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The Relationship of Body Mass and Fat Distribution With Incident Hypertension

Observations From the Dallas Heart Study

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ABSTRACT

BACKGROUND Obesity has been linked to the development of hypertension, but whether total adiposity or site-specific fat accumulation underpins this relationship is unclear.

OBJECTIVES This study sought to determine the relationship between adipose tissue distribution and incident hypertension.

METHODS Normotensive participants enrolled in the Dallas Heart Study were followed for a median of 7 years for the development of hypertension (systolic blood pressure [SBP] ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or initiation of blood pressure medications). Visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) was quantified by magnetic resonance imaging and proton-spectroscopic imaging, and lower body fat (LBF) was imaged by dual-energy x-ray absorptiometry. Multivariable relative risk regression was performed to test the association between individual fat depots and incident hypertension, adjusting for age, sex, race/ethnicity, diabetes, smoking, SBP, and body mass index (BMI).

RESULTS Among 903 participants (median age, 40 years; 57% women; 60% nonwhite; median BMI 27.5 kg/m^2), 230 (25%) developed incident hypertension. In multivariable analyses, higher BMI was significantly associated with incident hypertension (relative risk: 1.24; 95% confidence interval: 1.12 to 1.36, per 1-SD increase). However, when VAT, SAT, and LBF were added to the model, only VAT remained independently associated with incident hypertension (relative risk: 1.22; 95% confidence interval: 1.06 to 1.39, per 1-SD increase).

CONCLUSIONS Increased visceral adiposity, but not total or subcutaneous adiposity, was robustly associated with incident hypertension. Additional studies will be needed to elucidate the mechanisms behind this association.
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An epidemiological link between adiposity and hypertension development has been firmly established (1,2). However, many obese patients will remain normotensive despite significant adiposity. Differences in adipose tissue distribution may contribute to the heterogeneity of clinical and biological manifestations of obesity (3,4).

Under conditions of inadequate subcutaneous adipose tissue (SAT) (e.g., nutrient overload or lipodystrophy), excess triglyceride is stored ectopically

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ABBREVIATIONS AND ACRONYMS

BMI = body mass index

BP = blood pressure

DBP = diastolic blood pressure

DEXA = dual-energy x-ray absorptiometry

hs-CRP = high-sensitivity C-reactive protein

LBF = lower body fat

MRI = magnetic resonance imaging

SAT = subcutaneous adipose tissue

SBP = systolic blood pressure

VAT = visceral adipose tissue

in other depots, such as visceral adipose tissue (VAT), muscle, and liver. Whereas SAT is relatively metabolically inert, VAT is associated with increased cytokine production (5) and insulin resistance (4).

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The question remains whether the association between obesity and hypertension is influenced by site-specific adipose tissue accumulation. We hypothesized that VAT mass, rather than SAT or the degree of overall adiposity, would be associated with the development of hypertension.

METHODS

STUDY POPULATION. The DHS study (Dallas Heart Study) is a multiethnic, probability-based cohort study of Dallas County adults (age 18 to 65 years), with deliberate oversampling of African-American participants (6). The study schema is summarized in Figure 1. The current study population was drawn from 2,716 participants who completed all 3 visits of DHS phase 1 (DHS-1) from 2000 to 2002, which included blood pressure (BP) measurements, laboratory testing, abdominal magnetic resonance imaging (MRI), and dual-energy x-ray absorptiometry (DEXA) scan. Of these participants, those with baseline hypertension (systolic blood pressure [SBP] ≥140 mm Hg, diastolic blood pressure [DBP] ≥90 mm Hg, or on antihypertensive medications) were excluded, as were participants with borderline BP elevations at baseline (SBP ≥130 or DBP ≥85 mm Hg) to preclude minimal increases in BP meeting the incident hypertension definition. After these exclusions, 1,306 participants were eligible for follow-up.

Of these, 903 participants completed all 3 visits of DHS-1 and returned for DHS phase 2 (DHS-2), which consisted of follow-up studies during a single visit between 2007 and 2009. This comprised the current study population. There were no significant differences in medical history, demographics, or biomarker data between eligible participants who did and did not complete DHS-2 (4). All participants provided written informed consent, and the University of Texas-Southwestern Medical Center institutional review board approved the protocol.

HYPERTENSION DEFINITION. Trained professionals took BP measurements after 5 min of rest in the seated position using an automated oscillometric device (Series #52,000, Welch Allyn, Arden, North Carolina). Five measurements were taken, and the last 3 readings were averaged. Antihypertensive medications were defined as any diuretic, alpha-blocker, beta-blocker, calcium channel blocker, angiotensin-converting-enzyme inhibitor or angiotensin receptor blocker, nitrate, and hydralazine. Participants were asked to bring all their medications to their visit, and a trained professional examined all of the medications thoroughly. In both phases of the DHS, hypertension was defined as SBP ≥140 mm Hg, DBP ≥90 mm Hg, or the participant taking any antihypertensive medications.

ABDOMINAL FAT QUANTIFICATION. Participants were scanned at their baseline exam by a 1.5-T MRI scanner (Intera, Philips Healthcare, Best, the Netherlands). Retroperitoneal, intraperitoneal, and SAT abdominal fat masses were quantified by a single MRI slice taken at the L2-L3 level using manual contours, as previously validated against cadaveric samples (7). Areas were converted to mass (kg) using previously determined regression equations (8). VAT was then defined as the combination of both retroperitoneal and intraperitoneal fat masses to express the total intra-abdominal fat mass (4,9). Subjects also underwent ^{1}H-magnetic resonance spectroscopy for hepatic triglyceride quantification, as previously described (10).

LOWER BODY FAT QUANTIFICATION. Participants were scanned by DEXA, which was performed with a

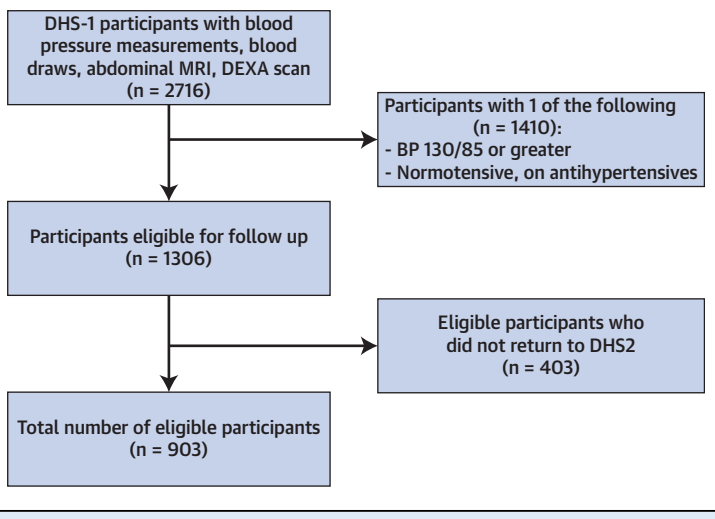

FIGURE 1 Flow Diagram of the DHS Study Cohort

BP = blood pressure; DEXA = dual-energy x-ray absorptiometry; DHS = Dallas Heart Study; MRI = magnetic resonance imaging.