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Height, ethnicity, and the incidence of diabetes: the San Antonio Heart Study

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Abstract

Mexican Americans are more obese and have more diabetes than non-Hispanic whites, but are also shorter. Height is used in some diabetes prediction models. Therefore, we examined the effect of height on the relationship between ethnicity and incident diabetes. Incident diabetes was ascertained in 1730 participants in the San Antonio Heart Study (age range, 25-64 years) after 7.4 years of follow-up. Height predicted diabetes in neither men (odds ratio [OR] × 1 SD, 1.14 [0.85-1.51]) nor women (OR × 1 SD, 0.88 [0.70-1.11]) after adjusting for age and ethnicity. The area under the receiver operating characteristic curve for predicting diabetes of a model that included waist circumference (in men, 0.775; in women, 0.781) was similar to that of models that included waist circumference + height (in men, 0.775, P = .702; in women, 0.783, P = .680) or waist-to-height ratio (in men, 0.764, P = .161; in women, 0.783, P = .619). The OR of incident diabetes according to ethnicity was lower in the model that was adjusted for the waist-to-height ratio than in the model that accounted only for waist circumference (in women, 1.45 [0.86-2.46] vs 1.84 [1.10-3.08], P < .001; in men, 2.00 [1.11-3.58] vs 2.74 [1.52-4.95], P < .001). In conclusion, the addition of height to adjust waist circumference does not increase the ability of waist circumference to predict diabetes, but may be useful in exploring differences in diabetic risk between populations of different race/ethnicity.

1. Introduction

According to estimates from the National Health and Nutrition Examination Survey 2005-2006, 12.9% of the US population aged at least 20 years have diabetes [1]. The number is likely to increase in the future because of changes in size and demographic characteristics of the US population as well as increasing prevalence [2]. Diabetes rates are increasing because of the obesity epidemic [3] in all race/ethnic groups [4]. Nevertheless, differences in diabetic risk between race/ethnic groups may be difficult to differentiate from the contribution of obesity to that risk for 2 reasons: first, race/ethnicity is frequently associated with distinct anthropometric measurements; second, standardized indices of obesity have been derived largely from studies in non-Hispanic white populations [5-7].

In San Antonio, Mexican Americans are more obese and have more type 2 diabetes mellitus than non-Hispanic whites [8], but are also shorter. Height is included in some clinical prediction models of type 2 diabetes mellitus [9,10]. Therefore, height may explain to some extent the difference in diabetes risk between Mexican Americans and non-Hispanic whites. To examine the impact of height, we compared the discriminatory capacity of height-adjusted waist circumference [11-14] with that of body mass index (BMI), waist circumference, and waist-to-hip circumference ratio in the San Antonio Heart Study (SAHS).

2. Materials and methods

2.1. Subjects

The SAHS was designed as a population-based study on type 2 diabetes mellitus and cardiovascular risk factors among Mexican Americans and non-Hispanic whites of San Antonio. The SAHS had protocols approved by the Institutional Review Board of the University of Texas Health Science Center at San Antonio. All subjects gave written informed consent. Detailed descriptions have been

The authors declare that there is no duality of interest associated with this manuscript.

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already published [8,15,16]. Briefly, all Mexican American and non-Hispanic white men and nonpregnant women aged 25 to 64 years who resided in randomly selected households from low-, middle-, and high-income census tracts were invited to participate (response rate, 65.3%). Mexican Americans and non-Hispanic whites were defined by previously published algorithm [17]. Enrollment was carried out in 2 phases: from January 1979 to December 1982 and from January 1984 to December 1988. We used data only from phase 2 participants (n = 2941) because waist circumference was not measured in phase 1 participants at baseline. Phase 2 participants were reexamined between October 1991 and October 1996. The median for the follow-up period was 7.4 years (range, 6.3-10.3 years).

2.2. Acquisition of data and definition of variables and outcomes

Anthropometric measurements were gathered by trained personnel after participants had removed their shoes and upper garments and put on an examination gown [15]. Waist and hip circumferences were measured with a nonstretchable standard tape at the level of the umbilicus and greater trochanter, respectively. The average of 2 readings was taken to reduce the measurement error. Blood specimens were obtained after a 12- to 14-hour fast. A 75-g oral glucose load (Orangedex; Custom Laboratories, Baltimore, MD) was administered to ascertain diabetes status at the baseline and follow-up examinations. Fasting and 2-hour glucose concentrations were measured with an Abbott Bichromatic Analyzer (South Pasadena, CA) in the laboratory of the Division of Clinical Epidemiology in San Antonio [16].

Body mass index was used as a measure of overall obesity; and waist circumference, waist-to-height ratio, and waist-to-hip ratio were used as measures of central obesity. *Diabetes* was defined according to the plasma glucose cut points of the 2003 American Diabetes Association (fasting glucose ≥7.0 mmol/L, 2-hour glucose ≥11.1 mmol/L) [18]. Regardless of glucose values, subjects who reported current therapy with antidiabetic medications were considered to have diabetes. The outcome of interest was incident diabetes. In nondiabetic individuals at the baseline examination, the presence of diabetes at the follow-up examination was synonymous of incident diabetes.

2.3. Statistical analyses

Statistical analyses were performed with the SAS statistical software (SAS Institute, Cary, NC). To account for the effect of age, anthropometric measurements and markers of obesity were compared by 1-way analysis of covariance; and incident diabetes, by logistic regression analysis. The relation of height to age and waist circumference was assessed by generalized linear models. In separate models, significant associations were tested for linearity (adding squared terms for height) as well as for interactions of ethnicity (adding an interaction term for ethnicity × height). Diabetic risk associated with height and obesity was determined by logistic regression analysis. Interaction terms for ethnicity × height and ethnicity × obesity were analyzed. The area under the receiver operating characteristic curve (AUC) was chosen as the parameter to compare the predictive discrimination between models [19]. The effect of each obesity index on the difference in incident diabetes according to ethnicity was ascertained by logistic regression analysis in sex-specific models that included age as a covariate. A bootstrap method with 1000 replications was applied to compare the odds ratio (OR) of incident diabetes according to ethnicity for the model that was adjusted for age + waist circumference with the OR for each one of the other nonnested models. We considered significant a P value < .050.

3. Results

Diabetes status was ascertained in 1734 of 2511 (69.1%) nondiabetic participants who were alive at follow-up. Ascertainment rates of incident diabetes were similar in Mexican Americans and non-Hispanic whites (68.8% vs 69.5%, P = .714), but younger individuals were less likely to return to the follow-up examination than older individuals (P < .001). A total of 1730 participants were eligible for analysis because relevant information was missing in 4 individuals. After adjusting for age and ethnicity, participants who were eligible for analysis (730 men and 1000 women) did not differ from those who were excluded

Table 1
Age-adjusted baseline characteristics by sex and ethnicity

	Mexican Americans	Non-Hispanic whites	P value
Men			
n[a]	463	267	–
Age (y)[a]	42.6 ± 0.50	43.8 ± 0.66	.178
Weight (kg)	81.1 ± 0.68	84.9 ± 0.89	<.001
Height (cm)	170.0 ± 0.29	177.9 ± 0.38	<.001
Waist circumference (cm)	94.6 ± 0.58	95.8 ± 0.77	.116
Hip circumference (cm)	101.0 ± 0.50	100.9 ± 0.65	.934
BMI (kg/m^2)	28.1 ± 0.24	26.8 ± 0.32	<.001
Waist-to-height ratio (×100)	55.7 ± 0.36	53.9 ± 0.48	<.001
Waist-to-hip ratio (×100)	93.6 ± 0.32	94.9 ± 0.42	.004
Women			
n[a]	679	321	–
Age (y)[a]	43.3 ± 0.41	43.7 ± 0.60	.519
Weight (kg)	70.6 ± 0.56	68.0 ± 0.81	.012
Height (cm)	156.9 ± 0.24	164.0 ± 0.35	<.001
Waist circumference (cm)	87.1 ± 0.48	81.3 ± 0.70	<.001
Hip circumference (cm)	104.1 ± 0.41	100.1 ± 0.59	<.001
BMI (kg/m^2)	28.7 ± 0.20	25.3 ± 0.29	<.001
Waist-to-height ratio (×100)	55.6 ± 0.30	49.6 ± 0.44	<.001
Waist-to-hip ratio (×)	83.5 ± 0.27	81.1 ± 0.39	<.001

Data are n or means ± standard error of the mean. P values for test of difference in baseline characteristics between Mexican Americans and non-Hispanic whites.

[a] Results not adjusted for age.

(n = 356 men and 425 women) in terms of any of the baseline anthropometric measurements ($P > .1$ for all comparisons).

Table 1 shows age-adjusted baseline characteristics of the eligible participants by sex and ethnicity. Mexican Americans were shorter and more obese than non-Hispanic whites. However, waist circumference was comparable in men of both ethnic groups.

In linear regression analysis, there was an indirect relationship between height and age (in men, β estimate ± standard error −0.09 ± 0.02, $P < .001$; in women, β −0.09 ± 0.02, $P < .001$). There was no significant interaction of ethnicity on the association of height and age (in men, $P = .818$; in women, $P = .346$). In addition, there was a direct association between waist circumference and height after accounting for the effect of age (in men, β 2.36 ± 0.56, $P < .001$; in women, β 1.74 ± 0.74, $P = .019$). This relationship was linear in both men (squared terms of height, $P = .986$) and women (height^2, $P = .498$) and was subject to no significant interaction of ethnicity in men ($P = .891$). In women, however, interaction terms of ethnicity × height were close to significance ($P = .054$). Waist circumference was related to height in non-Hispanic white women (β 3.80 ± 1.04, $P < .001$), but it was not in Mexican American women (β 0.62 ± 0.98, $P = .524$).

More Mexican Americans developed incident diabetes than non-Hispanic whites (in men, 12.7% vs 6.4%, $P < .001$; in women, 14.4% vs 6.5%, $P < .001$). In men, height did not predict future diabetes (OR × 1 SD, 0.85 [95% confidence intervals {CI}, 0.87-1.08]). Neither was height a predictor after adjusting for age and ethnicity (OR × 1 SD, 1.14 [0.85-1.51]). In women, however, height was associated with lower diabetic risk (OR × 1 SD, 0.72 [0.59-0.88]); but this association was no longer statistically significant after adjusting for age and ethnicity (OR × 1 SD, 0.88 [0.70-1.11]).

All indices of obesity predicted incident diabetes (Table 2). The odds of predicting diabetes associated with waist circumference did not change by introducing height into the model. In this model, height did not predict diabetes (in men, OR × 1 SD, 1.01 [0.75-1.36]; in women, OR × 1 SD, 0.82 [0.65-1.05]). In a separate waist circumference + height model, an interaction term for ethnicity × height was not statistically significant (in men, $P = .215$; in women, $P = .123$). Neither was significant the effect of ethnicity on the relationship between waist-to-height ratio and incident diabetes (in men, $P = .562$; in women, $P = .113$).

Table 2
Obesity indices as predictors of incident diabetes (7.4-year follow-up period)

	OR (95% CI)[a]
In men	
BMI (×1 SD)	2.04 (1.60-2.59)
Waist circumference (×1 SD)	2.09 (1.62-2.69)
Waist circumference (×1 SD)[b]	2.09 (1.62-2.69)
Waist-to-height ratio (×1 SD)	1.98 (1.54-2.54)
Waist-to-hip ratio (×1 SD)	1.76 (1.35-2.29)
In women	
BMI (×1 SD)	1.91 (1.58-2.31)
Waist circumference (×1 SD)	2.21 (1.80-2.70)
Waist circumference (×1 SD)[b]	2.24 (1.82-2.74)
Waist-to-height ratio (×1 SD)	2.29 (1.86-2.83)
Waist-to-hip ratio (×1 SD)	1.77 (1.44-2.18)

[a] All results were adjusted for age and ethnicity.
[b] Results adjusted also for height.

Table 3
Comparisons between AUC of obesity indices for predicting incident diabetes (7.4-year follow-up period)

	AUC	P value[a]
In men		
Model 1: age + ethnicity	0.685	<.001
Model 2: model 1 + BMI	0.778	.876
Model 3: model 1 + waist circumference	0.775	–
Model 4: model 1 + waist circumference + height	0.775	.702
Model 5: model 1 + waist-to-height ratio	0.764	.161
Model 6: model 1 + waist-to-hip ratio	0.744	.054
In women		
Model 1: age + ethnicity	0.653	<.001
Model 2: model 1 + BMI	0.755	.008
Model 3: model 1 + waist circumference	0.781	–
Model 4: model 1 + waist circumference + height	0.783	.680
Model 5: Model 1 + waist-to-height ratio	0.783	.619
Model 6: model 1 + waist-to-hip ratio	0.729	.001

[a] P values for test of difference in AUCs between the model that included age, ethnicity, and waist circumference (model 3) and each one of the other models were calculated by the method developed by DeLong et al [19].

The AUC for predicting incident diabetes of sex-specific models that included age, ethnicity, and waist circumference as independent variables did not change by adding height into the model or by using a height-adjusted measure of waist circumference (Table 3). In men, all models that included any index of obesity had similar AUCs for predicting incident diabetes. In women, however, the AUC of the model that included waist circumference was greater than that of models that included BMI or waist-to-hip ratio.

The OR of incident diabetes according to ethnicity (Mexican Americans vs non-Hispanic whites) was lower in the model that was adjusted for the waist-to-height ratio than in the model that did not account for height, reflecting in a more appropriate fashion that inclusion of height in the model attenuated the impact of ethnicity on incident diabetes even after adjustment for waist girth (Table 4). The OR of incident diabetes according to ethnicity for the model that was adjusted for the waist-to-height ratio was similar to that for the model that was adjusted for BMI (in men, $P = .740$; in women, $P = .312$).

4. Discussion

Waist circumference predicts diabetes better than BMI or waist-to-hip ratio in women, but all indices are similar in

Table 4
Effect of each obesity index on the relation of ethnicity to incident diabetes (7.4 years of follow-up) by multivariable logistic regression analysis

	OR (95% CI) of incident diabetes according to ethnicity: Mexican Americans vs non-Hispanic whites	*P* value[a]
In men		
Model 1: adjusted for age	2.30 (1.30-4.07)	.010
Model 2: adjusted for age + BMI	1.98 (1.10-3.55)	<.001
Model 3: adjusted for age + waist circumference	2.74 (1.52-4.95)	–
Model 4: adjusted for age + waist circumference + height	2.78 (1.43-5.41)	.982
Model 5: adjusted for age + waist-to-height ratio	2.00 (1.11-3.58)	<.001
Model 6: adjusted for age + waist-to-hip ratio	2.88 (1.59-5.24)	.506
In women		
Model 1: adjusted for age	2.48 (1.51-4.07)	<.001
Model 2: adjusted for age + BMI	1.74 (1.04-2.92)	.222
Model 3: adjusted for age + waist circumference	1.84 (1.10-3.08)	–
Model 4: adjusted for age + waist circumference + height	1.48 (0.83-2.66)	.178
Model 5: adjusted for age + waist-to-height ratio	1.45 (0.86-2.46)	<.001
Model 6: adjusted for age + waist-to-hip ratio	2.10 (1.27-3.48)	.016

[a] *P* values for test of difference in the OR of incident diabetes according to ethnicity between the model that was adjusted for age + waist circumference (model 3) and each one of the other nonnested models using a bootstrap method.

men. Correcting waist circumference for height does not help explain a larger proportion of the risk of diabetes in either men or women, but attenuates more the impact of ethnicity on incident diabetes.

Height is considered a marker of superior intrauterine and childhood nutrition and growth [20,21]. Height has been inversely associated with cardiovascular disease risk [20-22], although this association is not always observed [23,24]. Height has been also associated with lower diabetic risk and is included in some clinical prediction models for type 2 diabetes mellitus [9,10]. However, the relation of height to insulin resistance and type 2 diabetes mellitus may not retain statistical significance after accounting for the effect of other risk factors [25]. In our study, height is not associated with diabetes incidence in men. It is associated in women, but statistical significance is not observed after taking into account the effect of age and ethnicity. Recent reports have also indicated that leg length, a marker of prepubertal growth [26], is the component of stature that is related to insulin resistance, type 2 diabetes mellitus, and cardiovascular disease [25,27,28]. The ability of leg length to predict type 2 diabetes mellitus requires further research, but this anthropometric measure is not available in the SAHS.

Abdominal visceral fat is a major determinant of clustering of disorders associated with the metabolic syndrome [29]. However, evidence on the discriminatory capacity of markers of obesity for predicting future diabetes is conflicting. Some studies favor the use of waist circumference [15] or waist-to-hip ratio over BMI [30], but others favor BMI [31,32]. Moreover, some studies do not favor any index over the rest [33]; and others back the importance of both types of indices (central and overall obesity) [34]. Clearly, diabetic risk is driven by obesity in all ethnic groups; but the preeminence of one type of obesity over the rest remains to be elucidated by more precise markers of fat distribution (such as those derived from imaging techniques).

Waist circumference may be the best anthropometric marker of abdominal visceral fat [12], but it is not clear whether height affects the relationship between waist circumference and abdominal visceral fat. Height has no effect in some studies [11,12], but has significant effect in others [13,14]—linear in women and quadratic in men [14]. We cannot examine the influence of height on the relationship between waist circumference and abdominal visceral fat because precise measures of fat distribution are not available in the SAHS. Nevertheless, height does not affect the discriminatory capacity of waist circumference for predicting future diabetes.

If the model that includes waist-to-height ratio does not explain a larger proportion of the risk of diabetes than the model that includes waist circumference, how is it that waist-to-height ratio attenuates more the impact of ethnicity on incident diabetes? Mexican Americans, both men and women, have lower stature than non-Hispanic whites, although only Mexican American women have a higher waist circumference. Therefore, adjusting waist circumference for height lessens the relationship between ethnicity and incident diabetes. In addition, the significant anthropometric measurements may not be applicable uniformly to all populations [5,6]; and neither may be fat distribution [35-38]. Non-Hispanic whites have more abdominal visceral fat than African Americans and less than Asian Americans [35,37]. In the Insulin Resistance Atherosclerosis Family Study, Mexican Americans have more abdominal visceral fat than African Americans, although their BMI was similar [36]. Thus, it is plausible that the greater diabetic risk in Mexican Americans may be related not only to more obesity but also to a relatively greater amount of abdominal visceral fat.

In summary, diabetic risk associated with waist circumference may be independent of height within a given population. However, height may be an anthropometric measure to consider in studies that examine differences in diabetic risk between populations of different race/ethnicity.

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