Racial and Ethnic Differences in Anthropometric Measures as Risk Factors for Diabetes

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OBJECTIVE

The study objective was to examine the impact of race/ethnicity on associations between anthropometric measures and diabetes risk.

RESEARCH DESIGN AND METHODS

A total of 136,112 postmenopausal women aged 50–79 years participating in the Women's Health Initiative without baseline cancer or diabetes were followed for 14.6 years. BMI, waist circumference (WC), and waist-to-hip ratio (WHR) were measured in all participants, and a subset of 9,695 had assessment of whole-body fat mass, whole-body percent fat, trunk fat mass, and leg fat mass by DXA. Incident diabetes was assessed via self-report. Multivariate Cox proportional hazards regression models were used to assess associations between anthropometrics and diabetes incidence.

RESULTS

During follow-up, 18,706 cases of incident diabetes were identified. BMI, WC, and WHR were all positively associated with diabetes risk in each racial and ethnic group. WC had the strongest association with risk of diabetes across all racial and ethnic groups. Compared with non-Hispanic whites, associations with WC were weaker in black women ($P < 0.0001$) and stronger in Asian women ($P < 0.0001$). Among women with DXA determinations, black women had a weaker association with whole-body fat ($P = 0.02$) but a stronger association with trunk-to-leg fat ratio ($P = 0.03$) compared with white women.

CONCLUSIONS

In postmenopausal women across all racial/ethnic groups, WC was a better predictor of diabetes risk, especially for Asian women. Better anthropometric measures that reflect trunk-to-leg fat ratio may improve diabetes risk assessment for black women.

CARDIOVASCULAR AND METABOLIC RISK

More than 30 million Americans have diabetes currently, and the prevalence of diabetes increases with age, reaching a high of 25.2% among those aged 65 years or older (1). The burden of diabetes varies greatly by race/ethnicity, with blacks having the highest age-adjusted prevalence, followed by Hispanics, Asians, and then non-Hispanic whites (NHW) (1). Compared with white postmenopausal women in the U.S., there is a more than twofold higher risk of diabetes in blacks and approximately twofold higher risk in Hispanics and Asians (2).

Obesity is one of the major risk factors for type 2 diabetes. BMI, waist circumference (WC), and waist-to-hip ratio (WHR) are common surrogate measures of

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adiposity in clinical and public health practice. Body fat distribution changes according to menopausal status, with central obesity more pronounced in postmenopausal women (3). Studies have reported heterogeneity of human body fat distribution across racial groups (4,5). For example, abdominal visceral adiposity has been reported to be significantly greater in white men and women compared with black men and women, and white women had significantly lower measures of subcutaneous adipose tissue (SAT) than black women (4). This heterogeneity may lead to racial and ethnic differences in anthropometric measures as risk factors for diabetes, due to the importance of visceral adipose tissue (VAT) in the etiology of diabetes (6). However, relatively little research has prospectively examined how the utility of anthropometric measures as predictors of developing diabetes might differ by race/ethnicity, particularly for postmenopausal women.

A recent study reported that there were differences between anthropometric measures for blacks versus whites for risk of developing diabetes (7). WC had the highest association for diabetes among white females, whereas WHR had the highest association among black females (7). However, this study included only black and white participants. A cross-sectional study reported that BMI was not a significant predictor for diabetes in Asians and in general indicated that WC and its derivatives may be a more racially/ethnically appropriate alternative for use (8). However, the Multi-Ethnic Study of Atherosclerosis (MESA) identified a significant interaction between race and anthropometry, including BMI and WC; the slope of incident diabetes per anthropometric unit (1-SD increase) was greatest for Chinese people and weakest for black people relative to white people (9).

Since obesity is common in the U.S., and there are racial/ethnic disparities in the burden of diabetes, understanding the relationships between anthropometry and future diabetes risk in different racial/ethnic groups is of particular interest. The aims of this study were to examine whether the associations between anthropometrics (including BMI, WC, and WHR) and diabetes risk vary by race/ethnicity and to identify which anthropometric measure best predicts risk of diabetes within different racial/ethnic groups. We hypothesized that race/ethnicity may modify the utility of anthropometric measures as predictors of developing type 2 diabetes.

RESEARCH DESIGN AND METHODS

Participants

Participants were drawn from the Women's Health Initiative (WHI), a large prospective cohort study that is designed to address the major causes of morbidity and mortality among postmenopausal women (10). Details of the study are described elsewhere (11). In brief, 161,808 women ages 50–79 years were recruited from 40 clinical centers throughout the U.S. between 1993 and 1998. The WHI includes both clinical trial (CT) and observational study (OS) components. The study was approved by institutional review boards at all 40 clinical centers and at the coordinating center. All participants provided written informed consent.

In the present analysis, participants were excluded for the following reasons: 12,655 women had a history of cancer (except nonmelanoma skin cancer) at baseline, 792 joined but provided no follow-up information, 8,569 women had prevalent self-reported diabetes at baseline, 2,001 women had race/ethnicity indicated as "other," and 1,679 women had missing data for main exposures (including BMI, WC, or hip circumference). This yielded a final analytic sample of 136,112 women.

Measurements

Exposures

During the baseline clinical visit, trained and certified staff performed anthropometric measurements, including weight, height, and waist and hip circumferences. Weight and height were measured with a balance-beam scale and stadiometer using a standardized protocol. BMI was calculated as weight in kilograms divided by the square of height in meters. WC at the natural waist or narrowest part of the torso and hip circumference at the maximal circumference were measured to the nearest 0.1 cm. WHR was computed as the ratio of these two measurements.

In the WHI, a subset of women (9,695) in three designated centers (Birmingham, Tucson, and Pittsburgh) had body composition measured by whole-body DXA, including whole-body fat mass, whole-body percent fat, trunk fat mass, and leg fat mass (average of right and left legs). The latter two measures were used to calculate trunk-to-leg fat ratio.

Race/ethnicity was self-reported and included these categories: American Indian or Alaska Native, Asian, black or African American, Hispanic/Latina, and NHW.

Outcome

The primary outcome was incident diabetes during follow-up. This was defined via self-report by a positive report of a new diagnosis of diabetes treated with insulin or oral drugs during follow-up. Self-reported diabetes in the WHI has been found to be reliable and valid based on medication inventories, fasting glucose levels, and medical record review (12,13).

Covariates

We considered potential confounders at baseline including age, level of education, physical activity, smoking, alcohol intake, family history of diabetes, Healthy Eating Index (HEI)-2005 score as a measure of diet quality (14), high cholesterol requiring medicine, and different study cohorts (participation in OS or CTs and CT arm).

Statistical Analysis

Differences in the distribution of demographic and behavioral characteristics were assessed across race/ethnicity groups, using χ^2 tests and ANOVA for categorical and continuous variables, respectively. BMI was categorized into the following categories: normal, <25 kg/m^2; overweight, 25 to <30 kg/m^2; and obese, ≥30 kg/m^2. A cut point for WC (>88 or ≤88 cm for women) was based on recommendations by the American Heart Association (15). A cut point for WHR (>0.85 or ≤0.85 for women) was based on World Health Organization (WHO) abdominal obesity measurement guidelines (16). To make the referent categories more comparable, we subdivided the category for WC (≤88 cm) and WHR (≤0.85 cm) into two equal groups, so that BMI, WC, and WHR all contained three groups. When analyzed as a continuous variable, all exposures were standardized to a mean of zero and 1 SD first (*z* score) and then we modeled the impact of a 1-SD increase in the explanatory variable to make direct comparisons of βs across exposures.

Cox hazards regression models were used to evaluate relationships (hazard ratios [HRs] and 95% CI) between anthropometric measures and diabetes incidence. In the multivariate-adjusted models, potential confounders included the variables listed in the Covariates section above. Further, stratified analysis by race/ethnicity was performed to examine whether the associations between anthropometric measures and risk of diabetes were modified by race/ethnicity. Interactions between anthropometric measures and race/ethnicity were tested by adding multiplicative interaction terms into the model.

Several sensitivity analyses were performed to assess the robustness of our findings. First, we conducted a sensitivity analysis by excluding women in the Dietary Modification CT intervention arm. Second, we excluded the first 2 years of follow-up to exclude possible reverse causality and further adjusted for weight change between baseline and year 3. Finally, among the WHI DXA subcohort, sensitivity analyses were performed to examine the associations between DXA body composition and anthropometric measures, as well as the associations between DXA measurements and future risk of diabetes during follow-up.

Finally, we examined optimal cut points by race/ethnicity through the following steps. *1*) We dichotomized the variable of interest (BMI, WC, or WHR) as an indicator variable (i.e., >cut point = 1; ≤cut point = 0). *2*) The cut point was examined from its minimum to maximum value at 0.5 (kg/m^2) increments for BMI, 1 (cm) increments for WC, and 0.01 increments for WHR. The indicator variable was included in Cox proportional hazards regression models adjusting for major confounders. *3*) The minimum of Akaike information criterion was used to identify the cut point that produced the best-fitting model. Once the first cut point was identified, we added the indicator variable based on the best cut point into the model and then repeated processes 1 and 2 to identify the next best cut point that improved the model fit the most.

RESULTS

Table 1 presents means and proportions of baseline demographic and behavioral characteristics by race/ethnicity. Compared with NHW women, all minority groups but Asian were more likely to be younger, less educated, and current smokers (except for Hispanic/Latina); consume less alcohol; have a higher family history of diabetes; have lower levels of physical activity; and have lower HEI-2005 scores. Asian women were more likely to be never smokers, consume less alcohol, have a higher family history of diabetes, and have a higher HEI-2005 score compared with NHW women (Table 1).

Black women had the highest BMI, WC, whole-body fat mass, and leg fat mass but had the lowest trunk-to-leg fat ratio. American Indian or Alaska Native women had the highest WHR, whole-body fat percent, trunk fat, and trunk-to-leg fat ratio. Asian women had the lowest BMI, WC, whole-body fat mass, whole-body fat percent, trunk fat, and leg fat but had a higher trunk-to-leg fat ratio than black women (Table 1).

During follow-up, 18,706 cases of incident diabetes were diagnosed. The annualized diabetes incidence was the greatest in black women (1.7%), followed by American Indian or Alaska Native women (1.5%). Table 2 shows associations between anthropometric measures and risk of diabetes by race/ethnicity. Regardless of measurement as a categorical or continuous variable, all anthropometric measures (BMI, WC, and WHR) were positively associated with risk of diabetes across all racial and ethnic groups. When anthropometric measures were analyzed as continuous variables, WC had the strongest associations with risk of diabetes, followed by BMI and then WHR, across all racial and ethnic groups. Among different racial and ethnic groups, the associations between WC and risk of diabetes were the strongest in Asian women (HR 1.93 [95% CI 1.76–2.12]) and the weakest among black women (HR 1.42 [95% CI 1.37–1.47]) (Table 2).

Overall, associations between BMI, WC, and risk of diabetes were significantly modified by race/ethnicity (*P* for interaction <0.0001) (Table 2). Pairwise comparisons showed that compared with NHW women, black women had significantly weaker associations with BMI and WC, and Asian women had a significantly stronger association with WC.

When anthropometric measures were analyzed as categorical variables, the results were generally consistent with analyses as continuous variables. Additionally, we observed that compared with NHW women, the association between WHR and risk of diabetes was significantly weaker in black women (*P* = 0.01) but stronger in Asian women (*P* = 0.002) (Table 2).

In the sensitivity analysis excluding the diabetes intervention arm (*n* = 118,864), the results were nearly identical to those reported in Table 2. In the sensitivity analysis excluding the first 2 years of follow-up and further adjusting for weight gain between baseline and year 3, the associations were slightly attenuated; however, overall patterns between anthropometrics and diabetes risk (and level of significance) by race/ethnicity remained unchanged (Supplementary Table 1).

Analysis of the Pearson linear correlations between anthropometric measures and DXA body composition biomarkers (Supplementary Table 2) showed that BMI had the strongest correlation with whole-body fat (*r* = 0.90), whereas WC had the strongest correlation with trunk fat (*r* = 0.88). WHR had the strongest correlation with trunk-to-leg fat ratio, although the *r* was only 0.56.

Covariate-adjusted relationships between body composition and risk of diabetes by race/ethnicity among the subset studied by DXA (*n* = 9,695 with a total of 1,509 diabetes cases) are presented in Table 3. Among all DXA markers, trunk fat had the highest HRs for risk of diabetes in NHW women, whereas trunk-to-leg fat ratio had the highest HRs for black women. Compared with NHW women, black women had a weaker association with whole-body fat (*P* for interaction = 0.02) but a stronger association with trunk-to-leg fat ratio (*P* for interaction = 0.03). For Hispanic/Latina women, trunk fat and trunk-to-leg fat ratio were comparable predictors for risk of diabetes (Table 3).

Table 4 shows the optimal cut points for BMI, WC, and WHR in relation to risk of diabetes by race/ethnicity. For BMI, we identified similar cut points as widely accepted cut points (25 and 30 kg/m^2) for NHW, black, and Hispanic women. However, we identified lower cut points (24.5 and 27.0 kg/m^2) for Asian women and higher cut points

Table 1—Baseline characteristics and body composition biomarkers by race/ethnicity*

	NHW	American Indian or Alaskan Native	Asian	Black or African American	Hispanic/Latina
Number of women, *n*	115,412	524	3,484	11,370	5,322
Age-group (years), *n* (%)					
50–59	37,129 (32.2)	236 (45.0)	1,270 (36.5)	4,944 (43.5)	2,737 (51.4)
60–69	52,393 (45.4)	198 (37.8)	1,454 (41.7)	4,752 (41.8)	2,046 (38.4)
70–79	25,890 (22.4)	90 (17.2)	760 (21.8)	1,674 (14.7)	539 (10.1)
Education, *n* (%)					
High school diploma or less	23,794 (20.6)	151 (28.8)	701 (20.1)	2,751 (24.2)	2,260 (42.5)
Some college/technical training	43,238 (37.5)	243 (46.4)	1,199 (34.4)	4,372 (38.5)	1,841 (34.6)
College graduate or some postcollege	27,188 (23.6)	77 (14.7)	958 (27.5)	1,881 (16.5)	668 (12.6)
Master's degree or higher	20,448 (17.7)	48 (9.2)	599 (17.2)	2,230 (19.6)	461 (8.7)
Smoking status, *n* (%)					
Never smoked	57,161 (49.5)	253 (48.3)	2,514 (72.2)	5,555 (48.9)	3,317 (62.3)
Past smoker	49,453 (42.8)	200 (38.2)	816 (23.4)	4,308 (37.9)	1,532 (28.8)
Current smoker	7,457 (6.5)	56 (10.7)	137 (3.9)	1,280 (11.3)	367 (6.9)
Alcohol intake, *n* (%)					
Nondrinker	9,924 (8.6)	73 (13.9)	1,311 (37.6)	1,879 (16.5)	1,003 (18.8)
Past drinker	17,903 (15.5)	123 (23.5)	662 (19.0)	3,433 (30.2)	1,123 (21.1)
<1 drink per month	13,994 (12.1)	64 (12.2)	510 (14.6)	1,531 (13.5)	704 (13.2)
<1 drink per week	24,268 (21.0)	101 (19.3)	543 (15.6)	2,151 (18.9)	1,137 (21.4)
1 to <7 drinks per week	33,062 (28.6)	113 (21.6)	343 (9.8)	1,695 (14.9)	991 (18.6)
7+ drinks per week	15,558 (13.5)	43 (8.2)	100 (2.9)	526 (4.6)	260 (4.9)
Relative had adult diabetes, *n* (%)					
No	77,625 (67.3)	274 (52.3)	2,045 (58.7)	5,247 (46.1)	2,804 (52.7)
Yes	32,950 (28.5)	196 (37.4)	1,179 (33.8)	4,883 (42.9)	2,126 (39.9)
Total METs per week, mean (SD)	13.0 (13.8)	12.4 (15.4)	13.2 (14.1)	9.9 (13.1)	10.6 (13.9)
Total HEI-2005 score, mean (SD)	67.6 (10.6)	65.0 (11.3)	70.9 (9.2)	63.0 (11.9)	65.7 (10.6)
BMI (kg/m^2), mean (SD)	27.4 (5.6)	29.2 (5.8)	24.5 (4.3)	30.9 (6.6)	28.8 (5.7)
WC (cm), mean (SD)	85.4 (13.3)	89.9 (14.7)	77.9 (10.1)	90.7 (13.7)	86.2 (12.6)
WHR, mean (SD)	0.81 (0.081)	0.83 (0.09)	0.81 (0.07)	0.82 (0.08)	0.82 (0.08)
Body composition biomarkers among a subcohort, *n*	7,760	96	31	1,210	598
Whole-body fat mass (kg), mean (SD)	31.2 (10.8)	36.6 (11.3)	20.7 (7.7)	38.2 (13.0)	32.3 (10.30)
Whole-body percent fat, mean (SD)	43.4 (7.3)	47.3 (6.8)	36.0 (7.1)	45.9 (7.0)	45.0 (6.6)
Trunk fat mass (kg), mean (SD)	14.4 (6.0)	17.7 (6.1)	9.6 (3.8)	17.1 (6.4)	15.7 (5.6)
Leg fat mass (kg), mean (SD)	5.9 (2.0)	6.5 (2.2)	3.8 (1.5)	7.4 (2.7)	5.8 (1.9)
Trunk-to-leg fat ratio, mean (SD)	2.5 (0.8)	2.8 (0.9)	2.6 (0.7)	2.4 (0.7)	2.8 (0.7)

*All difference tests across race/ethnicity were significant.

(27.0 and 36.5 kg/m^2) for American Indian women.

For WC, the first best cut points that we identified were 88–91 cm for NHW, American Indian, or Hispanic women, which were similar to the current recommended cut point (88 cm) for women. For the black and Asian women, we identified a lower cut point of 84 and 79 cm, respectively. And it is interesting that the next best cut points were quite different across race/ethnicity.

For WHR, the first best cut points that we identified ranged from 0.76 to 0.85. Our data show that the best cut points for WHR were lower than the currently recommended cut point (0.85) based on WHO abdominal obesity measurement guidelines for all racial and ethnic groups other than Hispanic (for whom we observed the same cut point of 0.85.)

CONCLUSIONS

In this large prospective study of postmenopausal women, all anthropometric measures were associated with diabetes risk in all racial/ethnic groups, but WC had the strongest associations with diabetes risk across groups. Compared with NHW women, black women had a significantly weaker association, and Asian women had a stronger association with WC. Further, when compared with NHW women, black women had a weaker association with whole-body fat but a stronger association with trunk-to-leg fat ratio. Results of the cut point analysis indicate that optimal cut points for Asian women are lower than recognized standards for all anthropometric measures. We also found that the optimal cut point for WHR was lower than the commonly recommended cut point for all groups except Hispanic women.

Our finding that WC better predicted risk of diabetes than BMI across all racial or ethnic groups among postmenopausal women is in line with many previous

Table 2—Association between anthropometric measures and diabetes risk by race/ethnicity*

	Overall (n = 136,112)	NHW (n = 115,412)	American Indian or Alaska Native (n = 524)	Asian (n = 3,484)	Black or African American (11,370)	Hispanic/Latina (n = 5,322)	P for interaction
BMI, kg/m^2 (%)							0.0002
<25 (36.5)	1	1	1	1	1	1	
25 to <30 (35.2)	1.66 (1.59–1.73)	1.62 (1.55–1.70)	1.45 (0.72–2.94)	2.20 (1.79–2.71)	1.65 (1.41–1.92)	1.82 (1.47–2.25)	
≥30 (28.3%)	3.01 (2.89–3.13)	3.02 (2.88–3.15)	3.64 (1.86–7.15)	3.38 (2.55–4.46)	2.57 (2.22–2.97)	3.41 (2.76–4.22)	
ln continuous**	1.43 (1.41–1.44)	1.45 (1.43–1.47)	1.56 (1.24–1.95)	1.51 (1.39–1.63)	1.29 (1.25–1.33)	1.39 (1.32–1.46)	<0.0001
WC, cm (%)							<0.0001
<78 (30.5)	1	1	1	1	1	1	
78–88 (32.1)	1.59 (1.52–1.67)	1.52 (1.44–1.60)	1.06 (0.48–2.35)	2.61 (2.08–3.27)	1.78 (1.50–2.11)	1.73 (1.38–2.17)	
>88 (37.4)	3.24 (3.10–3.39)	3.15 (3.01–3.31)	2.55 (1.27–5.14)	4.37 (3.39–5.64)	3.13 (2.67–3.66)	3.98 (3.22–4.93)	
ln continuous**	1.54 (1.52–1.55)	1.55 (1.53–1.57)	1.57 (1.29–1.91)	1.93 (1.76–2.12)	1.42 (1.37–1.47)	1.58 (1.50–1.67)	<0.0001
WHR (%)							<0.0001
<0.78 (37.2)	1	1	1	1	1	1	
0.78–0.85 (37.1)	1.64 (1.57–1.70)	1.61 (1.54–1.68)	2.69 (1.25–5.76)	2.31 (1.71–3.13)	1.66 (1.48–1.85)	1.62 (1.34–1.96)	
>0.85 (25.7)	2.95 (2.84–3.07)	2.95 (2.83–3.09)	3.38 (1.62–7.08)	4.90 (3.62–6.64)	2.48 (2.22–2.77)	3.34 (2.77–4.03)	
ln continuous**	1.22 (1.21–1.23)	1.22 (1.21–1.23)	1.25 (1.07–1.46)	1.19 (1.15–1.24)	1.25 (1.22–1.29)	1.23 (1.19–1.27)	0.17

Data are HR (95% CI). *In the multivariable-adjusted models, we adjusted for age at enrollment (in continuous), race/ethnicity (for overall model only), education (high school or less, some college/technical training, college or some postcollege, and master's or higher), family history of diabetes (no/yes), different study cohorts (participation in OS or CTs), smoking (never, former, and current), alcohol intake (nondrinker, past drinker, current and <7 drinks/week, and current and ≥7 drinks/week), physical activity (<5, 5 to <10, 10 to <20, 20 to <30, and 30+ METs/week), HEI-2005 score, high cholesterol requiring medicine (no/yes), and different treatment assignments for all three CTs. **When anthropometric measures were analyzed as continuous variables, the corresponding HR presents increased risk of diabetes per 1 increased SD.

reports (7,17,18), although some studies reported that the three obesity indicators (BMI, WC, and WHR) had similar associations with incident diabetes (19,20). Our correlation analyses between anthropometric measures and body composition markers showed that BMI had the strongest correlation with whole-body fat, whereas WC had the strongest correlation with trunk fat, which supports the notion that BMI reflects overall adiposity and WC reflects central adiposity. Clinical evidence has also shown that central obesity, particularly visceral fat deposits, is the major contributor to metabolic complications (21,22). We observed that the body composition biomarker subset data did not outperform WC in predicting diabetes, suggesting that we can continue to rely on more easily measured factors such as WC.

We observed that the relationships between WC and risk of diabetes were relatively stronger among Asian women and weaker among black women relative to white women. These results were consistent with findings from MESA (9). In that study, Lutsey et al. (9) compared the associations between anthropometries and diabetes risk among four racial or ethnic groups (white, Chinese, black, and Hispanic) and reported that relative to white people, a 1-SD increase in most anthropometric measures was associated with a lower risk of incident diabetes for blacks but a greater risk of diabetes for Chinese. Hispanics were similar to whites.

Other studies have reported that Asians had a greater risk of diabetes compared with whites after adjustment for BMI (23–25). Although Asians generally had the lowest BMI, WC, whole-body fat mass, whole-body fat percent, and trunk fat among our study participants, they had higher trunk-to-leg fat ratios than black women. Other studies have also reported that the trunk-to-peripheral fat mass ratio and DXA-reported android-to-gynoid fat mass ratio were significantly higher among Asian than white pubertal girls (26,27). Similarly, studies have also reported that Asian women carry greater abdominal and visceral fat when compared with Caucasian women with similar overall adiposity (28,29). Thus, greater central relative to leg adiposity may explain why Asian women have a greater risk of

Table 3—Associations between body composition biomarkers and diabetes risk by race/ethnicity

	Overall (*n* = 9,695)	NHW (NHW) (*n* = 7,760)	Black or African American (*n* = 1,210)	Hispanic/Latina (*n* = 598)	*P* for interaction (black vs. NHW)	*P* for interaction (Hispanic vs. NHW)
Whole-body fat						
Quartile						
1	1	1	1	1		
2	1.49 (1.24–1.80)	1.41 (1.14–1.74)	1.84 (1.05–3.23)	1.92 (0.90–4.09)		
3	2.11 (1.77–2.53)	2.13 (1.75–2.61)	1.98 (1.15–3.40)	2.95 (1.40–6.20)		
4	3.11 (2.61–3.71)	3.13 (2.56–3.82)	2.91 (1.75–4.84)	4.76 (1.25–10.05)		
In continuous**	1.41 (1.34–1.48)	1.47 (1.38–1.56)	1.22 (1.10–1.35)	1.59 (1.29–1.96)	0.02	0.90
Whole-body fat percent						
Quartile						
1	1	1	1	1		
2	1.35 (1.14–1.61)	1.25 (1.03–1.53)	1.64 (1.03–2.61)	2.43 (1.13–5.23)		
3	1.77 (1.50–2.09)	1.74 (1.44–2.11)	1.85 (1.19–2.87)	2.36 (1.11–5.02)		
4	2.15 (1.82–2.54)	2.11 (1.74–2.56)	2.18 (1.40–3.38)	3.28 (1.56–6.90)		
In continuous**	1.35 (1.28–1.44)	1.38 (1.29–1.48)	1.23 (1.07–1.41)	1.40 (1.09–1.80)	0.48	0.96
Trunk fat						
Quartile						
1	1	1	1	1		
2	1.33 (1.10–1.62)	1.33 (1.06–1.65)	1.70 (0.98–2.94)	1.34 (0.55–3.28)		
3	2.17 (1.81–2.60)	2.11 (1.72–2.59)	2.27 (1.35–3.82)	2.96 (1.28–6.83)		
4	3.77 (3.16–4.49)	3.92 (3.21–4.79)	3.54 (2.15–5.84)	4.94 (2.13–11.44)		
In continuous**	1.57 (1.49–1.65)	1.60 (1.51–1.69)	1.40 (1.25–1.58)	1.81 (1.47–2.23)	0.27	0.62
Trunk-to-leg fat ratio						
Quartile						
1	1	1	1	1		
2	1.56 (1.30–1.88)	1.47 (1.18–1.83)	1.79 (1.21–2.64)	1.68 (0.54–5.27)		
3	2.29 (1.92–2.73)	2.16 (1.76–2.66)	2.56 (1.74–3.76)	3.28 (1.13–9.54)		
4	3.78 (3.19–4.48)	3.67 (3.01–4.48)	3.78 (2.53–5.64)	5.05 (1.77–14.40)		
In continuous**	1.54 (1.48–1.61)	1.52 (1.44–1.60)	1.69 (1.49–1.93)	1.81 (1.49–2.20)	0.03	0.14

Data are HR (95% CI). **When anthropometric measures were analyzed as continuous variables, the corresponding HR presents increased risk of diabetes per 1 increased SD.

diabetes compared with other race and ethnic groups.

Results for Asian women suggested lower optimal cut points for anthropometric measures than other race/ethnicity groups. The BMI value of 24.5 kg/m^2 found here for Asian women for the first cut point, although lower than other groups, was still higher than the value of 23 that has been presented in a position statement by the American Diabetes Association (30), suggesting that our estimate may be conservative. For WC, our cut point of 79 cm is within the range of prior estimates, including 75 cm (31) or 78–82 cm (32) identified for Asian women.

Although black women in our study had the highest average BMI, WC, and whole-body fat mass, they had the lowest trunk-to-leg fat ratios. Our finding is consistent with literature that has evaluated racial and ethnic differences in fat distribution. Black women tend to have more "pear-shaped" bodies, i.e., they tend to have more subcutaneous fat deposited in the hips and thighs versus in the abdominal areas (25,33,34). Among all body composition metrics studied, we observed a weaker association between risk of diabetes and whole-body fat, but a stronger association between risk of diabetes and trunk-to-leg fat ratio, among black women relative to white women. The trunk-to-leg fat ratio can be considered a marker of body shape. It is established that regional adiposity is an important predictor of chronic disease risk independent of total adiposity (21), and a high ratio of trunk-to-leg volume or an "apple" body shape (defined by android-to-gynoid ratio $\geq$1) is a strong indicator of diabetes, independent of BMI and WC (35,36). This suggests that the trunk-to-leg fat ratio may be a more accurate biomarker of diabetes risk among black women. None of the common anthropometric measures (BMI, WC, and WHR) had high correlations with the trunk-to-leg fat ratio; this may be one of the reasons why we observed weaker associations between conventional anthropometric measures and risk of diabetes among black women. Another study also reported that black women had weaker associations between body composition markers and lipid profiles than their white and Hispanic counterparts (37). Furthermore, a recent study found that the adverse effects of increased VAT on subclinical atherosclerosis and measures of glucose homeostasis were attenuated as SAT increased only in black women (38), suggesting that greater hip and leg adiposity, more reflective of SAT, may be protective against diabetes risk among black women with high VAT. Therefore, WC may be a weaker predictor of risk in black women and it may be important to consider SAT.

In addition, we observed the strongest relationships between BMI and risk of diabetes in American Indians or Alaska Natives among all race/ethnicity groups, although no statistically significant difference was observed compared with white women (which may be due to

Table 4—Optimal cut points for BMI, WC, and WHR in relation to risk of diabetes by race/ethnicity

	Overall	NHW	American Indian or Alaska Native	Asian	Black or African American	Hispanic/Latina
BMI (kg/m^2)						
First sweep	29.0	29.0	36.5	24.5	29.5	29.5
Second sweep	25.5	25.5	27.0	27.0	26.5	25.0
WC (cm)						
First sweep	90	90	91	79	84	88
Second sweep	79	102	118	69	98	83
WHR						
First sweep	0.82	0.82	0.76	0.82	0.81	0.85
Second sweep	0.90	0.90	0.91	0.79	0.84	0.88

the small sample size in the American Indian or Alaska Native group). Based on a U.S. Department of Health and Human Services Office of Minority Health recent report, American Indian or Alaska Native adults are 50% more likely to be obese than NHW (43.7% vs. 28.5%) (39). We also observed that American Indian or Alaska Native women had the highest whole-body fat percent, trunk fat, and trunk-to-leg fat ratio, which were strongly associated with risk of diabetes. Our sample size did not permit examination of the associations between these body composition markers with diabetes for American Indian or Alaska Native women. Further studies incorporating body composition measures for the group may help to explain why American Indian/Alaska Natives have the highest prevalence of diagnosed diabetes in the U.S. (1).

The strengths of our study include the large sample size, prospective design with a long follow-up, comprehensive assessment of sociodemographic characteristics, and a diverse population that allowed us to assess the relationships among different racial/ethnic groups. Another strength is that we had both anthropometric measures and body composition biomarkers in a substantial subgroup, which aided understanding of the different associations between anthropometric measures and risk of diabetes across race/ethnicity. Our study also has several limitations. First, the diagnosis of diabetes was based on self-report, which may have resulted in some misclassification of the outcome. WHI validation studies have shown a high degree of concordance between self-report, medical record review, and medication inventories (12, 13). However, it is unclear whether there may be differences in validity of self-report of baseline diabetes status by race/ethnicity, which could lead to differences in prevalence of undiagnosed diabetes across race/ethnicity groups. In addition, the information on race/ethnicity was also based on self-report, which may not be indicative of actual genetic or even cultural difference. Second, our exposures and all covariates were based on information collected at baseline, and we could not consider changes during follow-up, which may have caused some exposure misclassification and further biased our results toward the null. Third, the sample size of the subset cohort was not large enough to assess the relationships between body composition biomarkers and risk of diabetes for American Indian/Alaska Native and Asian women. Finally, our results are limited to postmenopausal women in the U.S. and may not be generalizable to other populations.

In conclusion, our study indicates that WC is a better predictor of risk of diabetes compared with WHR and BMI across all racial/ethnic groups among postmenopausal women. This is especially the case for Asian women. Our data suggest that the cut point for Asian women for all measures should be lower than current standards. Since the trunk-to-leg fat ratio may be the best marker of diabetes risk among black women, better anthropometric measures that reflect the trunk-to-leg fat ratio may improve risk assessment for diabetes among black women. In addition, further research should examine whether cut points should be lower for WHR.

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Author Contributions. J.L. conceived and designed the study; acquired, managed, analyzed, and interpreted data; and drafted the manuscript. M.H. and J.E.M. conceived and designed the study, interpreted data, and critically reviewed and revised the manuscript. D.L., L.S.P., R.C., E.S.L., D.B.A., D.A.N., Y.L., M.C.R., and M.L.S. interpreted data and critically reviewed and revised the manuscript. J.L. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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