculated using the below equation.:

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. Table 2 describes the prevalence of hypertension, diabetes, hyperglycemia, dyslipidemia, and metabolic abnormality among HEXA-G participants by sex. More than half of the participants had at least a metabolic abnormality of diabetes, hypertension, and dyslipidemia in both men (65.7%) and women (55.7%). The prevalence of metabolic abnormality was higher in men than in women. Among the components of metabolic abnormality, the prevalence was lowest in hyperglycemia (11.5% for men; 6.0% for women) and highest in dyslipidemia (48.4% for men; 44.6% for women).

Table 1 Anthropometric indices of obesity and metabolic characteristics among HEXA-G participants by sex, mean ± standard deviation.

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

Table 2 Prevalence of metabolic abnormality among HEXA-G participants by sex.

	Men	Women
Hypertension*, n (%)	15,310 (34.0)	21,386 (24.0)
Hyperglycemia†, n (%)	5,196 (11.5)	5,319 (6.0)
Dyslipidemia‡, n (%)	21,794 (48.4)	39,768 (44.6)
Metabolic abnormality§, n (%)	29,605 (65.7)	49,680 (55.7)

* Systolic blood pressure higher than 140 mmHg, diastolic blood pressure higher than 90 mmHg or those who reported taking antihypertensive medication; † Fasting glucose higher than 126 mg/dL or those who reported taking antidiabetic medication; ‡ Triglyceride higher than 150 mg/mL, high density lipoprotein cholesterol lower than 40 mg/dL or those who reported taking medication for dyslipidemia; § Having at least one of the aforementioned factors.

‡

§

The AUCs of the obesity indices associated with metabolic abnormality and its components are shown in Table 3. Among men, the highest AUCs to discriminate metabolic abnormality 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 metabolic abnormality for all obesity indices than men.

Table 3 Area under the receiver operating characteristic curves and the corresponding 95% confidence interval of obesity indices associated with metabolic abnormality 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)
Dyslipidemia‡		
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)
Metabolic abnormality§		
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)

* Systolic blood pressure higher than 140 mmHg, diastolic blood pressure higher than 90 mmHg or those who reported taking antihypertensive medication; † fasting glucose higher than 126 mg/dL or those who reported taking antidiabetic medication; ‡ triglyceride higher than 150 mg/mL, high density lipoprotein cholesterol lower than 40 mg/dL or those who reported taking medication for dyslipidemia; § Having at least one of the aforementioned factors.

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

Table 4 Optimal cut-off value, Youden index, sensitivity and specificity of obesity indices associated with metabolic *abnormality* and its components among HEXA-G participants by sex.

* Systolic blood pressure higher than 140 mmHg, diastolic blood pressure higher than 90 mmHg or those who reported taking antihypertensive medication;† Fasting glucose higher than

	Men				Women			
	Optimal cut-off valuevalue	Youden's index	Sensitivity	Specificity	Optimal cut-off value 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	0.896	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
Dyslipidemia‡								
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
Metabolic abnormality§								
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

126 mg/dL or those who reported taking antidiabetic medication; ‡ Triglyceride higher than 150 mg/mL, high density lipoprotein cholesterol lower than 40 mg/dL or those who reported taking medication for dyslipidemia;§ Having at least one of the aforementioned factors.

Discussion

We analyzed baseline data from a large community-based cohort study, and the results showed that the range of AUCs for obesity indices was between 0.570 and 0.715. Waist circumference and waist to hip ratio show a better performance of obesity indices as a diagnostic tool for metabolic abnormality than body mass index. Among the abdominal obesity indices, WHtR was the best discriminator to metabolic abnormality. The abdominal obesity index has been reported as a better tool for the discrimination of metabolic abnormality in Asians [19-23], Australians [24], and Americans [25]. Furthermore, several meta-analyses have compared WHtR with BMI and WC and reported WHtR as a better tool for cardiometabolic risk factors [26-28]. A previous prospective cohort study on obesity index and metabolic dysfunction had also presented that the waist to hip ratio was a better predictor than body mass index of developing multiple metabolic risk factors in the Korean population [29].

Cut-off values from the present study were lower than previous guidelines of WHO [6] and the National Cholesterol Educational Program (NCEP) [9]. Our results showed that a body mass index of more than 24.3 kg/m^2 among men and 23.4 kg/m^2 among women was associated with the presence of a metabolic abnormality, while the WHO recommended that obesity in Asian populations be defined as a body mass index of 25 kg/m^2 or higher [7]. We obtained waist circumference cut-offs of 84.4 cm for men and 77.0 cm for women, and these results are lower than the NCEP guideline for metabolic syndrome, defined obesity as a waist circumference of more than 90 cm for men and 80 cm for women [9]. We suggested that lowered abdominal obesity could discriminate the metabolic dysfunction for Asians. A previous prospective cohort study in Korea has also described that lower waist circumference (80cm for men and 78cm for women) had a better performance to predict the development of metabolic abnormality than the NCEP guideline [29].

This study had several limitations. First, there is an inherent limitation of temporality in the cross-sectional design. However, our results are similar to the results from prospective studies in Korea [20], and we suggest the theoretical effect of the temporality of the results is not strong. Second, it is difficult to generalize these results to young people. 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 to the middle-aged Korean population.

Conclusions

Obesity indices, especially the waist-related indices, can discriminate metabolic abnormality among middle-aged Korean. We believe that these results can support the establishment of policies for the primary prevention of cardiovascular disease via appropriate recommendations for obesity in Korea

List Of 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;

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). We explained the aim of the study to the study participants and obtained written informed consent.

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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Figures

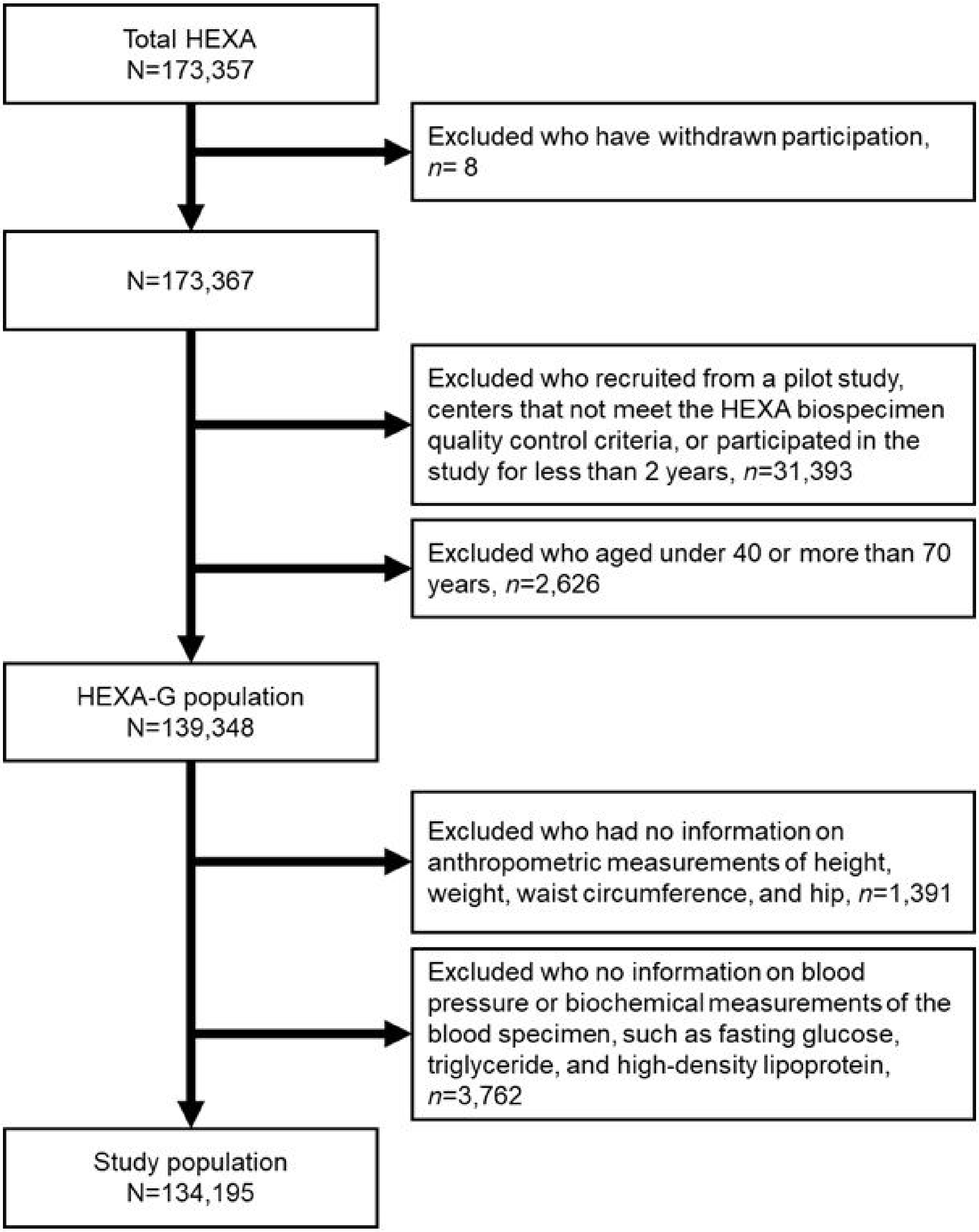
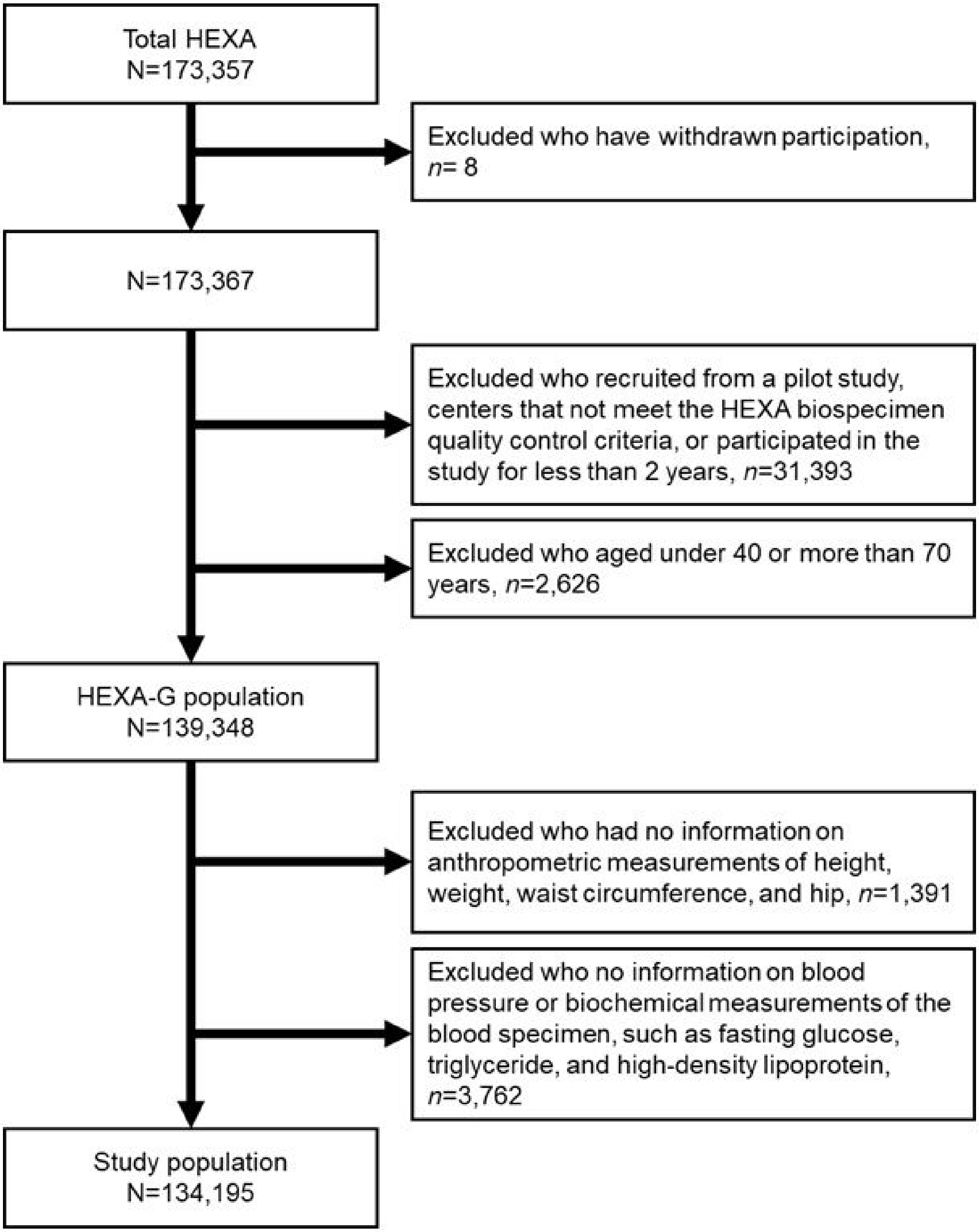


Figure 1

Inclusion and exclusion criteria of the study population.



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