

# Prediction of Type 2 Diabetes Using Alternate Anthropometric Measures in a Multi-Ethnic Cohort

## The Insulin Resistance Atherosclerosis Study

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**OBJECTIVE** — To compare different anthropometric measures in terms of their ability to predict type 2 diabetes and to determine whether predictive ability was modified by ethnicity.

**RESEARCH DESIGN AND METHODS** — Anthropometry was measured at baseline for 1,073 non-Hispanic white (nHW), African American (AA), and Hispanic (HA) subjects, of whom 146 developed type 2 diabetes after 5.2 years. Logistic regression models were used with areas under the receiver operator characteristic curve (AROCs) comparing the prediction of models.

**RESULTS** — Waist-to-height ratio (AROC 0.678) was the most predictive measure, followed by BMI (AROC 0.674). Results were similar in nHW and HA subjects, although in AA subjects, central adiposity measures appeared to best predict type 2 diabetes.

**CONCLUSIONS** — Measures of central and overall adiposity predicted type 2 diabetes to a similar degree, except in AA subjects, for whom results suggested that central measures were more predictive.

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Various assessment approaches have been used to characterize the relationship between obesity and type 2 diabetes. Computed tomography and other imaging techniques allow for direct quantification of visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT). These methods are costly and invasive, however; thus, anthropometric measurements are more commonly utilized. The majority of previous studies have assessed only BMI, waist circumference (WC), and waist-to-hip ratio (WHR), and few data are available from multi-ethnic cohorts (1–6). Our objective, therefore, was to compare a wide range of anthropometric measures in

terms of their ability to predict incident type 2 diabetes in three ethnic groups.

### RESEARCH DESIGN AND METHODS

The Insulin Resistance Atherosclerosis Study has been previously described (7). The current report was comprised of 1,073 nondiabetic subjects aged 40–69 years at baseline (1992–1994); 56% were women, 40% were non-Hispanic white (nHW), 34% were Hispanic (HA), and 26% were African American (AA).

Glucose tolerance was established using 1999 World Health Organization criteria for a 2-h oral glucose tolerance test. Height, weight, WC, hip circumference

(HC), and skinfold thicknesses (triceps and subscapular) were measured following a standardized protocol (7). The sum of the skinfold thicknesses (SumSF) was used to indicate overall obesity, and the ratio of subscapular to triceps (STratio) measures was used to determine the ratio of central to peripheral body fat, with a greater ratio indicating a larger proportion of centrally distributed adipose tissue. The RJL (RJL Systems, Clinton Township, MI) method of bioelectrical impedance (BIA) was used to determine percent body fat calculated according to the Segal formula (8). RJL BIA has previously been shown to have good reliability (interclass correlation  $\geq 0.99$ ) (9). Follow-up examinations occurred an average of 5.2 years later, with 146 cases of incident diabetes diagnosed by oral glucose tolerance test.

Logistic regression analysis was used to evaluate the association between baseline measures of obesity and incident diabetes. All anthropometric variables were log transformed, and odds ratios (ORs) were presented per one standard deviation change. Two models were run for each measure: model A controlled for age, sex, and ethnicity, whereas model B controlled for age, sex, and ethnicity as well as family history of diabetes and systolic blood pressure. These variables are common in current diabetes risk scores and are easily and noninvasively obtained in clinical settings. The area under the receiver operating characteristic (AROC) curve (c-statistic) for each model was calculated and used as the primary criterion upon which to judge a model's discriminative ability (10). Different AROCs were statistically compared using the method of DeLong (11). All analyses were performed using SAS, version 9.1 (SAS Institute, Cary, NC).

**RESULTS** — Associations between anthropometric measures and risk of diabetes for the overall cohort are presented in Table 1. Waist-to-height ratio (WHtR) was the most predictive of diabetes

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**Table 1—Association of baseline anthropometric measures with the 5-year incidence of type 2 diabetes: the Insulin Resistance Atherosclerosis Study, 1992–1994**

	Full cohort (n = 1073)		Non-Hispanic white (n = 430)		African American (n = 282)		Hispanic (n = 361)	
	OR (95% CI)	AROC	OR (95% CI)	AROC	OR (95% CI)	AROC	OR (95% CI)	AROC
WHtR	1.79 (1.49–2.15)	0.678	2.25 (1.63–3.10)	0.730	1.62 (1.16–2.26)	0.645	1.55 (1.14–2.10)	0.650
BMI	1.76 (1.47–2.10)	0.674	2.22 (1.63–3.02)	0.734	1.46 (1.04–2.03)	0.616	1.62 (1.20–2.17)	0.658
WC	1.75 (1.45–2.12)	0.667	2.25 (1.59–3.17)	0.716	1.51 (1.08–2.11)	0.630	1.59 (1.15–2.19)	0.647
% BF	2.33 (1.74–3.12)	0.662	3.43 (2.06–5.71)	0.728	1.49 (0.88–2.54)	0.597*	2.12 (1.30–3.38)	0.657
STratio	1.85 (1.44–2.37)	0.659	2.34 (1.51–3.62)	0.729	2.78 (1.65–4.70)	0.714	1.12 (0.75–1.67)	0.564*
WHR	1.93 (1.49–2.50)	0.641	2.19 (1.39–3.45)	0.670	2.52 (1.57–4.05)	0.691	1.38 (0.90–2.13)	0.582
SumSF	1.65 (1.33–2.04)	0.630*	2.01 (1.40–2.90)	0.669*	1.28 (0.85–1.93)	0.585*	1.67 (1.18–2.38)	0.638
HC	1.42 (1.20–1.69)	0.625*	1.75 (1.31–2.23)	0.694*	1.05 (0.74–1.49)	0.567*	1.45 (1.09–1.93)	0.627

Model A adjusted for age, sex, and ethnicity. ORs are estimated by logistic regression analysis and refer to one standard deviation change in the natural log of the variable. Each row is an individual model with adjustments as indicated. \*AROC  $P < 0.05$  compared with Table's most predictive model. % BF, percent fat from BIA.

(AROC 0.678; OR 1.79 [95% CI 1.49–2.15]), followed closely by BMI (AROC 0.674; OR 1.76 [1.47–2.10]). The remainder of the indexes had AROCs ranging from 0.667 to 0.625 with no consistent patterning of central compared with overall measures in predicting diabetes. The only measures that were significantly less predictive than WHtR were SumSF and HC ( $P < 0.05$ ) (Table 1). The results according to AROC ranking were similar after further adjustment for family history of diabetes and systolic blood pressure (see Table A, available in the online appendix at <http://care.diabetesjournals.org/cgi/content/full/dc08-1663/DC1>), or for fasting glucose concentration.

There were no significant interactions of sex with anthropometric measures in the prediction of diabetes. Given our a priori interest in ethnic differences in diabetes prediction by anthropometric measurements, logistic models were stratified by ethnicity.

In the nHW and HA populations, BMI was most predictive of diabetes, although there was no clear pattern in central versus overall measures in outcome prediction (Table 1). In contrast, for the AA subgroup, all measures of central adiposity ranked higher in predicting diabetes than overall obesity measures. STratio had the greatest AROC (0.714) and OR (2.78 [95% CI 1.65–4.70]), followed by WHR, WHtR, and WC. HC, percent fat from BIA, and SumSF were significantly less predictive than STratio in model A for this ethnic group (Table 1). Results of analyses in model B were generally similar for each ethnic subgroup (see Table A in the online appendix).

**CONCLUSIONS**— Our main finding was that measures of central adiposity were, in general, not superior to measures of overall obesity in predicting diabetes. In the full cohort, as well as in the nHW and HA subgroups, there was no clear distinction between measures of central versus overall obesity in prediction of diabetes. In contrast, among AA subjects, the results suggested a greater diabetes predictive ability for measures of central adiposity, although there was limited statistical power within this subgroup. Previous studies that have directly measured body fat distribution have shown that AA subjects have less VAT at levels of obesity similar to those of nHW subjects (12). Thus, it is possible that accumulation of greater amounts of VAT has a more detrimental effect on risk of diabetes in AA individuals compared with populations that have higher average levels of VAT.

This is the first paper to examine the predictive ability of a wide range of anthropometric measurements on incident diabetes in three ethnic groups. In previous studies of single or pooled ethnic groups, findings have been inconsistent (1–6), and a recent meta-analysis of 32 studies showed that there was no significant difference between the relative risks of BMI, WC, and WHR for incident diabetes (13).

There are two possible explanations for the nonsuperiority of central versus overall adiposity measures in the prediction of diabetes. First, both VAT and SAT are associated with inflammatory biomarkers and disease risk (14). Second, anthropometric measurements contain a misclassification error in characterizing

body fat depots. While WC has been shown to be the simple anthropometric measure that best correlates to VAT, WC actually captures both VAT and abdominal SAT, and it has been reported that WC is more highly correlated to SAT than to VAT (15). Limitations of the present study include a modest sample size for subgroup analysis, a relatively short follow-up period, and skinfold thickness measures from two rather than four sites.

In conclusion, we found no strong evidence that anthropometric measures of central adiposity were more predictive of diabetes than measures of overall obesity in the nHW and HA populations. However, our data suggest that central obesity measures may be useful in predicting diabetes among AA subjects, although additional studies in this population are needed.

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