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The Relationship of BMI and WHR on the 9-Year Incidence of Type 2 Diabetes and Hypertension in a Predominantly African-origin Population

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Abstract

Purpose—To provide 9-year incidence data for type 2 diabetes and hypertension and evaluate the relationship of body mass index (BMI) and waist-hip ratio (WHR) on these comorbidities in an Afro-Caribbean population.

Methods—A longitudinal, population-based cohort study including 4,631 participants at baseline; 2,793 were reexamined at the 9-year follow-up. Type 2 diabetes was defined by self-reported history and/or GHb measurement; hypertension was defined as systolic blood pressure (BP) ≥ 140 mmHg and/or diastolic BP ≥ 90 mmHg and/or use of antihypertensive treatment. Incidence rates were based on persons without such conditions at baseline.

Results—The 9-year incidence of hypertension (95% confidence interval) was higher in women [37.5% (34.0, 41.2)] than men [30.6% (26.9, 34.6)], whereas the incidence of diabetes was similar for both genders (14%). Body size was related to both conditions; however, the incidence of hypertension was more strongly associated to WHR, whereas diabetes had a stronger association with BMI.

Conclusions—Incidence rates for diabetes and hypertension were high in this cohort and the relationship of BMI and WHR on these co-morbidities was significant. These findings suggest the need to develop tailored interventions and preventive strategies in this Afro-Caribbean and similar high risk populations.

Keywords

type 2 diabetes; hypertension; incidence; body mass index; waist-hip ratio

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INTRODUCTION

Numerous cross-sectional studies have documented the association between body size and type 2 diabetes and hypertension (1–4), especially among populations of African origin where the prevalence rates of obesity and diabetes/hypertension are known to be high (5–11). It is only through the evaluation of newly diagnosed cases of these comorbidities, however, that the true impact of excess weight can be realized. Reports detailing the impact of obesity on the incidence of these conditions in African-origin populations, to date, are limited (12–15). The present investigation provides new population-based longitudinal data on the 9-year incidence of type 2 diabetes and hypertension in a population of African descent from Barbados, West Indies. Additionally, we evaluate the association between body size and the incidence of these comorbidities in this population, thus providing important data that may be used to identify those at highest risk, design prevention programs, and decrease the public health burden associated with these conditions.

METHODS

The Barbados Eye Studies are a series of investigations spanning a 15-year period aimed at determining the prevalence, incidence and risk factors for the major eye diseases in Barbados, West Indies. These studies were funded by the National Eye Institute and included an initial baseline phase, the Barbados Eye Study (BES: 1987–1992), followed by 4-year and 9-year incidence phases, the Barbados Incidence Studies of Eye Diseases I (BISED I: 1992–1997) and II (BISED II: 1997–2002). The population-based BES cohort represented a simple random sample of the country's adult citizens and included 4,631 participants (84% of those eligible) between 40 and 84 years of age. Of those, 4,314 (93%) self-reported their race as black, 184 (4%) as mixed (black and white) and 133 (3%) and white/other. After 9 years, a total of 2,793 (81% of those eligible) participated.

The BES, BISED I and BISED II protocols were all standardized and have been described in detail elsewhere (16–18). In summary, the study examination included a complete ocular evaluation, as well as a detailed interview including demographic information, medical history and medication use, anthropometric and blood pressure measurements, and venipuncture for glycosylated hemoglobin (GHb), along with quality control procedures. A balance beam scale and wall-mounted height measure were used to assess weight and height, respectively. Body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters. Steel tapes were used to measure waist and hip circumferences, and waist-hip ratio (WHR) was defined as the waist measurement divided by the hip measurement. A Hawksley random zero sphygmomanometer was used to assess blood pressure and the average of two measurements was recorded. Systolic blood pressure (SBP) was defined by the point of the first Korotkoff sound and diastolic blood pressure (DBP) at the fifth sound. GHb levels were determined by affinity chromatography of venous whole blood (19) using Glyc-Affin kits (Isolab, Akron, Ohio). This assay has a reference range between 4% and 8% and measures all GHb variants.

Definitions

Hypertension was defined as a SBP $\geq$ 140 mmHg and/or DBP $\geq$ 90 mmHg and/or use of antihypertensive treatment. Diabetes was defined as a self-reported history of physician-diagnosed diabetes and/or a GHb level $>10\%$ (greater than 2 standard deviations (SD) above the population mean of persons without a history of diabetes, mean=7%, SD=1.5%). GHb assays were only available on 3,754 (81%) of the participants at baseline, as these measurements were not obtained at the beginning of the study. BMI was categorized into three levels: normal (<25 kg/m²), overweight (25– <30 kg/m²), and obese (≥ 30 kg/m²).

Statistical Analyses

Incidence of hypertension was based on the number of persons with hypertension at 9 years among those who did not have hypertension at baseline. Likewise, diabetes incidence was calculated as the number of persons who developed diabetes by their 9-year visit among those without diabetes in BES. Age- and gender-specific incidence is presented with 95% confidence intervals (CI). Logistic regression models were developed to determine the relationship of body size with these conditions, with the magnitude of the relative risks (RR) used to quantify the relationships. Since the distribution of body size measurements in Barbados tends to be higher than in many other populations (20), quartile values based on baseline BMI and WHR were used in the regression analyses while adjusting for age, gender, smoking status, alcohol consumption, family history and the other concomitant condition (history of diabetes or hypertension, respectively).

RESULTS

Of the 4,631 BES participants, 2,793 (81% of those eligible) had a BISED II examination. Table 1 presents the baseline characteristics for participants and non-participants of the 9-year follow-up. Those who participated were significantly younger than those who did not (56.0 years vs. 63.5 years) and a higher proportion of those who were examined after 9 years were female (59.3% vs. 53.4%). After adjusting for age and gender, participants were found to have higher BMI, less hypertension and less diabetes than non-participants. The median systolic and diastolic blood pressures were 10 mmHg and 1 mmHg lower, respectively, among those who attended their 9 year visit compared to those who did not. Similarly, the mean baseline GHb level was significantly higher among non-participants (8.0 vs. 7.5, $p < 0.05$). Due to the small number of whites/others in the study, the remaining analyses are based on African-Barbadian (AB) participants only.

The age- and gender-specific 9-year incidence rates of hypertension and diabetes are presented in Table 2. The results indicate that one-third of those at risk developed hypertension over the 9-year study period. Newly developed hypertension increased steadily with age and was higher among women than men (37.5% vs. 30.6%). Incidence increased from 31.1% among persons 40–49 years to 42.2% for those 60 years of age or older. The incidence of diabetes, however, tended to decrease with age and had similar overall rates for men and women (14.3% vs 14.0%, respectively). Incidence decreased from 15.6% for persons younger than 50 years to 12.0% for persons 60+ years, with about 14% of those unaffected at baseline developing diabetes over 9 years.

At baseline, one-quarter of AB participants were considered to be obese based on WHO standards for BMI (3rd quartile cutoff = 29.8 kg/m²). The 25th and 50th percentile cutoffs for BMI were 23.3 and 26.3 kg/m², respectively. The corresponding quartile cutoffs for baseline WHR were 0.87 and 0.92, with one-quarter of the cohort having a WHR ≥ 0.97 .

Table 3 presents the logistic regression analyses for incident hypertension. Older age [RR = 1.02, 95% CI (1.01, 1.03)] and female gender (1.48 (1.13, 1.94)) were found to be associated with increased risk, along with higher WHR. Waist-hip ratio ≥ 0.87 yielded similar risks, regardless of the magnitude of the measurement. Due to the similarity of RRs for WHR between the 2nd and 4th quartiles, a subsequent analysis was performed dichotomizing WHR at a cutoff of 0.87 (the 25th percentile point), while adjusting for all other factors. This analysis yielded a RR = 1.61 (1.22, 2.12). Smoking was also associated with a trend to increased risk [1.51 (0.98, 2.31; $p = 0.06$]; however, higher BMI measurements did not significantly impact the incidence of hypertension.

The evaluation of relevant variables on the incidence of diabetes is presented in Table 4. BMI was the most significant factor influencing diabetes incidence with increased risk noted for those with BMIs in the 3rd and 4th quartiles compared to the reference group (1st quartile). Persons with a BMI in the 4th quartile were more than 3.5 times more likely to develop incident diabetes over 9 years [RR = 3.65 (2.45, 5.46)], and those with a WHR in the 4th quartile had an increased risk over 1.5 times that of persons in the reference group [RR = 1.60 (1.12, 2.30)]. Alcohol consumption was also shown to be strongly associated with the development of diabetes [RR = 1.43 (1.00, 2.04)].

DISCUSSION

The high prevalence of hypertension and diabetes in populations of African origin, as well as the influence of obesity on these co-morbidities, has been well documented in large, cross-sectional studies (1,3,4,8). However, data on the incidence of these conditions and the subsequent impact of excess weight are limited. The present investigation provides 9-year incidence data on hypertension and diabetes in a population of predominantly African descent and indicates that incidence is high, with one-third of those at risk developing hypertension over 9 years and 14% developing diabetes (Table 2). Although body size affected the incidence of both conditions, the development of hypertension was related to higher WHR (Table 3), whereas diabetes was associated with increases in BMI (Table 4).

Hypertension

A previous report based on the BES cohort highlighted the high prevalence of elevated blood pressure and the public health importance of controlling hypertension in this and other African-origin populations, as treated uncontrolled hypertensives were at significantly increased risk of early mortality (6). One report from the International Collaborative Study on Hypertension in Blacks (ICSHIB) indicated that 6–29% of hypertension was attributable to overweight and 0–16% was due to obesity among seven populations of African origin (5). In a separate investigation using the ICSHIB data, the population attributable risk (PAR) percentages for overweight (defined as waist circumference (WC) ≥ 94 and ≥ 80 cm for men and women, respectively) on hypertension status indicated that one-quarter of hypertension in Barbadian men and one-half of hypertension in women might be prevented by avoidance of overweight (9). These attributable fraction percentages in Barbados were 25% higher than those in the US. In the present investigation, the population attributable risks among AB men and women (using the same WC cutoffs to define overweight) were 25.0% and 32.8%, respectively. The somewhat lower PAR percents found among women in the BES compared to ICHSIB may be due to the fact that the ICSHIB estimates were based on cross-sectional data, whereas the BES estimates were based on incidence data. The estimates among the men were not affected as much since the distribution of WC in AB males was less variable over time.

Two landmark longitudinal studies showed that weight status was associated with incident hypertension. The Framingham Heart Study (21) and the Nurses Health Study (2) each reported an association between weight gain and a subsequent increase in the incidence of hypertension. Both studies included predominantly Caucasian persons, in which the prevalence of both hypertension and obesity is lower than in populations of African origin (4,22). Since then two additional longitudinal studies have investigated the relationship between weight status and incident hypertension in the African American (AA) population (14,15). The Atherosclerosis Risk in Communities (ARIC) Study included over 9,000 participants, of which more than 1,500 were AA. The study indicated that the prevalence of hypertension was twice as high in AAs as Caucasians (56% vs. 27%), with incidence rates almost double in AAs, as well. The incidence of hypertension among AA males and females was 16–17% during the first three years of the study, with an additional 19–20% during years four to six. The Pitt County Study

investigated the relationship between baseline BMI and incident hypertension (15) in a stratified random sample of 668 AA men and 1168 AA women, 25–50 years of age living in Pitt County, NC. The results indicated that the 5-year incidence of hypertension was approximately 14% for both genders and that although baseline BMI was positively associated with BP change, baseline BMI was not associated with hypertension incidence among AA males or females. It should be noted that hypertension was defined as SBP $\geq$ 160 mmHg and/or DBP $\geq$ 95 mmHg and/or the current use of antihypertensive treatment in that study. In the present investigation, one in every three persons at risk developed hypertension over the 9-year period. This finding is generally consistent with the data from ARIC, although direct comparisons are difficult due to differences in the duration of the studies and the demographic distributions of the cohorts. In the BES, incidence increased with age, gender and baseline WHR, whereas BMI was not significantly related to the development of hypertension over 9 years. This finding is consistent with some studies (15,23,24), but not all (25). The BES findings suggest that a WHR of 0.87 or above increases one's risk more than 1.5-fold compared to those with lower ratios.

Diabetes

Data from cross-sectional studies have indicated that the prevalence of type 2 diabetes is significantly higher among obese men and women, with elevated rates corresponding to increased weight categories (4). A previous report from the BES documented the high prevalence of diabetes in the present cohort and demonstrated a positive association between diabetes and BMI as well as waist-hip ratio (7). In addition, data from the Health, Wellbeing and Aging Project indicated that Barbados had the highest prevalence of diabetes compared to other cities in Latin America and the Caribbean (26). Obesity has been reported as one of the main risk factors for Type 2 diabetes(27), with its life-shortening effect estimated to be approximately 13 years (22). Data from ICSHB indicated that the PAR percent for overweight (BMI $\geq$ 25 kg/m²) on diabetes was 28.3% in Barbados and 35.6% among AAs (11). In the BES, using the same definition for overweight (BMI $\geq$ 25 kg/m²), the PAR percent was 57.9%. Again, the estimates reported from ICSHB were based on prevalence data, whereas the BES estimates resulted from our 9-year incidence data. This difference, as well as other possible factors may contribute to the higher PAR percents found in the present investigation.

Several studies investigating the association between obesity and diabetes incidence have been carried out in various groups including populations of European, Asian, and Indian descent, as well as among Mexican- and Japanese-Americans (28–35). A limited number of studies, however, have reported on the incidence of diabetes among populations of African origin. Data from NHANES (1971–1992), which included 1,531 AA and 9,852 Caucasian participants found that incidence, defined by self-report of physician diagnosis, medical records or death certificates, was 10% in a 20 year period (13). The effect of BMI on diabetes risk was larger for AAs than Caucasians, with an age adjusted OR of diabetes for AAs compared to Caucasians of 2.1 (1.8, 2.4). In the ARIC study, there were 298 incident cases of diabetes among 1,670 AA women at risk and 161 of 976 AA men developed diabetes, yielding 9-year incidence rates of 17.8% and 16.5%, respectively (36). In that study, diabetes was defined by self-report of physician-diagnosis, use of diabetes medications or fasting glucose of 7.0 mmol/L and diabetes incidence per 1000 person years was found to be about 2.4 times higher in AA women and 1.5 times greater in AA men than in their Caucasian counterparts. Additionally, adiposity was found to increase diabetes risk among AA women, while conferring little excess risk in AA men. The 9-year incidence rates of diabetes in the BES were similar for men and women (14.3% vs. 14.0%, respectively) and slightly lower than those in ARIC. This may be due to population differences, as well as the different criteria used to define diabetes in the respective studies.

There has been some debate as to whether other measures of body size such as waist circumference (WC) or waist-hip ratio (WHR) may be more appropriate than BMI in assessing the impact of obesity in diabetes (37–40). Whereas one study among Mexican-Americans reported WC as the best predictor of type 2 diabetes (39), another study in Jamaica found BMI, WHR and WC to be essentially equivalent (40). In the Nurse's Health Study, all three measurements were useful for predicting diabetes incidence; however, the RR for BMI was 3–4 times higher than the RR for WHR (11.2 [7.9, 15.9] vs. 3.1 [2.3, 4.1]) (38). Findings from the present investigation are consistent with those of the Nurse's Health Study and suggest that high WHR plays some role in the development of diabetes, however, BMI appears to be the stronger predictor of disease.

Although the study had a commendable participation rate of 81% at follow-up, the BES had a considerable number of non-participants after 9 years, representing a group of older persons with significantly more hypertension and diabetes than their participating counterparts. This represents one of the study's limitations as the analyses are based on a group of survivors that may be intrinsically different than the baseline cohort. A second limitation was the lack of fasting glucose measurements. It has been shown, however, that GHb is a good indicator of glycemic status (41–44) and that self-report of diabetes status is highly accurate (45). Therefore, we do not feel as though this limitation significantly affected the findings.

In summary, the incidence of both hypertension and type 2 diabetes are high in this older adult population, with one-third of those at risk of developing hypertension and one in seven developing diabetes in a 9-year period. Although women generally had a higher incidence of hypertension, the rates of diabetes were comparable between the sexes. As expected, increases in BMI and/or WHR were associated with both co-morbidities. These findings suggest the need for the development of interventions and preventive strategies in this population and others of African-origin, where the public and individual burdens associated with diabetes and hypertension continue to rise.

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REFERENCES

1. Brown CD, Higgins M, Donato KA, et al. Body mass index and the prevalence of hypertension and dyslipidemia. *Obes Res* 2000;8:605–619. [PubMed: 11225709]
2. Huang Z, Willett WC, Manson JE, et al. Body weight, weight change, and risk for hypertension in women. *Ann Intern Med* 1998;128:81–88. [PubMed: 9441586]
3. Gregg EW, Cheng YJ, Cadwell BL, et al. Secular trends in cardiovascular disease risk factors according to body mass index in US adults. *Jama* 2005;293:1868–1874. [PubMed: 15840861]
4. Must A, Spadano J, Coakley EH, et al. The disease burden associated with overweight and obesity. *Jama* 1999;282:1523–1529. [PubMed: 10546691]
5. Kaufman JS, Durazo-Arvizu RA, Rotimi CN, et al. Obesity and hypertension prevalence in populations of African origin. The Investigators of the International Collaborative Study on Hypertension in Blacks. *Epidemiology* 1996;7:398–405. [PubMed: 8793366]
6. Hennis A, Wu SY, Nemesure B, et al. Hypertension prevalence, control and survivorship in an Afro-Caribbean population. *J Hypertens* 2002;20:2363–2369. [PubMed: 12473859]
7. Hennis A, Wu SY, Nemesure B, et al. Diabetes in a Caribbean population: epidemiological profile and implications. *Int J Epidemiol* 2002;31:234–239. [PubMed: 11914326]
8. Okosun IS, Chandra KM, Choi S, et al. Hypertension and type 2 diabetes comorbidity in adults in the United States: risk of overall and regional adiposity. *Obes Res* 2001;9:1–9. [PubMed: 11346661]
9. Okosun IS, Forrester TE, Rotimi CN, et al. Abdominal adiposity in six populations of West African descent: prevalence and population attributable fraction of hypertension. *Obes Res* 1999;7:453–462. [PubMed: 10509602]
10. Foster C, Rotimi C, Fraser H, et al. Hypertension, diabetes, and obesity in Barbados: findings from a recent population-based survey. *Ethn Dis* 1993;3:404–412. [PubMed: 7888992]
11. Cooper RS, Rotimi CN, Kaufman JS, et al. Prevalence of NIDDM among populations of the African diaspora. *Diabetes Care* 1997;20:343–348. [PubMed: 9051385]
12. Lipton RB, Liao Y, Cao G, et al. Determinants of incident non-insulin-dependent diabetes mellitus among blacks and whites in a national sample. The NHANES I Epidemiologic Follow-up Study. *Am J Epidemiol* 1993;138:826–839. [PubMed: 8237971]
13. Resnick HE, Valsania P, Halter JB, et al. Differential effects of BMI on diabetes risk among black and white Americans. *Diabetes Care* 1998;21:1828–1835. [PubMed: 9802729]
14. Juhaeri, Stevens J, Chambless LE, et al. Associations between weight gain and incident hypertension in a bi-ethnic cohort: the Atherosclerosis Risk in Communities Study. *Int J Obes Relat Metab Disord* 2002;26:58–64. [PubMed: 11791147]
15. Curtis AB, Strogatz DS, James SA, et al. The contribution of baseline weight and weight gain to blood pressure change in African Americans: the Pitt County Study. *Ann Epidemiol* 1998;8:497–503. [PubMed: 9802594]
16. Leske MC, Connell AM, Schachat AP, et al. The Barbados Eye Study. Prevalence of open angle glaucoma. *Arch Ophthalmol* 1994;112:821–829. [PubMed: 8002842]
17. Leske MC, Connell AM, Wu SY, et al. Incidence of open-angle glaucoma: the Barbados Eye Studies. The Barbados Eye Studies Group. *Arch Ophthalmol* 2001;119:89–95. [PubMed: 11146731]
18. Leske MC, Wu SY, Nemesure B, et al. Nine-year incidence of lens opacities in the Barbados Eye Studies. *Ophthalmology* 2004;111:483–490. [PubMed: 15019323]
19. Willey DG, Rosenthal MA, Caldwell S. Glycosylated hemoglobin and plasma glycoprotein assays by affinity chromatography. *Diabetologia* 1984;27:56–58. [PubMed: 6468800]
20. Nemesure B, Wu SY, Hennis A, et al. Prevalence of obesity and associated sex-specific factors in an African-origin population. *Ethn Dis* 2007;17:508–514. [PubMed: 17985506]
21. Kannel WB, Brand N, Skinner JJ Jr, et al. The relation of adiposity to blood pressure and development of hypertension. The Framingham study. *Ann Intern Med* 1967;67:48–59. [PubMed: 6028658]

22. Burt VL, Cutler JA, Higgins M, et al. Trends in the prevalence, awareness, treatment, and control of hypertension in the adult US population. Data from the health examination surveys, 1960 to 1991. *Hypertension* 1995;26:60–69. [PubMed: 7607734]
23. Visscher TL, Seidell JC, Mollarius A, et al. A comparison of body mass index, waist-hip ratio and waist circumference as predictors of all-cause mortality among the elderly: the Rotterdam study. *Int J Obes Relat Metab Disord* 2001;25:1730–1735. [PubMed: 11753597]
24. Gus M, Fuchs SC, Moreira LB, et al. Association between different measurements of obesity and the incidence of hypertension. *Am J Hypertens* 2004;17:50–53. [PubMed: 14700512]
25. Kristjansson K, Sigurdsson JA, Lissner L, et al. Blood pressure and pulse pressure development in a population sample of women with special reference to basal body mass and distribution of body fat and their changes during 24 years. *Int J Obes Relat Metab Disord* 2003;27:128–133. [PubMed: 12532164]
26. Barcelo A, Pelaez M, Rodriguez-Wong L, et al. The prevalence of diagnosed diabetes among the elderly of seven cities in Latin America and the Caribbean: The Health Wellbeing and Aging (SABE) Project. *J Aging Health* 2006;18:224–239. [PubMed: 16614342]
27. Rimm EB, Stampfer MJ, Giovannucci E, et al. Body size and fat distribution as predictors of coronary heart disease among middle-aged and older US men. *Am J Epidemiol* 1995;141:1117–1127. [PubMed: 7771450]
28. Wang SL, Pan WH, Hwu CM, et al. Incidence of NIDDM and the effects of gender, obesity and hyperinsulinaemia in Taiwan. *Diabetologia* 1997;40:1431–1438. [PubMed: 9447951]
29. Bonora E, Kiechl S, Willeit J, et al. Population-based incidence rates and risk factors for type 2 diabetes in white individuals: the Bruneck study. *Diabetes* 2004;53:1782–1789. [PubMed: 15220202]
30. Bergstrom RW, Newell-Morris LL, Leonetti DL, et al. Association of elevated fasting C-peptide level and increased intra-abdominal fat distribution with development of NIDDM in Japanese-American men. *Diabetes* 1990;39:104–111. [PubMed: 2210052]
31. Haffner SM, Hazuda HP, Mitchell BD, et al. Increased incidence of type II diabetes mellitus in Mexican Americans. *Diabetes Care* 1991;14:102–108. [PubMed: 2060411]
32. Lundgren H, Bengtsson C, Blohme G, et al. Adiposity and adipose tissue distribution in relation to incidence of diabetes in women: results from a prospective population study in Gothenburg, Sweden. *Int J Obes* 1989;13:413–423. [PubMed: 2793297]
33. Stolk RP, van Splunder IP, Schouten JS, et al. High blood pressure and the incidence of non-insulin dependent diabetes mellitus: findings in a 11.5 year follow-up study in The Netherlands. *Eur J Epidemiol* 1993;9:134–139. [PubMed: 8519350]
34. Saad MF, Knowler WC, Pettitt DJ, et al. The natural history of impaired glucose tolerance in the Pima Indians. *N Engl J Med* 1988;319:1500–1506. [PubMed: 3054559]
35. Hara H, Egusa G, Yamakido M. Incidence of non-insulin-dependent diabetes mellitus and its risk factors in Japanese-Americans living in Hawaii and Los Angeles. *Diabet Med* 1996;13:S133–S142. [PubMed: 8894497]
36. Brancati FL, Kao WH, Folsom AR, et al. Incident type 2 diabetes mellitus in African American and white adults: the Atherosclerosis Risk in Communities Study. *Jama* 2000;283:2253–2259. [PubMed: 10807384]
37. Kragelund C, Omland T. A farewell to body-mass index? *Lancet* 2005;366:1589–1591. [PubMed: 16271629] Carey VJ, Walters EE, Colditz GA, et al. Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women. The Nurses' Health Study. *Am J Epidemiol* 1997;145:614–619. [PubMed: 9098178]
38. Wei M, Gaskill SP, Haffner SM, et al. Waist circumference as the best predictor of noninsulin dependent diabetes mellitus (NIDDM) compared to body mass index, waist/hip ratio and other anthropometric measurements in Mexican Americans—a 7-year prospective study. *Obes Res* 1997;5:16–23. [PubMed: 9061711]
39. Sargeant LA, Bennett FI, Forrester TE, et al. Predicting incident diabetes in Jamaica: the role of anthropometry. *Obes Res* 2002;10:792–798. [PubMed: 12181388]
40. Little RR, England JD, Wiedmeyer HM, et al. Relationship of glycosylated hemoglobin to oral glucose tolerance. Implications for diabetes screening. *Diabetes* 1988;37:60–64. [PubMed: 3335278]

41. Rohlfing CL, Little RR, Wiedmeyer HM, et al. Use of GHb (HbA1c) in screening for undiagnosed diabetes in the U.S. population. *Diabetes Care* 2000;23:187–191. [PubMed: 10868829]
42. Hanson RL, Nelson RG, McCance DR, et al. Comparison of screening tests for non-insulin-dependent diabetes mellitus. *Arch Intern Med* 1993;153:2133–2140. [PubMed: 8379805]
43. McCance DR, Hanson RL, Charles MA, et al. Comparison of tests for glycated haemoglobin and fasting and two hour plasma glucose concentrations as diagnostic methods for diabetes. *Bmj* 1994;308:1323–1328. [PubMed: 8019217]
44. Bush TL, Miller SR, Golden AL, et al. Self-report and medical record report agreement of selected medical conditions in the elderly. *Am J Public Health* 1989;79:1554–1556. [PubMed: 2817172]

Figure 1. Relative Risk of Hypertension by BMI* Level

*BMI=Body Mass Index ** Reference Group

Figure 2. Relative Risk of Diabetes by BMI* Level
*BMI=Body Mass Index ** Reference Group

Table 1

Baseline Characteristics for Participants and Non-Participants After 9 Years

	Participants	Non-Participants**	Total
Characteristic	(n=2793)	(n=1838)	(n=4631)
Age, years [*] mean±sd (median)	56.0±10.8 (55)	63.5±12.5 (65)	59.0±12.1 (58)
Gender, % Female [*]	59.3	53.4	57.0
Race, % Black	93.5	92.6	93.2
BMI, kg/m ² [†] mean±sd (median)	27.3±5.3 (26.7)	26.2±5.4 (25.6)	26.9±5.4 (26.2)
WHR mean±sd (median)	0.91 ± 0.09 (0.92)	0.92 ± 0.08 (0.92)	0.92 ± 0.08 (0.92)
Hypertension, % [†]	49.1	64.0	55.0
SBP, mmHg [†] mean±sd (median)	133.6±21.9 (130)	141.4±23.8 (140)	136.7±23.0 (134)
DBP, mmHg [†] mean±sd (median)	80.8±11.6 (80)	81.9±12.8 (81)	81.2±12.1 (80)
BP Treatment, % [†]	26.3	33.7	29.2
Family History of High BP, %	40.6	31.5	37.0
Diabetes, % [†]	15.7	23.9	19.0
GHb level [†] mean±sd (median)	7.5±2.1 (7.1)	8.0±2.6 (7.2)	7.7±2.3 (7.1)
Diab Treatment, % [†]	12.2	19.3	15.0
Family History of Diabetes, %	29.0	22.6	26.4
Ever Smoke, %	9.4	12.2	10.6
Ever Drink, %	17.6	18.6	18.0

* p<0.05 for participants vs non-participants

[†] p<0.05 for participants vs non-participants from logistic regression analyses after adjusting for age and sex

** Non-participants included those who died or did not participate for other reasons

Hypertension: SBP≥140 or DBP≥90 or Hx of treatment

Diabetes: GHb>10 or self-reported hx of diabetes

Table 2
Age and Sex-Specific 9-Year Incidence of Hypertension and Diabetes

	9-Year Incidence of Hypertension*					
	Male			Female		
Baseline Age, years	no./no. at risk	% (95% CI)		no./no. at risk	% (95% CI)	Total
40-49	69/271	25.5 (20.4, 31.1)		124/350	35.4 (30.4, 40.7)	193/621
50-59	50/156	32.0 (24.8, 40.0)		80/224	35.7 (29.4, 42.4)	130/380
60+	55/141	39.0 (30.9, 47.6)		66/146	45.2 (37.0, 53.7)	121/287
Total	174/568	30.6 (26.9, 34.6)		270/720	37.5 (34.0, 41.2)	444/1288
9-Year Incidence of Hypertension*						
	Male			Female		
	no./no. at risk	% (95% CI)		no./no. at risk	% (95% CI)	Total
Baseline Age, years						
40-49	58/355	16.3 (12.7, 20.6)		70/467	15.0 (11.9, 18.6)	128/822
50-59	41/251	16.3 (12.0, 21.5)		51/373	13.7 (10.4, 17.6)	92/624
60+	31/301	10.3 (7.1, 14.3)		57/429	13.3 (10.2, 16.9)	88/730
Total	130/907	14.3 (12.1, 16.8)		178/1269	14.0 (12.2, 16.1)	308/2176

* Hypertension: SBP≥140 or DBP≥90 or Hx of treatment
Diabetes: GHb> 10 or self-reported hx of diabetes

Table 3

Relative Risks* for the 9-year Incidence of Hypertension

Baseline Characteristics	Relative Risk (95% Confidence Interval)
Age	1.02 (1.01, 1.03)
Female Gender	1.48 (1.13, 1.94)
BMI	1.0
1 st Quartile	1.03 (0.73, 1.45)
2 nd Quartile	0.98 (0.70, 1.38)
3 rd Quartile	1.30 (0.92, 1.85)
4 th Quartile	
WHR	1.0
1 st Quartile	1.55 (1.12, 2.16)
2 nd Quartile	1.65 (1.18, 2.30)
3 rd Quartile	1.63 (1.15, 2.32)
4 th Quartile	
Diabetes	0.85 (0.59, 1.23)
Family History of High BP	1.03 (0.80, 1.34)
Ever Smoke	1.51 (0.98, 2.31) [†]
Ever Drink	0.92 (0.65, 1.30)

* Adjusted relative risk based on logistic regression model, including variables presented in this table.

[†] p = 0.06

BMI = Body mass index; WHR = Waist-hip ratio; BP = Blood pressure

BMI quartiles (< 23.3, ≥ 23.3 and < 26.3, ≥ 26.3 and < 29.8, ≥ 29.8)

WHR quartiles (<0.87, ≥ 0.87 and < 0.92, ≥ 0.92 and < 0.97, ≥ 0.97)

Table 4

Relative Risks* for the 9-year Incidence of Diabetes

Baseline Characteristics	Relative Risk (95% Confidence Interval)
Age	1.00 (0.98, 1.01)
Female Gender	0.78 (0.58, 1.05)
BMI	1.0
1 st Quartile	0.84 (0.53, 1.34)
2 nd Quartile	2.14 (1.43, 3.20)
3 rd Quartile	3.65 (2.45, 5.46)
4 th Quartile	
WHR	1.0
1 st Quartile	1.08 (0.74, 1.58)
2 nd Quartile	1.17 (0.82, 1.69)
3 rd Quartile	1.60 (1.12, 2.30)
4 th Quartile	
Hypertension	0.96 (0.74, 1.25)
Family History of Diabetes	1.10 (0.84, 1.42)
Ever Smoke	0.92 (0.57, 1.49)
Ever Drink	1.43 (1.00, 2.04)

* Adjusted relative risk based on logistic regression model, including variables presented in this table.

BMI = Body mass index; WHR = Waist-hip ratio

BMI quartiles (< 23.3, ≥ 23.3 and < 26.3, ≥ 26.3 and < 29.8, ≥ 29.8)

WHR quartiles (<0.87, ≥ 0.87 and < 0.92, ≥ 0.92 and < 0.97, ≥ 0.97)