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

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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 between 1988 and 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.

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 comorbidities, which can lead to further morbidity and mortality [3]. In recent years, there have been an increased

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.

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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 $\geq$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 $\geq$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 12 h 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 (18.5–24.9 as normal weight; 25–29.9 as overweight; $\geq$30 as obese) and waist circumference ($\geq$102 cm for males and $\geq$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 $\geq$5 min of sitting quietly using mercury sphygmomanometers. Two readings separated by 2 min 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 $\geq$126 mg/dL, a history of physician diagnosis, or insulin use. Hypercholesterolemia was defined as total cholesterol of $\geq$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