Plasma Adiponectin and the Risk of Hypertension in White and Black Postmenopausal Women

Lu Wang, 1* JoAnn E. Manson, 1,2 J. Michael Gaziano, 1,3,4 Simin Liu, 5 Barbara Cochrane, 6 Nancy R. Cook, 1 Paul M Ridker, 1,7 Nader Rifai, 8 and Howard D. Sesso 1,2,3

BACKGROUND: Adiponectin may have a protective role in the development of obesity-related metabolic and vascular disorders, including hypertension. We conducted a prospective, nested case control study to investigate the relationship between baseline plasma adiponectin, measures of adiposity, and subsequent risk of hypertension.

METHODS: We selected 400 white and 400 black postmenopausal women, age <70 years, who developed incident hypertension during 5.9-year follow-up and an equal number of age- and race-matched controls in the Women’s Health Initiative Observational Study. We measured plasma concentrations of total adiponectin in their baseline blood samples.

RESULTS: In crude matched models, plasma adiponectin was inversely associated with risk of hypertension among both white and black women. The association appeared to be nonlinear in white women but dose related in black women. Adjustment for lifestyle factors, measures of obesity, and obesity-related clinical factors attenuated these associations. The multivariable relative risk (95% CI) of hypertension across increasing quartiles of plasma adiponectin were 1.00, 0.98 (0.66–1.46), 0.63 (0.41–0.97), and 0.92 (0.60–1.42) in white women (P trend: 0.38) and 1.00, 0.96 (0.64–1.46), 0.83 (0.53–1.29), and 0.58 (0.36–0.94) in black women (P trend: 0.02). Further adjustment for inflammatory markers and endothelial markers eliminated the association in white, but not black, women.

CONCLUSIONS: In this prospective, nested case control study, we found an inverse association between plasma adiponectin and risk of hypertension in white and black postmenopausal women. The reduced risk of hypertension was limited to only intermediate concentrations of adiponectin in white women whereas it was graded across quartiles of adiponectin in black women. © 2012 American Association for Clinical Chemistry

Obesity is a modifiable risk factor for hypertension. Measures of obesity such as high body mass index (BMI) are consistently associated with increases in blood pressure (BP) and a greater risk of hypertension (1–3). Conversely, weight loss among overweight and obese individuals has shown BP-lowering benefits (4, 5). The mechanisms underlying these observations remain unclear. Recently, adipose tissue has been characterized as an endocrine organ that produces a variety of biologically active compounds. These compounds, collectively known as adipokines, have profound effects on metabolism and vasculature, and potentially play important roles in the pathogenesis of obesity-related disorders, including hypertension (6).

Adiponectin is one adipokine that is produced and secreted exclusively by adipocytes (7). Concentrations of circulating adiponectin are inversely correlated with BMI, waist-to-hip ratio, and percentage body fat (8, 9). Laboratory studies show that adiponectin suppresses several pathophysiological processes related to obesity, including insulin resistance, endothelial dysfunction, inflammation, and atherosclerosis (7). Epidemiologic studies have revealed evidence for hypoadiponectinemia as an independent risk factor for type 2 diabetes (10, 11) and coronary heart disease (12). Despite several cross-sectional and case control studies showing an inverse association between plasma adiponectin and BP levels or hypertension status (13–16), prospective

1 Division of Preventive Medicine, Brigham and Women’s Hospital, Boston, MA; 2 Department of Epidemiology, Harvard School of Public Health, Boston, MA; 3 Division of Aging, Brigham and Women’s Hospital, Boston, MA; 4 Massachusetts General Hospital, Boston, MA; 5 Department of Laboratory Medicine, Children’s Hospital, Boston, MA; 6 Department of Laboratory Medicine, Massachusetts General Hospital, Boston, MA; 7 Division of Cardiovascular Medicine, Brigham and Women’s Hospital, Boston, MA; 8 Department of Laboratory Medicine, Children’s Hospital, Boston, MA.

* Address correspondence to: Brigham and Women’s Hospital, 900 Commonwealth Ave., Boston MA 02215. Fax 617-731-3843; e-mail luwang@rics.bwh.harvard.edu.

Received June 8, 2012; accepted July 11, 2012. Previously published online at DOI: 10.1373/clinchem.2012.191080

Nonstandard abbreviations: BMI, body mass index; BP, blood pressure; WHI-OS, Women’s Health Initiative-Observational Study; SBP, systolic BP; DBP, diastolic BP; hsCRP, high-sensitivity C-reactive protein; IL-6, interleukin-6; sICAM-1, soluble intercellular adhesion molecule-1; RR, relative risk.

Copyright (C) 2012 by The American Association for Clinical Chemistry
studies of adiponectin in association with risk of hypertension remain sparse (17–19).

Black individuals have significantly higher BP and higher prevalence of hypertension than white individuals (20, 21). In addition, circulating adiponectin concentrations are lower in African-Americans compared with Caucasians (22, 23). Whether the racial difference in adiponectin concentrations explains the differences in BP and hypertension risk has yet to be tested. We therefore investigated the association between plasma adiponectin, measures of adiposity, and the risk of hypertension in a nested case control study within a prospective multiethnic cohort of postmenopausal women.

Materials and Methods

STUDY PARTICIPANTS

The Women’s Health Initiative-Observational Study (WHI-OS) is a prospective cohort study of chronic diseases among ethnically diverse postmenopausal women. Details of the study have been reported previously (24). The study has been reviewed and approved by the human study participant review committees at each participating institution, and signed informed consent was obtained from all participants.

Of the 93,676 women enrolled into the WHI-OS, we limited our study to those <70 years old to minimize the impact of preexisting atherosclerosis. We identified potential hypertension cases during a median follow-up of 5.9 years by meeting 1 of the following criteria: systolic BP (SBP) ≥140 mmHg, diastolic BP (DBP) ≥90 mmHg, or medication use specifically for increased BP. BP was measured at the WHI clinic visit with standard protocols after participants sat quietly for 5 min. The mean of 2 BP readings, obtained 30 s apart, was used for analysis. Antihypertensive medication use was reported on annual follow-up questionnaires and confirmed by the year 3 and/or year 6 medication inventories review. We excluded cases with hypertension and other major morbidities at baseline and those who did not provide baseline blood samples, leaving 5251 (4774 white and 477 black) eligible incident cases for the current study. To minimize misclassification of borderline hypertension, we defined free-of-baseline hypertension as an SBP <135 mmHg, DBP <85 mmHg, no diagnosis of hypertension, and no antihypertensive medication use. When the same exclusion criteria were applied to potential controls, who never reported antihypertensive medication use and maintained an SBP <135 mmHg and DBP <85 mmHg during follow-up, 20,679 (19,773 white and 906 black) controls were eligible for the current study.

For each case of incident hypertension, we matched 1 control by age (within 2 years), ethnicity (white/Caucasian or black/African-American), clinical center (geographic location), and date of enrollment (within 2 years). In total, 400 white and 400 black case–control pairs were selected from the eligible case and control pool via random sampling.

ASSESSMENT OF COVARIATES AND PLASMA ADIPONECTIN

WHI-OS participants provided comprehensive self-reported information on demographics, lifestyle, diet, and medical history through questionnaires. At the baseline visit, body weight was measured with a calibrated balance beam scale, height was measured with a calibrated, wall-mounted stadiometer, and waist circumference was measured at the end of normal expiration over nonbinding undergarments in a horizontal plane at the natural waist. Baseline blood samples were collected and stored in liquid nitrogen until analysis. We measured plasma adiponectin by RIA (Linco Diagnostics Laboratory). The intraassay CVs were 8.6%. We also measured high-sensitivity C-reactive protein (hsCRP) and interleukin-6 (IL-6) as markers of chronic inflammation and soluble intercellular adhesion molecule-1 (sICAM-1) as a marker of endothelial activation. All investigators and laboratory personnel were blinded to the participants’ case–control status. All blood samples were handled identically throughout the processes of collection, storage, retrieval, and assays.

STATISTICAL ANALYSIS

We conducted analyses using SAS version 9.1 (SAS Institute) for white and black women separately. We used paired t-tests (for means) and McNemar tests (for proportions) to compare baseline hypertension risk factors between cases and controls. We then compared hypertension risk factors across the quartile of adiponectin as determined among the controls. We calculated relative risks (RRs) and 95% CIs of incident hypertension for each quartile of adiponectin using conditional logistic regression. Crude models controlled only for matching factors. Multivariable models sequentially adjusted for known lifestyle risk factors for hypertension, including cigarette smoking (never, past, current), alcohol use (never, past, <1 drink/month, <1 drink/week, 1 to <7 drinks/week, ≥7 drinks/week), recreational physical activity (continuous MET (metabolic equivalent task)-h/week), and hormone replacement therapy (never, past, current) (model 1); measures of adiposity (continuous BMI or waist circumference); adiposity-related clinical factors including history of diabetes and use of cholesterol-lowering medication (both yes, no) (model 2); and lastly, plasma inflammatory and endothelial markers (both continuous) (model 3). We also assessed the association between measures of adiposity and risk of
hypothesis before and after adjustment for plasma adiponectin, and evaluated the combined association of plasma adiponectin and measures of adiposity with risk of hypertension.

Several sensitivity analyses were conducted: first, excluding women with baseline prehypertension (SBP/DBP between 120/80 and 135/85 mmHg); second, excluding women with baseline diabetes; third, additionally adjusting for baseline SBP; and fourth, modeling BMI and waist circumference with quadratic terms. All sensitivity analyses yielded results similar to the main analyses.

Results

Compared with white women in this study, black women were younger, heavier, less physically active, more likely to be current smokers or diabetic, and less likely to consume alcohol ≥7 drinks/week or use hormone therapy, regardless of case–control status. Plasma adiponectin was substantially lower in black vs white women (P < 0.0001). When hypertension cases and controls were compared (Table 1), cases had greater baseline BMI and waist circumference and were engaged in less physical activity than controls. Plasma adiponectin was significantly lower in cases than in controls for both white and black women (both P < 0.05).

Among controls, the Spearman r of plasma adiponectin with measures of adiposity was −0.29 with BMI and −0.36 with waist circumference in white women, and −0.31 with BMI and −0.36 with waist circumference in black women (all P < 0.0001). When adiposity-related factors were compared across quartiles of adiponectin (Table 2), BMI, waist circumference, plasma hsCRP, and IL-6 progressively decreased with increasing adiponectin in both white and black women, whereas sICAM-1 was only slightly lower in higher quartiles of adiponectin in white, but not black, women. Lifestyle factors, other clinical factors, and BP at baseline did not significantly differ by quartiles of adiponectin (see Table 1 in the Data Supplement that accompanies the online version of this article at http://www.clinchem.org/content/vol58/issue10).

Because our study aimed to examine the race-specific association between plasma adiponectin and the risk of hypertension, we a priori stratified our analysis by race (Table 3), although the test for interaction by race did not reach statistical significance. In white women, only those in the third quartile of adiponectin had a significantly lower risk of hypertension; the linear trend across quartiles was not significant after adjusting for lifestyle factors. In black women, there was a graded inverse association between adiponectin and hypertension risk, the association did not materially change after adjusting for lifestyle factors. Additional

| Table 1. Baseline characteristics of white and black hypertension case–control pairs in the WHI-OS.a |
|---------------------------------------------------------------|---------------------|----------------------|---------------------|---------------------|---------------------|
| Characteristic                                              | White               | Black               | White               | Black               | White               |
|                                                             | Controlsb (n = 400) | Cases (n = 400)     | Controlsb (n = 400) | Cases (n = 400)     | Controlsb (n = 400) |
| Age, years                                                  | 60.8 (5.4)          | 60.8 (5.4)          | 0.18                | 58.1 (5.2)          | 58.2 (5.3)          |
| BMI, kg/m²                                                   | 25.2 (5.1)          | 26.8 (5.5)          | <0.0001             | 28.2 (5.8)          | 30.1 (6.6)          | <0.0001             |
| Waist circumference, cm                                    | 79.0 (10.5)         | 83.6 (12.7)         | <0.0001             | 84.6 (12.6)         | 88.8 (13.6)         | <0.0001             |
| Physical activity, MET-h/week                               | 16.9 (16.2)         | 15.0 (14.9)         | 0.09                | 12.9 (16.4)         | 10.8 (14.0)         | 0.05                |
| Current smoking, %                                          | 6.1                 | 5.8                 | 0.96                | 10.4                | 13.3                | 0.48                |
| Alcohol use ≥7 drinks/week, %                               | 12.8                | 12.8                | 0.24                | 5.6                 | 4.8                 | 0.35                |
| Current hormone therapy use, %                              | 53.8                | 60.5                | 0.30                | 34.5                | 39.4                | 0.15                |
| History of diabetes, %                                      | 1.0                 | 2.5                 | 0.11                | 4.0                 | 9.8                 | 0.002               |
| Cholesterol-lowering medication use, %                       | 8.5                 | 11.1                | 0.24                | 9.1                 | 9.2                 | 0.90                |
| Baseline blood pressure, mmHg                                |                     |                     |                     |                     |                     |
| Systolic                                                    | 113.3 (10.9)        | 120.9 (8.7)         | <0.0001             | 115.3 (10.4)        | 121.1 (8.6)         | <0.0001             |
| Diastolic                                                   | 70.2 (7.0)          | 74.1 (6.4)          | <0.0001             | 71.9 (7.0)          | 74.7 (5.9)          | <0.0001             |
| Plasma adiponectin, ng/mL                                   | 7805 (3184)         | 7285 (3272)         | 0.03                | 5366 (2553)         | 4885 (2395)         | 0.004               |

a Results are shown as mean (SD) or percentage.

b Cases and controls were matched by age, race/ethnicity, clinical center, and time of enrollment.

P values were derived from paired t-test for continuous variables and McNemar's test for categorical variables.
Table 2. Baseline adiposity-related factors according to quartiles of plasma adiponectin in 400 white and 400 black control women.a

| Baseline characteristic | White | Quartiles of plasma adiponectin | Black | Quartiles of plasma adiponectin | P* | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | P_trend |
|-------------------------|-------|---------------------------------|-------|---------------------------------|----|-----|-----|-----|-----|-----|-----|-----|---------|
| Median (range), ng/mL   | 4261(1278–5497) | 6695 (5539–7541) | 8334 (7547–9464) | 11236 (9468–20590) | 2862 (1015–3456) | 4150 (3510–4907) | 5575 (4811–6749) | 8309 (6770–15495) | 59.7 | 57.7 | 59.3 | 57.7 | 0.98 |
| Age, years              | 60.3  | 61.2  | 60.5  | 61.5  | 0.19 | 57.9  | 57.7  | 59.3  | 57.7  | 0.98 |
| BMI, kg/m²              | 27.1  | 25.2  | 24.4  | 24.2  | <0.0001 | 29.9  | 29.1  | 28.1  | 25.7  | <0.0001 |
| Waist circumference, cm | 84.6  | 79.6  | 77.5  | 74.4  | <0.0001 | 90.3  | 86.2  | 83.4  | 78.5  | <0.0001 |
| Plasma biomarkers       |       |       |       |       |       |       |       |       |       |       |
| CRP, mg/Lb              | 2.10  | 1.53  | 1.17  | 1.05  | <0.0001 | 3.13  | 2.40  | 1.70  | 1.00  | <0.0001 |
| IL-6, pg/mLb            | 1.58  | 1.44  | 1.12  | 1.12  | 0.0003 | 1.90  | 1.84  | 1.72  | 1.42  | 0.005 |
| sICAM-1, pg/mL          | 310.3 | 294.8 | 276.9 | 294.8 | 0.05 | 240.9 | 259.5 | 265.2 | 238.0 | 0.61 |

a Results are shown as means.
b Geometric means are shown.

Table 3. Risk of hypertension according to race-specific quartiles of plasma adiponectin.a

<table>
<thead>
<tr>
<th>Quartiles of plasma adiponectin</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>P_trend</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>P_trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases/controls, n</td>
<td>130/100</td>
<td>114/99</td>
<td>66/100</td>
<td>88/99</td>
<td>122/100</td>
<td>128/100</td>
<td>85/100</td>
<td>64/100</td>
<td>122/100</td>
<td>128/100</td>
</tr>
<tr>
<td>Crudeb</td>
<td>1.00</td>
<td>0.89 (0.61–1.28)</td>
<td>0.54 (0.36–0.80)</td>
<td>0.71 (0.48–1.04)</td>
<td>0.02</td>
<td>1.00</td>
<td>1.06 (0.74–1.51)</td>
<td>0.68 (0.46–1.02)</td>
<td>0.49 (0.32–0.76)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Multivariable model 1c</td>
<td>1.00</td>
<td>0.89 (0.61–1.31)</td>
<td>0.57 (0.37–0.86)</td>
<td>0.82 (0.55–1.24)</td>
<td>0.14</td>
<td>1.00</td>
<td>1.04 (0.71–1.52)</td>
<td>0.72 (0.47–1.10)</td>
<td>0.49 (0.31–0.77)</td>
<td>0.0006</td>
</tr>
<tr>
<td>Multivariable model 1 + BMId</td>
<td>1.00</td>
<td>0.98 (0.66–1.46)</td>
<td>0.63 (0.41–0.97)</td>
<td>0.96 (0.62–1.47)</td>
<td>0.46</td>
<td>1.00</td>
<td>0.97 (0.65–1.44)</td>
<td>0.75 (0.49–1.16)</td>
<td>0.53 (0.33–0.86)</td>
<td>0.006</td>
</tr>
<tr>
<td>Multivariable model 2e</td>
<td>1.00</td>
<td>0.98 (0.66–1.46)</td>
<td>0.63 (0.41–0.97)</td>
<td>0.92 (0.60–1.42)</td>
<td>0.38</td>
<td>1.00</td>
<td>0.96 (0.64–1.46)</td>
<td>0.83 (0.53–1.29)</td>
<td>0.58 (0.36–0.94)</td>
<td>0.02</td>
</tr>
<tr>
<td>Multivariable model 3f</td>
<td>1.00</td>
<td>1.02 (0.68–1.54)</td>
<td>0.66 (0.42–1.02)</td>
<td>1.02 (0.65–1.59)</td>
<td>0.67</td>
<td>1.00</td>
<td>0.90 (0.59–1.37)</td>
<td>0.79 (0.51–1.24)</td>
<td>0.59 (0.36–0.96)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

a Results are shown as RR (95% CI).
b Crude model controlled only for matching factors including age, clinical center, and time of enrollment.
c Model adjusted for smoking, alcohol use, physical activity, and hormone replacement therapy.
d Model additionally adjusted for BMI, history of diabetes, and lipid-lowering medication use.

\[ \text{Clinical Chemistry} \ 58:10 (2012) \]
adjustment for measures of adiposity and related clinical factors only moderately attenuated these associations. The corresponding multivariable RRs and 95% CI of hypertension across increasing quartiles of adiponectin were 1.00, 0.98 (0.66–1.46), 0.63 (0.41–0.97), and 0.92 (0.60–1.42) in white women (P\text{trend}: 0.38) and 1.00, 0.96 (0.64–1.46), 0.83 (0.53–1.29), and 0.58 (0.36–0.94) in black women (P\text{trend}: 0.02). Further adjustment for inflammatory and endothelial markers eliminated the association in white, but not black, women. Including waist circumference as measure of adiposity and IL-6 as marker of inflammation obtained similar results (data not shown).

We further explored the impact of adjusting for plasma adiponectin on the relation between measures of adiposity and risk of hypertension. In white women, the lifestyle- and clinical factors–adjusted RR for a 1-SD increase in BMI was 1.34 (95% CI: 1.14–1.57) before further adjustment for adiponectin and 1.31 (95% CI: 1.11–1.55) after the adjustment. In black women, the corresponding RRs were 1.32 (1.14–1.53) and 1.27 (1.09–1.48), respectively. The change of RR for a 1-SD increase in waist circumference before and after adjustment for adiponectin was similar (data not shown).

Lastly, we evaluated the joint association of plasma adiponectin and measures of adiposity with risk of hypertension (Fig. 1). In white women, compared with those who had plasma adiponectin in the highest quartile and BMI <25 kg/m², the RR of hypertension was 1.12 for those with only lower adiponectin, 2.77 for those with only higher BMI, and 2.09 for those with both low adiponectin and high BMI. In black women, the corresponding RRs were 2.25, 2.88, and 3.45, respectively. The joint associations of plasma adiponectin and waist circumference with risk of hypertension were similar. None of the interactions was statistically significant.

Discussion

In this prospective, nested case control study of postmenopausal women, we found an inverse association
between plasma adiponectin and risk of hypertension in both white and black women. In white women, the association was confined to a reduced risk of hypertension in the third quartile of plasma adiponectin. In black women, the association was linear and remained significant after adjustment for measures of adiposity and adiposity-related metabolic factors and biochemical markers.

Adiponectin is a cytokine produced and secreted exclusively by adipocytes, and it modulates several obesity-induced pathophysiologic processes potentially involved in development of hypertension (7). Adiponectin enhances peripheral-tissue insulin sensitivity and promotes fatty acid oxidation (25). In patients with obesity-related metabolic disorders, improvements in insulin sensitivity (26) and fatty acid metabolism (27) occurred with lowering of BP. Adiponectin also stimulates the production of nitric oxide in endothelial cells, (28) and attenuates smooth muscle cell proliferation and migration (29), which exert direct benefits on the vascular system. Moreover, adiponectin can inhibit the production and activity of tumor necrosis factor-α in macrophages (30) and suppress the generation and release of reactive oxygen species (31). These antiinflammatory and antioxidative properties may also contribute to prevention of hypertension. In our study, plasma adiponectin was inversely associated with glucose and lipid metabolism disorders and markers of inflammation and endothelial activation irrespective of race, supporting the hypothesis that these factors potentially mediate the protective effect of adiponectin against hypertension.

Prospective studies have indicated that hypoadiponectinemia is an independent risk factor for type 2 diabetes (10, 11) and coronary heart disease (12). The relation between adiponectin and BP or hypertension was less studied. An inverse correlation between adiponectin and BP or hypertension was found in cross-sectional studies of healthy individuals (15, 16). At least 2 case control studies revealed significantly lower concentrations of adiponectin in hypertensive patients compared with normotensive controls (13, 14), but the reverse has also been reported (32). We are aware of 3 prospective studies of circulating adiponectin and incident hypertension. In a nested case control study of 70 Chinese nondiabetic participants who developed incident hypertension during 5 years of follow-up and 140 controls, the odds ratio of hypertension was 2.76 (95%CI: 1.06–7.16) for those with baseline serum adiponectin in the lowest vs the highest tertile after adjusting for baseline mean BP, BMI, and hsCRP (17). In a prospective cohort study of 391 healthy Japanese men, those in the lowest quartile of serum adiponectin had a 3.42 (95% CI: 1.16–10.05)-fold greater risk of developing hypertension than those in the highest quartile (18). In contrast, another prospective cohort study of 920 European men and women found no association between adiponectin and incident hypertension during more than 10 years of follow-up; the odds ratio of hypertension was 1.02 (95% CI: 0.84–1.24) for a 1-SD increase in the log-transformed adiponectin concentration (19). Our study expanded these earlier investigations to a larger, multiethnic cohort of postmenopausal women and found a nonlinear inverse association between plasma adiponectin and risk of hypertension in white women and a graded inverse association in black women. Notably, after adjusting for obesity-related metabolic factors, inflammatory and endothelial biomarkers, the association in black women was attenuated, but not completely eliminated. This finding suggested that plasma adiponectin may have an independent protective effect on hypertension beyond the expected pathways.

Our study was specifically designed to investigate the association between plasma adiponectin and risk of hypertension in white and black women. Because we expect to find sizable differences in plasma adiponectin between whites and blacks on the basis of previous studies (22, 23), we conducted a priori race-specific analyses despite our finding that tests for interaction with race were not statistically significant. Consistent with our assumption, we found significantly lower adiponectin concentrations in black vs white women. This finding likely reflects differences in body composition and adiposity (33) between whites and blacks. Because we matched hypertension cases and controls on race, we cannot determine whether the difference in adiponectin explains the racial disparities in hypertension risk. Nevertheless, our study suggested that the association of plasma adiponectin with risk of hypertension may differ by race, for which additional studies are needed. Previously, a cross-sectional study found a significant correlation between adiponectin and insulin sensitivity in white, but not black, women (22), whereas an inverse association of adiponectin with incident coronary heart disease was observed in black, but not white, men and women in a prospective cohort study (34). Racial differences were also found in body fat and metabolic profiles in relation to adiponectin gene variations: in blacks but not in whites, the IVS2+G62T polymorphism was associated with adiposity and total cholesterol concentrations, and the Gly15Gly polymorphism was associated with cholesterol and triglyceride concentrations (35). These previous findings indicate that the effect of adiponectin on various physical parameters may differ by race, leading to different etiology or susceptibility for hypertension. On the other hand, we can-
not rule out the possibility that the racial differences observed in our study were due to chance.

Maintenance of normal body weight is an integral component of current clinical guidelines for prevention and treatment of hypertension (36, 37). Several obesity-induced pathophysiological processes may lead to elevation of BP (38), yet the specific mechanisms linking obesity to hypertension remain incompletely understood. Recent research has characterized adipose tissue as an active endocrine organ that synthesizes and secretes various adipokines (6). The expression of adipokines parallels progression of obesity and potentially mediates the pathogenesis of obesity complications, including hypertension. In our study, we examined the association between BMI and waist circumference with risk of hypertension before and after adjustment for plasma adiponectin, finding that adiponectin only slightly attenuated the associations in whites and blacks. Whether other plasma adipokines or alternative mechanisms play a more important role in the relation between obesity and hypertension requires further investigation.

Several limitations of this study deserve discussion. First, we had only baseline measurements of plasma adiponectin and were unable to account for any change over time. The random misclassification would tend to bias the association toward null. Second, adiponectin circulates in multimeric complexes of high, medium, and low molecular weight. High molecular weight adiponectin is the most biologically active form (39), whereas we measured only total adiponectin. However, previous study has demonstrated that measurement of high molecular weight complexes does not provide more information in addition to total adiponectin (40). Third, despite comprehensive adjustment for multiple covariates, residual confounding will persist. Finally, because we limited our study to participants who had no major chronic disease and were aged 50–70 years, our findings apply to a selected subgroup of postmenopausal women who were generally healthy and developed hypertension later in life.

In summary, this prospective nested case control study showed an inverse association between plasma adiponectin and risk of hypertension in white and black postmenopausal women. In white women, a reduced risk of hypertension was found only in those with moderately high adiponectin, whereas in black women, the inverse association was linear and remained significant after adjustment for adiposity-related factors. Nevertheless, the difference by race was not statistically significant. Additional studies are warranted to further elucidate these associations in more representative and ethnically diverse populations.

### References


### Author Contributions

All authors confirmed they have contributed to the intellectual content of this paper and have met the following 3 requirements: (a) significant contributions to the conception and design, acquisition of data, or analysis and interpretation of data; (b) drafting or revising the article for intellectual content; and (c) final approval of the published article.

### Authors’ Disclosures or Potential Conflicts of Interest

#### Employment or Leadership:

N. Rifai, Clinical Chemistry, ACCC.

#### Consultant or Advisory Role:

None declared.

#### Stock Ownership:

None declared.

#### Honoraria:

None declared.

#### Research Funding:

NHLBI, research grant HL-075445, NIH, NHLBI and Department of Health and Human Services, contracts N01WH22116, 24152, 32100–2, 32105–6, 32106–9, 32111–13, 32115, 32118–32119, 32122, 42107–26, 42129–32, and 44221; L. Wang, NHLBI, career development grant HL095649 , H.D. Sesso, NIH.

#### Expert Testimony:

None declared.

#### Role of Sponsor:

The funding organizations played no role in the design of study, choice of enrolled patients, review and interpretation of data, or preparation or approval of manuscript.

#### Acknowledgments:

We gratefully acknowledge the dedicated efforts of investigators and staff at the WHI clinical centers and coordinat-