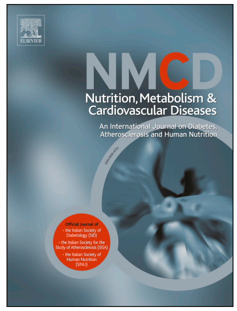

Body adiposity index and incident hypertension: The Aerobics Center Longitudinal Study

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HIGHLIGHTS

- High blood pressure is well recognized as a major cause of morbidity and mortality.
- A strong association between obesity and the risk of hypertension has been reported.
- BAI has been recently proposed as a new method to estimate percentage of body fat.
- BAI is revealed as an alternative to traditional body adiposity measures in order to predict incident hypertension in adults.

Title

Body adiposity index and incident hypertension: The Aerobics Center Longitudinal Study

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Abbreviations

ACLS: Aerobics center longitudinal study

ANOVA: Analysis of the variance

BAI: Body adiposity index

BF: Body fat

BMI: Body mass index

CI: Confidence interval

CRF: Cardiorespiratory fitness

CVD: Cardiovascular disease

DXA: Dual-energy X-ray absorptiometry

ECG: Electrocardiogram

HR: Hazard ratio

MET: Maximal metabolic equivalent

Abstract

Background and Aim: The body adiposity index (BAI) has been recently proposed as a new method to estimate the percentage of body fat. The association between BAI and hypertension risk has not been investigated yet. The aim of our study was to evaluate the ability of BAI to predict hypertension in males and females compared with traditional body adiposity measures.

Methods and Results: The present follow-up analysis comprised 10 309 individuals (2259 females) free of hypertension from the Aerobics Center Longitudinal Study, who completed a baseline examination during 1988-2003. Body adiposity measures included BAI, body mass index (BMI), waist circumference, hip circumference, percentage of body fat and waist to hip ratio (WHR). Incident hypertension was ascertained from responses to mail-back surveys between 1990 and 2004. During an average of 9.1 years of follow-up, 872 subjects (107 females) became hypertensive. Hazard ratios (HRs) and 95% confidence intervals (95% CI) showed that males in the highest categories of all body adiposity measures showed a higher incident risk of hypertension (HRs ranged from 1.37 to 2.09). Females showed a higher incident risk of hypertension only in the highest categories of BAI, BMI and WHR (HRs ranged from 1.84 to 3.36).

Conclusion: Our results suggest that in order to predict incident hypertension BAI could be considered as an alternative to traditional body adiposity measures.

Key words

Obesity, blood pressure, adiposity, body composition, adults.

INTRODUCTION

Hypertension, defined as a persistent resting systolic/diastolic blood pressure ≥140/90 mmHg, has reached epidemic proportions worldwide. In fact, more than a quarter of the world's adult population had hypertension in the year 2000, and this proportion is estimated to increase to around 30% in the year 2025 [1]. Currently, high blood pressure is well recognized as a major cause of morbidity and mortality [2].

Overweight and obesity may also increase risk of co-morbidities, which can lead to further morbidity and mortality [3]. In recent years, there have been an increased number of studies showing the strong association between obesity and the risk of hypertension [4, 5].

Body mass index (BMI), waist circumference and waist to hip ratio (WHR) are strong predictors of obesity-related morbidity and mortality [6, 7]. Despite their limitations, both are commonly used as adiposity measures in large epidemiological studies where the use of more accurate methods are not available due to complexity and/or cost [8].

Recently, Bergman et al. [9], proposed the body adiposity index (BAI) as a new method to estimate percentage of body fat (%BF) without requiring a measure of body weight. Several validation studies have analyzed the correlation between BAI and %BF estimated by accurate methods such as DXA [9-13], magnetic resonance [14], or computed tomography [11]. Moreover, other studies have examined the association of BAI with traditional and novel cardiovascular disease (CVD) risk factors [11, 14-19].

In our best knowledge, the association between BAI and hypertension risk has not been investigated. Therefore, the aim of our study was to compare BAI and established body adiposity measures with respect to their ability to predict hypertension risk in a sample of men and women participating in the Aerobics Center Longitudinal Study (ACLS). Furthermore, we analyzed the cross-sectional association of BAI and established body adiposity measures with traditional CVD risk factors.

METHODS

Subjects

Data for this report are from the ACLS, a prospective epidemiological study of individuals who received extensive preventive medical examinations at the Cooper Clinic in Dallas, Texas, USA. Details of the study design and the characteristics of the cohort have been reported previously [20]. Study participants were referred by their employers or physicians, or were self-referred. They were mainly Caucasian, relatively well-educated, and from middle-to-upper socioeconomic strata. After receiving complete information about the aims and methods of the study, all participants gave written informed consent for the examinations and follow-up. The study protocol was reviewed and approved annually by Cooper Institute's Institutional Review Board.

For the present analysis we included all individuals who received a baseline medical examination between 1988 and 2003, responded to at least one mail-back health survey during follow-up, and with valid data for all the body adiposity measures. Among 12 303 participants aged ≥20 years at baseline, we excluded 53 reporting myocardial infarction or stroke; 52 reporting cancer; 127 with BMI <18.5 kg/m^2; 887 with resting systolic/diastolic blood pressure ≥140/90 mmHg or physician diagnosis of hypertension; and 633 not reaching 85% of their age-predicted maximal heart rate (220 minus age in years) on a treadmill test. In addition, 242 subjects with <1 year of follow-up were excluded to minimize potential bias due to undetected hypertension. The final sample size for the present report comprised 8050 males and 2259 females for analyses of incident hypertension.

Clinical Examination

Clinical examinations were completed after 12h fast and have been described in detail elsewhere [20]. Briefly, weight, height, waist and hip circumferences were measured with a standard clinical scale, stadiometer and plastic tape according to ACLS standard procedures. BMI was computed as weight in kilograms divided by height in meters squared (kg/m^2), and WHR as waist circumference in centimeters divided by hip circumference in centimeters. BAI was calculated according to Bergman et al. [9] equation ((hip circumference in cm/height in meters$^{1.5}$)-18). %BF was assessed using hydrostatic weighing, the sum of seven skinfold measures, or both methods, following standardized protocols [21]. Participants were classified according to adiposity categories using standard clinical definitions for BMI (18.5 to 24.9 as normal weight; 25 to 29.9 as overweight; ≥30 as obese) and waist circumference (≥102 cm for males and ≥88 cm for females as having central obesity) [22]. Since there is not a specific agreement about obesity cut-off points for BAI, hip circumference, %BF and WHR, specific tertiles from this population were used.

Resting blood pressure was measured by trained technicians using auscultatory methods in the seated position and was recorded as the first and fifth Korotkoff sounds after ≥5 minutes of sitting quietly using mercury sphygmomanometers. Two readings separated by 2 minutes were averaged. If the first 2 readings differed by >5 mmHg, additional readings were obtained and averaged. Electrocardiogram (ECG) was measured at rest and with exercise, and abnormal ECG responses included rhythm and conduction disturbances and ischemic ST-T wave abnormalities. Serum samples were analyzed for glucose and total cholesterol using standardized automated bioassays at the Cooper Clinic Laboratory. Diabetes mellitus was defined as fasting plasma glucose concentration of ≥126 mg/dL, a history of physician diagnosis, or insulin use. Hypercholesterolemia was defined as total cholesterol of ≥240 mg/dL or a history of physician diagnosis.

Physical activity, cigarette smoking, alcohol intake, and parental history of CVD and hypertension were assessed by self-report on a medical history questionnaire. Physically inactive was defined as reporting no leisure-time physical activity in the 3 months before the baseline examination. Smoking status was classified as current smoker or not. Heavy alcohol consumption was defined as >14 units/week for males and >7 units/week for females. One unit of alcohol intake was defined as a bottle or can of beer [355 mL (12 oz)], a glass of wine [148 mL (5 oz)], or 44 mL (1.5 oz) of hard liquor. Parental history of CVD was defined as the occurrence of heart attacks, coronary disease, angioplasty, or stroke before the age of 50 years in either father or mother. Parental history of hypertension was defined as a history of physician diagnosis in either father or mother.

Cardiorespiratory fitness (CRF) was quantified as the total time of a symptom-limited maximal treadmill exercise test, using a modified Balke protocol [23]. To standardize exercise performance, we estimated maximal metabolic equivalents (METs; 1 MET = 3.5 mL O_2 uptake per kilogram per minute) from the final treadmill speed and grade [24].

Incident hypertension

Incident hypertension was ascertained from responses to mail-back surveys in 1990, 1995, 1999, and 2004. A case-finding question for physician-diagnosed illness was used to identify cases of hypertension. Participants were asked if a physician had ever told them they had hypertension. If yes, respondents were asked to report the year of diagnosis. In participants who completed multiple surveys, the first survey in which hypertension was reported was used in the analyses. This method of case ascertainment has been used in other large, population-based epidemiologic studies of hypertension [23]. The aggregate survey response rate across all survey periods in the ACLS is about 65%, but it has been investigated in ACLS and does not present a major source of bias [25]. Sensitivity and specificity of self-reported, physician-diagnosed hypertension was verified in this cohort and observed 98% and 99%, respectively [23].

Statistical analysis

Descriptive analyses summarized baseline characteristics of the participants based on sex-specific BAI tertiles. Differences between groups were tested using analysis of the variance (ANOVA) for continuous variables and chi-square tests for categorical variables. Partial correlations between body adiposity measures were calculated after controlling for age and baseline examination year. We also examined the association of body adiposity measures with CVD risk factors using linear regression, controlling for age, baseline examination year, and survey response pattern. Cox proportional hazards regression analysis was used to estimate hazard ratios (HRs), and associated 95% confidence intervals (95% CIs) for incidence of hypertension, according to adiposity exposure categories from BAI, BMI, waist and hip circumferences, %BF and WHR. The lowest adiposity category was ever used as the reference category. To allow comparisons between adiposity measures, the results were also presented as standardized HRs by transforming each variable to have a mean of 0 and SD of 1. Indicator variables (yes/no) were constructed for each survey period to account for differences in survey response patterns in order to reduce the influence of ascertainment bias. In multivariable analyses, model 1 accounted for age, baseline examination year, and survey response pattern. Model 2 included physical activity, smoking habit, alcohol intake, abnormal ECG, hypercholesterolemia, diabetes, and parental history of CVD and hypertension as confounders. Model 3 additionally adjusted for CRF. The proportional hazards assumption was examined by comparing the cumulative hazard plots grouped on exposure and no appreciable violations were noted. All the analyses were performed using PASW statistical package version 18.0 (SPSS Inc, Chicago, IL), considering $P<0.05$ as statistically significant.

RESULTS

During an average follow-up of 9.1 years, 872 subjects (107 females) became hypertensive.

The characteristics of the study population by sex-specific BAI tertiles are shown in Table 1. Except for current smokers and parental history of hypertension in males, and diabetes, parental history of CVD and hypertension in females, all variables presented significant differences across BAI tertiles.

Table 1 here

Partial correlations examining the associations between body adiposity measures after controlling for age and examination year are shown in Table 2. All body adiposity measures were positively correlated each other ($P\leq0.001$). The highest correlation values for BAI were observed with BMI in males ($r=0.787$) and with hip circumference in females ($r=0.832$).

Table 2 here

According to Table 3, all body adiposity measures were significantly associated with CVD risk factors (all P≤0.001). BAI showed the lowest correlation values with fasting blood glucose when it was compared with the other body adiposity measures in both males and females. BAI associations with total cholesterol, fasting blood glucose and CRF were stronger among males, while BAI associations with systolic and diastolic blood pressure were stronger among females. Except for the WHR in females, all body adiposity measures showed the strongest association with CRF among all the risk factors in males and females.

Table 3 here

Table 4 shows HRs for incidence of hypertension according to 3 different sets of confounders (model 1, model 2 and model 3). In the fully-adjusted model, males in all the highest categories of body adiposity measures showed a higher incidence risk of hypertension (HRs ranged from 1.37 to 2.09). Females showed a higher incidence risk of hypertension in the highest categories of BAI, BMI and WHR (HRs 1.84 and 3.36, respectively). Per 1 SD increase, HRs were similar between all the body adiposity measures in males (ranging from 1.15 to 1.29) and between BAI, BMI and WHR in females (ranging from 1.25 to 1.31).

Table 4 here

DISCUSSION

The results of this report suggest that in order to predict incident hypertension among participants enrolled in the ACLS between 1988 and 2003, BAI could be considered as an alternative to established body adiposity measures.

The BAI has recently been proposed by Bergman et al. [9] to provide valid direct estimates of %BF. In our study, the mean intra-individual difference between BAI and %BF ranged from 2.5 to 3.9% in males, and from 1.8 to 2.0% in females across BAI tertiles. Moreover, in general BAI showed slightly lower correlation values with %BF than other body adiposity measures. Similar results have been found in some BAI validation studies when correlation analyses were sex-stratified, indicating that calculation of BAI results in inaccurate estimation of %BF [10, 12-14].

Previous studies showed a strong association of established body adiposity measures with CVD risk factors [6, 26, 27], but the association with BAI seemed to be weaker [11, 14-19]. Our results concur with previous ones reporting significant associations between all adiposity measures and CVD risk factors (e.g. cholesterol, glucose, blood pressure, and CRF). However, in general BAI showed weaker associations than established body adiposity measures, indicating that in our sample BAI did not provide a meaningful alternative to established adiposity measures as a CVD risk indicator.

Due to the limitations of established body adiposity measures, the development of other simple, accurate, and inexpensive methods to assess %BF are needed for clinical and epidemiological research. Those methods need to be valid to assess body composition and to derive some insight into health risks associated with obesity. We tested if the new BAI proposed by Bergman et al. [9] may be a valid method to assess body composition by analyzing its ability to predict incidence risk of hypertension in adults. Such data may be essential to establish the validity of BAI for screening agent, as well as to be used in research protocols were a high number of participants are involved.

In our best knowledge, no previous studies have analyzed the ability of BAI to predict the risk of incident hypertension. Combined with previous results, our study shows that BAI may not be a better indicator of body fat [10, 12-14] or CVD risk [11, 14-19] than the established body adiposity measures. Nevertheless, in order to predict incident hypertension BAI could be considered as an alternative to established body adiposity measures, particularly when a weight measurement is not available. The middle tertile of BAI only identified higher risk of hypertension in males, thus showing lower discrimination accuracy in females. These gender differences could indicate that BAI is an approach of %BF, but does not reflect fat distribution, which is known to have large differences between males and females (android vs. gynoid obesity).

The results of the present analysis should be interpreted with caution due to several limitations. First, since our study mainly included Caucasian, well-educated men from middle-to-upper socioeconomic strata, the results may not extend to other populations. However, the homogeneity of the sample enhances internal validity of our findings because it reduces the likelihood of confounding by these characteristics. Second, %BF was estimated from skinfold measures or hydrostatic weighing, each of which have well known methodological limitations. Third, as we only have baseline data of exposures, we do not know whether changes in any of these variables occurred during follow-up and how this might have influenced the results. Fourth, we could not take into account dietary habits (e.g. sodium intake) or medication use to control for these potential confounders in the analysis. Finally, because of the widespread geographical distribution of participants, we were unable to verify all reported hypertension events. However, it appears that an acceptable level of agreement exists between participants' self-reported histories and their medical records based on a validation study [23]. Despite these limitations, the main strengths of this study include the large, well-characterized cohort, the prospective design of the study, the relatively long follow-up period, and the extensive baseline examination that reduced the possible bias of subclinical disease.

In conclusion, the findings of the present analyses add information about the newly proposed BAI, suggesting that in order to predict incident hypertension BAI could be considered as an alternative to established body adiposity measures. Also, our results show that the association of BAI with CVD risk factors is slightly weaker than for traditional body adiposity measures. Further epidemiological studies examining the utility of BAI for other populations are still needed for a better understanding of the validity of this new index.

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TABLES

Table 1. Baseline characteristics of participants by sex-specific body adiposity index (BAI) tertiles.

Table 2. Partial correlations examining the association between body adiposity measures after controlling for age and baseline examination year.

Table 3. Standardized regression coefficients examining the association of body adiposity index (BAI), body mass index (BMI), waist circumference, hip circumference, and percentage of body fat (%BF) with cardiovascular disease risk factors.

Table 4. Hazard ratios for incidence of hypertension according to different measures of adiposity.

Table 1. Baseline characteristics of participants by sex-specific body adiposity index (BAI) tertiles.

Characteristic	BAI (tertliles)							
	Males				Females			
	Lower (n=2677)	Middle (n=2693)	Upper (n=2680)	P value[a]	Lower (n=749)	Middle (n=755)	Upper (n=755)	P value[a]
Age (years)	46.1 (9.7)	47.9 (9.4)	48.8 (9.4)	<0.001	45.2 (8.8)	48.1 (9.5)	49.2 (9.7)	<0.001
Body mass index (kg/m^2)	23.6 (1.8)	25.6 (2.0)	28.7 (3.2)	<0.001	20.9 (1.7)	22.6 (1.9)	26.6 (4.0)	<0.001
Waist circumference (cm)	86.6 (6.9)	91.6 (7.2)	98.6 (9.4)	<0.001	68.7 (8.0)	71.5 (6.1)	79.6 (10.1)	<0.001
Hip circumference (cm)	96.6 (4.9)	100.3 (4.8)	106.0 (6.9)	<0.001	89.3 (6.1)	95.4 (4.7)	104.6 (8.3)	<0.001
BAI (%)	21.1 (1.3)	23.9 (0.7)	27.4 (2.2)	<0.001	23.3 (2.3)	27.3 (1.0)	32.5 (3.4)	<0.001
%BF	17.2 (5.0)	20.6 (4.7)	24.9 (5.2)	<0.001	21.5 (5.1)	25.3 (5.1)	30.7 (5.5)	<0.001
WHR	0.9(0.1)	0.9 (0.1)	0.9 (0.1)	>0.001	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	<0.001
Treadmill time (min)	21.9 (4.4)	19.9 (4.2)	17.2 (4.2)	<0.001	16.9 (4.4)	14.8 (3.7)	12.3 (3.7)	<0.001
Maximal metabolic equivalents (MET)	13.6 (2.4)	12.6 (2.1)	11.3 (2.0)	<0.001	11.2 (2.1)	10.2 (1.7)	9.0 (1.7)	<0.001
Total cholesterol (mg/dL)	194.3 (36.0)	202.9 (37.0)	208.6 (38.3)	<0.001	187.8 (31.9)	196.4 (33.8)	202.0 (33.1)	<0.001
Fasting blood glucose (mg/dL)	97.1 (14.1)	98.2 (12.2)	100.9 (17.2)	<0.001	92.7 (14.8)	93.0 (8.3)	95.0 (18.4)	0.003
Blood pressure (mmHg)								
Systolic	116.6 (9.5)	117.4 (9.1)	118.4 (9.2)	<0.001	108.4 (10.7)	110.9 (10.9)	113.6 (11.0)	<0.001
Diastolic	77.2 (6.8)	78.0 (6.4)	79.0 (6.2)	<0.001	72.9 (7.5)	74.5 (7.1)	75.9 (7.2)	<0.001
Physically inactive, No (%)[b]	402 (15.0)	509 (18.9)	665 (24.8)	<0.001	95 (12.7)	114 (15.1)	153 (20.3)	<0.001
Current smokers, No (%)	283 (10.6)	299 (11.1)	316 (11.8)	0.364	36 (4.8)	44 (5.8)	23 (3.0)	0.032
Heavy drinkers, No (%)[c]	199 (7.4)	252 (9.4)	257 (9.6)	0.009	143 (19.1)	133 (17.6)	105 (13.9)	0.022
Baseline medical conditions, No (%)								
Abnormal ECG[d]	195 (7.3)	238 (8.8)	261 (9.7)	0.005	55 (7.3)	63 (8.3)	85 (11.3)	0.022
Hypercholesterolemia[e]	542 (20.2)	725 (26.9)	865 (32.3)	<0.001	118 (15.8)	178 (23.6)	211 (27.9)	<0.001
Diabetes mellitus[f]	63 (2.4)	68 (2.5)	127 (4.7)	<0.001	22 (2.9)	27 (3.6)	33 (4.4)	0.330
Parental history of CVD, No (%)	501 (18.7)	560 (20.8)	615 (22.9)	0.001	170 (22.7)	196 (26.0)	201 (26.6)	0.171
Parental history of hypertension, No (%)	623 (23.3)	689 (25.6)	690 (25.7)	0.064	287 (38.3)	310 (41.1)	322 (42.6)	0.224

Values are means (standard deviations) or numbers (percentage). %BF indicates percentage of body fat; WHR, waist to hip ratio; CVD, cardiovascular disease; MET: metabolic equivalents.

[a] Analysis of the variance (ANOVA) for continuous variables and chi-square tests for categorical variables.

[b] Defined as reporting no physical activity during leisure time in the 3 months before the examination.

[c] Defined as >14 and >7 drinks/week for males and females, respectively.

[d] Abnormal resting or exercise electrocardiogram.

[e] Defined as total cholesterol ≥240 mg/dL or previous physician diagnosed hypercholesterolemia.

[f] Defined as fasting blood glucose ≥126 mg/dL, previous physician diagnosed diabetes or use of insulin.

Table 2. Partial correlations examining the association between body adiposity measures after controlling for age and baseline examination year.

	Males						Females					
	BAI	**BMI**	**Waist**	**Hip**	**%BF**	**WHR**	**BAI**	**BMI**	**Waist**	**Hip**	**%BF**	**WHR**
BAI	-						-					
BMI	0.787	-					0.780	-				
Waist	0.616	0.864	-				0.519	0.819	-			
Hip	0.687	0.804	0.831	-			0.832	0.791	0.658	-		
%BF	0.607	0.694	0.740	0.669	-		0.638	0.724	0.620	0.660	-	
WHR	0.255	0.548	0.754	0.264	0.500	-	-0.172	0.260	0.629	-0.156	0.143	-

BAI indicates body adiposity index; BMI, body mass index; waist, waist circumference; hip, hip circumference; %BF, percentage of total body fat; WHR, waist to hip ratio.

All correlations were statistically significant at $P \leq 0.001$

Table 3. Standardized regression coefficients examining the association of body adiposity index (BAI), body mass index (BMI), waist circumference, hip circumference, percentage of body fat (%BF), and waist to hip ratio (WHR) with cardiovascular disease risk factors.

	Body Adiposity Index (BAI)							
	Males				**Females**			
	R^2	β	r	R^2 change	R^2	β	r	R^2 change
Total cholesterol	0.054	0.162	0.170	0.026	0.137	0.117	0.163	0.013
Fasting blood glucose	0.027	0.114	0.127	0.013	0.043	0.084	0.086	0.007
Systolic blood pressure	0.022	0.085	0.099	0.007	0.122	0.171	0.212	0.028
Diastolic blood pressure	0.023	0.122	0.128	0.014	0.061	0.154	0.180	0.023
Cardiorespiratory fitness[a]	0.321	-0.400	-0.450	0.157	0.353	-0.401	-0.460	0.155
	Body Mass Index (BMI)							
Total cholesterol	0.052	0.157	0.143	0.024	0.147	0.156	0.186	0.024
Fasting blood glucose	0.040	0.163	0.164	0.026	0.049	0.113	0.119	0.012
Systolic blood pressure	0.033	0.136	0.145	0.018	0.143	0.224	0.250	0.049
Diastolic blood pressure	0.042	0.187	0.194	0.034	0.080	0.207	0.222	0.042
Cardiorespiratory fitness[a]	0.348	-0.437	-0.467	0.184	0.359	-0.404	-0.447	0.160
	Waist Circumference							
Total cholesterol	0.053	0.158	0.174	0.024	0.147	0.155	0.199	0.024
Fasting blood glucose	0.045	0.179	0.194	0.031	0.058	0.148	0.156	0.021
Systolic blood pressure	0.028	0.114	0.127	0.013	0.132	0.199	0.237	0.039
Diastolic blood pressure	0.039	0.177	0.179	0.030	0.080	0.208	0.229	0.042
Cardiorespiratory fitness[a]	0.395	-0.488	-0.541	0.231	0.320	-0.353	-0.411	0.121

All analyses adjusted for age and baseline examination year.

All *P* values were significant at ≤ 0.001.

[a] Maximal metabolic equivalents, MET.

Table 3. Continued.

	Hip circumference							
	Males				Females			
	R^2	β	r	R^2 change	R^2	β	r	R^2 change
Total cholesterol	0.038	0.102	0.094	0.010	0.132	0.093	0.120	0.008
Fasting blood glucose	0.029	0.124	0.128	0.015	0.046	0.100	0.091	0.010
Systolic blood pressure	0.026	0.106	0.115	0.011	0.123	0.174	0.198	0.029
Diastolic blood pressure	0.033	0.160	0.167	0.025	0.068	0.177	0.195	0.030
Cardiorespiratory fitness[a]	0.315	-0.392	-0.423	0.150	0.345	-0.389	-0.426	0.147
	Percentage of body fat (%BF)							
Total cholesterol	0.059	0.185	0.188	0.031	0.152	0.173	0.237	0.028
Fasting blood glucose	0.030	0.131	0.152	0.016	0.041	0.068	0.101	0.004
Systolic blood pressure	0.019	0.066	0.094	0.004	0.112	0.139	0.193	0.018
Diastolic blood pressure	0.029	0.151	0.159	0.021	0.063	0.164	0.186	0.025
Cardiorespiratory fitness[a]	0.463	-0.572	-0.641	0.298	0.440	-0.505	-0.574	0.241
	Waist to hip ratio (WHR)							
Total cholesterol	0.052	0.159	0.189	0.024	0.133	0.098	0.129	0.010
Fasting blood glucose	0.038	0.159	0.176	0.024	0.043	0.082	0.100	0.007
Systolic blood pressure	0.020	0.071	0.082	0.005	0.099	0.072	0.097	0.005
Diastolic blood pressure	0.022	0.121	0.114	0.014	0.045	0.083	0.093	0.007
Cardiorespiratory fitness[a]	0.306	-0.388	-0.437	0.141	0.203	-0.070	-0.107	0.005

All analyses adjusted for age and baseline examination year.

All *P* values were significant at ≤ 0.001.

[a] Maximal metabolic equivalents, MET.

Table 4. Hazard ratios for incidence of hypertension according to different measures of adiposity.

	Hazard ratio (95% CI)					
	Males			Females		
	Model 1 [a]	Model 2 [b]	Model 3 [c]	Model 1 [a]	Model 2 [b]	Model 3 [c]
BAI						
Low	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Middle	1.47 (1.22 – 1.78)	1.45 (1.20 – 1.75)	1.39 (1.15 – 1.68)	1.15 (0.67 – 1.95)	1.13 (0.66 – 1.92)	1.09 (0.64 – 1.87)
Upper	1.92 (1.60 – 2.31)	1.86 (1.55 – 2.23)	1.68 (1.38 – 2.04)	2.01 (1.24 – 3.27)	1.99 (1.22 – 3.26)	1.84 (1.10 – 3.08)
Per 1 SD increase	1.33 (1.24 – 1.42)	1.31 (1.22 – 1.40)	1.26 (1.16 – 1.35)	1.32 (1.10 – 1.58)	1.32 (1.10 – 1.59)	1.28 (1.04 – 1.56)
BMI						
18.5 - 24.9 kg/m^2	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
25.0 - 29.9 kg/m^2	1.56 (1.34 – 1.83)	1.53 (1.30 – 1.79)	1.45 (1.23 – 1.71)	1.73 (1.11 – 2.69)	1.67 (1.07 – 2.62)	1.61 (1.01 – 2.58)
≥ 30.0 kg/m^2	2.53 (2.02 – 3.17)	2.37 (1.88 – 2.98)	2.09 (1.63 – 2.70)	3.62 (1.97 – 6.65)	3.59 (1.92 – 6.72)	3.36 (1.71 – 6.60)
Per 1 SD increase	1.35 (1.26 – 1.44)	1.32 (1.24 – 1.42)	1.28 (1.18 – 1.38)	1.34 (1.14 – 1.57)	1.35 (1.14 – 1.59)	1.31 (1.08 – 1.58)
Waist circumference[d]						
Low	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
High	1.80 (1.51 – 2.14)	1.70 (1.42 – 2.03)	1.49 (1.23 – 1.81)	1.98 (1.13 – 3.45)	1.92 (1.09 – 3.39)	1.72 (0.95 – 3.09)
Per 1 SD increase	1.36 (1.27 – 1.45)	1.33 (1.24 – 1.43)	1.29 (1.19 – 1.40)	1.31 (1.11 – 1.55)	1.30 (1.09 – 1.54)	1.25 (1.04 – 1.51)

BAI indicates body adiposity index; BMI, body mass index; SD, standard deviation; %BF, percentage of body fat.

[a] Adjusted for age, baseline examination year, and survey response pattern.

[b] Adjusted for model 1 plus physical activity (active or inactive), smoking (current smoker or not), alcohol intake (> 14 drinks/week ♂ / > 7 drinks/week ♀ or not), abnormal electrocardiogram, hypercholesterolemia and diabetes (present or not for each), and parental history of CVD and hypertension.

[c] Adjusted for model 2 plus cardiorespiratory fitness (treadmill test duration in minutes).

[d] Low waist circumference indicates < 102 cm ♂ and < 88 cm ♀; High waist circumference, ≥ 102 cm ♂ and ≥ 88 cm ♀.

Table 4. Continued.

	Hazard ratio (95% CI)					
	Males			Females		
	Model 1 [a]	Model 2 [b]	Model 3 [c]	Model 1 [a]	Model 2 [b]	Model 3 [c]
Hip circumference						
Low	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Middle	1.21 (1.01 – 1.46)	1.20 (0.99 – 1.44)	1.14 (0.95 – 1.38)	1.15 (0.71 – 1.87)	1.12 (0.68 – 1.82)	1.06 (0.65 – 1.74)
Upper	1.70 (1.42 – 2.02)	1.64 (1.37 – 1.96)	1.46 (1.21 – 1.77)	1.39 (0.87 – 2.23)	1.31 (0.81 – 2.11)	1.16 (0.70 – 1.90)
Per 1 SD increase	1.28 (1.19 – 1.37)	1.26 (1.17 – 1.35)	1.20 (1.11 – 1.29)	1.22 (1.01 – 1.47)	1.20 (0.99 – 1.45)	1.14 (0.92 – 1.40)
%BF						
Low	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Middle	1.23 (1.02 – 1.48)	1.19 (0.99 – 1.44)	1.10 (0.90 – 1.33)	1.19 (0.71 – 1.97)	1.14 (0.68 – 1.91)	1.04 (0.62 – 1.76)
Upper	1.69 (1.41 – 2.02)	1.60 (1.33 – 1.93)	1.37 (1.11 – 1.69)	1.40 (0.86 – 2.29)	1.34 (0.81 – 2.23)	1.12 (0.64 – 1.95)
Per 1 SD increase	1.26 (1.17 – 1.36)	1.23 (1.14 – 1.33)	1.15 (1.05 – 1.26)	1.20 (0.99 – 1.47)	1.19 (0.97 – 1.46)	1.12 (0.89 – 1.41)
Waist to hip ratio						
Low	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Middle	1.84 (1.50 – 2.25)	1.81 (1.47 – 2.21)	1.73 (1.41 – 2.12)	0.98 (0.56 – 1.71)	0.99 (0.57 – 1.72)	0.97 (0.56 – 1.70)
Upper	2.20 (1.80 – 2.69)	2.11 (1.72 – 2.58)	1.90 (1.54 – 2.36)	2.00 (1.23 – 3.24)	1.98 (1.21 – 3.24)	1.90 (1.16 – 3.12)
Per 1 SD increase	1.29 (1.20 – 1.38)	1.26 (1.17 – 1.36)	1.20 (1.11 – 1.30)	1.13 (0.98 – 1.31)	1.13 (0.97 – 1.31)	1.12 (0.96 – 1.31)

BAI indicates body adiposity index; BMI, body mass index; SD, standard deviation; %BF, percentage of body fat.

[a] Adjusted for age, baseline examination year, and survey response pattern.

[b] Adjusted for model 1 plus physical activity (active or inactive), smoking (current smoker or not), alcohol intake (> 14 drinks/week ♂ / > 7 drinks/week ♀ or not), abnormal electrocardiogram, hypercholesterolemia and diabetes (present or not for each), and parental history of CVD and hypertension.

[c] Adjusted for model 2 plus cardiorespiratory fitness (treadmill test duration in minutes).

Table 5. Baseline characteristics of participants who developed incident hypertension by sex.

	Males (n=765)	Females (n=107)	Total (n=872)	P value[a]
Age (years)	50.8 (9.6)	51.5 (9.9)	50.9 (9.7)	
Body mass index (kg/m^2)	26.5 (3.3)	24.4 (4.5)	26.3 (3.6)	<0.001
Waist circumference (cm)	94.7 (9.3)	75.9 (11.0)	92.4 (11.3)	<0.05
Hip circumference (cm)	101.8 (6.9)	97.4 (10.2)	101.3 (7.5)	<0.001
BAI (%)	24.8 (3.0)	28.8 (4.9)	25.3 (3.5)	<0.001
%BF	21.9 (5.6)	27.5 (6.2)	22.6 (6.0)	
WHR	0.9 (0.1)	0.8 (0.1)	0.9 (0.1)	<0.01
Treadmill time (min)	18.8 (4.6)	13.3 (3.8)	18.1 (4.8)	<0.05
Maximal metabolic equivalents (MET)	12.0 (2.2)	9.5 (1.8)	11.7 (2.3)	<0.01
Total cholesterol (mg/dL)	207.4 (35.6)	200.9 (29.0)	206.6 (34.9)	<0.05
Fasting blood glucose (mg/dL)	100.3 (19.0)	99.0 (24.9)	100.1 (19.8)	
Blood pressure (mmHg)				
Systolic	122.2 (8.5)	120.5 (10.6)	122.0 (8.8)	<0.01
Diastolic	80.7 (5.8)	78.0 (7.0)	80.4 (6.0)	<0.01
Physically inactive, No (%)[b]	172 (22.5)	23 (21.5)	195 (22.4)	
Current smokers, No (%)	83 (10.8)	7 (6.5)	90 (10.3)	
Heavy drinkers, No (%)[c]	79 (10.3)	21 (19.6)	10 (11.5)	<0.01
Baseline medical conditions, No (%)				
Abnormal ECG[d]	88 (11.5)	15 (14.0)	103 (14.8)	
Hypercholesterolemia[e]	209 (23.7)	28 (26.2)	237 (27.2)	
Diabetes mellitus[f]	32 (4.2)	4 (3.7)	36 (4.1)	
Parental history of CVD, No (%)	161 (21.0)	33 (30.8)	194 (22.2)	<0.05
Parental history of hypertension, No (%)	170 (22.2)	50 (46.7)	220 (25.2)	<0.001

Values are means (standard deviations) or numbers (percentage). BAI indicates body adiposity index; %BF indicates percentage of body fat; WHR indicates waist to hip ratio; CVD, cardiovascular disease; MET: metabolic equivalents.

[a] Analysis of the variance (ANOVA) for continuous variables and chi-square tests for categorical variables.

[b] Defined as reporting no physical activity during leisure time in the 3 months before the examination.

[c] Defined as >14 and >7 drinks/week for males and females, respectively.

[d] Abnormal resting or exercise electrocardiogram.

[e] Defined as total cholesterol ≥240 mg/dL or previous physician diagnosed hypercholesterolemia.

[f] Defined as fasting blood glucose ≥126 mg/dL, previous physician diagnosed diabetes or use of insulin.