EPIDEMIOLOGY/HEALTH SERVICES RESEARCH

Ethnic-Specific Obesity Cutoffs for Diabetes Risk: Cross-sectional Study of 490,288 UK Biobank Participants

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OBJECTIVE

To compare the relationship between adiposity and prevalent diabetes across ethnic groups in the UK Biobank cohort and to derive ethnic-specific obesity cutoffs that equate to those developed in white populations in terms of diabetes prevalence.

RESEARCH DESIGN AND METHODS

UK Biobank recruited 502,682 U.K. residents aged 40–69 years. We used baseline data on the 490,288 participants from the four largest ethnic subgroups: 471,174 (96.1%) white, 9,631 (2.0%) South Asian, 7,949 (1.6%) black, and 1,534 (0.3%) Chinese. Regression models were developed for the association between anthropometric measures (BMI, waist circumference, percentage body fat, and waist-to-hip ratio) and prevalent diabetes, stratified by sex and adjusted for age, physical activity, socioeconomic status, and heart disease.

RESULTS

Nonwhite participants were two- to fourfold more likely to have diabetes. For the equivalent prevalence of diabetes at 30 kg/m^2 in white participants, BMI equated to the following: South Asians, 22.0 kg/m^2; black, 26.0 kg/m^2; Chinese women, 24.0 kg/m^2; and Chinese men, 26.0 kg/m^2. Among women, a waist circumference of 88 cm in the white subgroup equated to the following: South Asians, 70 cm; black, 79 cm; and Chinese, 74 cm. Among men, a waist circumference of 102 cm equated to 79, 88, and 88 cm for South Asian, black, and Chinese participants, respectively.

CONCLUSIONS

Obesity should be defined at lower thresholds in nonwhite populations to ensure that interventions are targeted equitably based on equivalent diabetes prevalence. Furthermore, within the Asian population, a substantially lower obesity threshold should be applied to South Asian compared with Chinese groups.

Obesity and diabetes are major causes of morbidity and mortality (1). There is substantial evidence that obesity is an independent, causal risk factor for type 2 diabetes (2–4), with a dose relationship whereby risk increases above a BMI of 20 kg/m^2 (3). Obesity accounts for ~6% of deaths annually in the U.K. (4), and diabetes is the fifth leading cause of noncommunicable disease death globally (1,5). Diabetes and obesity both predispose to cardiovascular disease, the leading cause of

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mortality in the U.K. (4–7) and a major contributor to health care costs (6–8). Both obesity and diabetes are increasing in prevalence, particularly among people from nonwhite ethnic groups (6,7). Type 2 diabetes is up to six times more common in people of South Asian descent and up to three times more common among people of African and African-Caribbean origin (7,9), compared with white populations.

Epidemiological studies carried out in North America, Europe, and Australia suggest that South Asian, black, and Chinese people experience a higher risk of diabetes at lower levels of obesity than whites (9–18). This suggests that conventional clinical thresholds for obesity that were originally derived from populations of white European descent, namely BMI $\geq$30 kg/m^2 (19) or a waist circumference $\geq$88 cm in women or $\geq$102 cm in men (20), may not be appropriate for nonwhite groups (15–18). Accordingly, both the World Health Organization (WHO) and International Diabetes Federation (IDF) have proposed the development of different thresholds for defining overweight and obesity in Asian populations worldwide, with the WHO Expert Consultation recommending that overweight should be defined as BMI $>$23 kg/m^2 and obese as BMI $>$27.5 kg/m^2 in Asian populations (19,19) and the IDF recommending waist circumference cutoffs of 80 cm for Asian women and 90 cm for Asian men (21). Another proposal, by experts in India, suggested that slightly lower cutoffs for BMI of 23 and 25 kg/m^2, for overweight and obesity respectively, should be used for Asian Indians (15). However, insufficient data were available to derive cutoffs for black populations, and the IDF has suggested that the European cutoff points should be used until such data are generated (21).

One limitation of the available data is that most cohorts recruited relatively small numbers of nonwhite participants, making it difficult to obtain robust estimates of the BMI and waist circumference at which diabetes prevalence is equivalent. Furthermore, despite diabetes prevalence differing markedly between South Asians and Chinese populations (22), current proposals for ethnicity-specific obesity cutoffs have generally considered Asians as a single group and have not evaluated whether obesity thresholds should differ between ethnic groups of Asian origin. Because of its large overall size, UK Biobank recruited sufficient numbers of participants from the black, Chinese, and South Asian populations to make such determinations possible. The aim of this paper was therefore to compare the relationship between adiposity and prevalent diabetes across ethnic groups in the UK Biobank cohort and then derive robust ethnic-specific obesity cutoffs for black, Chinese, and South Asian populations that equate to those developed on white populations in terms of diabetes prevalence.

RESEARCH DESIGN AND METHODS

Study Population

This cross-sectional study used baseline data from UK Biobank, a large, population-based cohort study set up to study the lifestyle, environmental, and genetic determinants of a range of important diseases of adulthood (23). Around 9.2 million invitation letters were sent out to potential participants in order to recruit at least 500,000 participants. Between April 2007 and December 2010, UK Biobank recruited 502,682 participants (5.5% response rate) aged between 40 and 69 years, via 22 assessment centers located across the U.K. (23,24). Extensive baseline information was collected via questionnaires and physical measurements (23).

Definitions and Exclusion Criteria

Diabetes and heart disease were based on self-report of a physician diagnosis. Participants classified themselves into 1 of 16 ethnic groups consistent with the U.K. Office of National Statistics census categories (25). This study was restricted to participants who identified themselves as belonging to one of the following ethnic groups: white, Indian, Pakistani, Bangladeshi, black African, black Caribbean, or Chinese. In order to maximize statistical power, Indian, Pakistani, and Bangladeshi participants were analyzed collectively as South Asian, and the black African and black Caribbean participants were grouped together as the black ethnic group in the initial analyses. Indian and Pakistani participants were considered separately in a supplementary analysis. Socioeconomic status was measured using the Townsend deprivation score, an area of residence–based index of material deprivation derived from census information on housing, employment, social class, and car availability. Alcohol intake, smoking, and physical activity were self-reported. Physical activity was measured in accordance with the International Physical Activity Questionnaire scoring protocol (http://www.ipaq.ki.se/scoring.pdf). We computed total physical activity as the sum of walking, moderate activity, and vigorous activity, measured as METs (min/week), and analyzed the derived measure as a continuous variable.

Anthropometric measurements were obtained by trained research clinic staff who followed standard operating procedures and used regularly calibrated equipment. Weight was measured, without shoes and outdoor clothing, using the Tanita BC 418 body composition analyzer. Height was measured, without shoes, using the wall-mounted SECA 240 height measure. BMI was calculated from weight (in kilograms) divided by the square of height (in meters). Waist circumference was measured at a point midway between the lowest rib margin and the iliac crest, in a horizontal plane, and hip circumference was measured just over the buttocks at the point of maximum circumference. Both were measured using a nonelastic SECA 200 tape measure. The waist-to-hip ratio (WHR) was calculated from waist circumference divided by hip circumference. Percentage body fat was measured using the Tanita BC418MA body composition analyzer.

Statistical Analyses

All statistical analyses were performed using Stata version 12.2 (Stata Corporation, College Station, TX). Participants with missing information on diabetes were excluded, and men and women were analyzed separately. The demographic and anthropometric characteristics of each ethnic group were summarized using the median and interquartile range for continuous variables and frequencies and percentages for categorical data. The statistical significance of differences between ethnic groups was tested using the Kruskal-Wallis test for continuous variables and Pearson χ^2 test for categorical variables. Ordinal variables were tested using a χ^2 test for trend. The *P* values for all hypothesis tests were two-sided, and $P < 0.05$ was interpreted as statistically significant.

Univariate binary logistic regression models were used to examine the crude association between level of adiposity and diabetes. Separate models were run for each of the anthropometric measures, and all were treated as continuous variables. All ethnic groups were entered into the same model, and the model was stratified by ethnic group, with white used as the referent category. All of the models were rerun adjusting for the potential confounding effects of age and Townsend score. Finally, alcohol consumption, physical activity, and presence/absence of heart disease were also added as covariates. Goodness of fit of the logistic regression models was assessed using the area under the receiver operating characteristic curve.

To determine ethnic-specific cut points for adiposity, BMI and waist circumference were modeled using restricted cubic splines (RCS) with three knots. RCS was preferred over a linear model because the Akaike information criterion static was lower for all RCS models compared with the linear models, for determining adiposity cut points (26). We examined the age-adjusted interaction with ethnicity of each of the anthropometric measures separately by sex and plotted the prevalence of diabetes against the level of adiposity by ethnic group. The cutoff values applied to white men were 30 kg/m^2 for BMI and 102 cm for waist circumference. For women, they were 30 kg/m^2 and 88 cm, respectively. The figures were used to determine the ethnic-specific cutoffs at which the prevalence of diabetes was equal to that in the white population. We repeated the analyses, excluding those who had been diagnosed with diabetes for 5 years or longer, to determine whether this changed the ethnic-specific cutoffs.

RESULTS

Of the 502,682 UK Biobank participants, 491,741 (97.8%) belonged to the eligible ethnic groups. Information on diabetes was missing for 1,453 (0.3%) eligible participants. Therefore, the study population comprised 490,288 participants. Of these, 471,174 (96.1%) were white, 9,631 (2.0%) South Asian, 7,949 (1.6%) black, and 1,574 (0.3%) Chinese. A total of 38,632 participants provided information on the "year immigrated to United Kingdom." Of these, 15,271 (39.5%) were from nonwhite ethnic groups, and their median time living in the U.K. was 34 years. Overall, 25,567 (5.2%) had diabetes.

The prevalence of diabetes was higher than in whites among all nonwhite groups and highest among South Asian participants (Table 1). In comparison with white women, most anthropometric measures were higher among South Asian and black women and lower among Chinese women (Table 1). All of the anthropometric measures, other than WHR, suggested that adiposity was highest among black women. Among men, the results were less consistent across the individual measures. In both sexes, there were significant differences between the ethnic groups in age, socioeconomic status, smoking status, alcohol intake, and level of physical activity (Table 1).

The univariate logistic regression analyses confirmed a stronger association between adiposity and diabetes in nonwhite groups, among both men and women (Table 2). The association was strongest among South Asian participants, irrespective of their sex and the anthropometric measure used (Table 2). After adjustment for the potential confounding effects of age and socioeconomic status, the stronger associations in nonwhite groups increased further. The associations were modestly attenuated after inclusion of alcohol consumption, physical activity, and presence/absence of heart disease in the models, but all associations remained statistically significant, and the association between adiposity and diabetes remained three- to fourfold greater in South Asian than white participants (Table 2).

In Fig. 1, the prevalence of diabetes is plotted against the level of adiposity by ethnic group. Irrespective of the anthropometric measure used (BMI or waist circumference), the prevalence of diabetes among nonwhite groups was equivalent to that in the white group at a lower level of adiposity. Compared with white women with a BMI of 30 kg/m^2, diabetes prevalence was equivalent in South Asian women with a BMI of 22.0 kg/m^2, in black women with a BMI of 26.0 kg/m^2, and in Chinese women with a BMI of 24.0 kg/m^2 (Fig. 1*A* and Table 3). In men, the equivalent figures were comparable at 21.6, 26.0, and 26.0 kg/m^2 for South Asian, Chinese, and black men, respectively (Fig. 1*B* and Table 3). For waist, a circumference of 88 cm in white women was equivalent to 70 cm in South Asian women, 74 cm in Chinese women, and 79 cm in black women, in terms of diabetes prevalence (Fig. 1*C* and Table 3). A waist circumference of 102 cm in white men was equivalent to 79, 88, and 88 cm in South Asian, Chinese, and black men, respectively (Fig. 1*D* and Table 3). We repeated the analysis considering Indians and Pakistanis separately and found that for women, BMI values of 21.6 kg/m^2 in Pakistanis and 22.3 kg/m^2 in Indians, and for men, BMI values of 21.5 and 22.0 kg/m^2 for Pakistanis and Indians, respectively, were equivalent to a BMI of 30 kg/m^2 in whites for diabetes prevalence. Similarly, equivalent waist circumference values were lower for Pakistani than Indian women (68.0 vs. 70.0 cm) and men (78.0 vs. 80.0 cm) (Supplementary Fig. 1 and Supplementary Table 1). When we repeated the analyses excluding participants who had been diagnosed with diabetes for 5 years or longer, the BMI and waist circumference cutoffs were very similar to the previous values for black and Chinese groups, but the values for South Asian men were slightly higher (Table 3). The areas under the receiver operating characteristic curves showed that the logistic regression models were a good fit, ranging from 74 to 78% (Supplementary Table 2).

CONCLUSIONS

Our study demonstrated ethnic differences in both the prevalence of diabetes and the association between adiposity and prevalent diabetes. Consistent with previous studies, South Asians had the highest prevalence of diabetes, followed by Chinese and black participants, with whites having the lowest prevalence (7,10,11). Obesity was a risk factor in all ethnic groups, but the risk associated with obesity, as defined by current guidelines, was two- to fourfold higher in nonwhite participants. In nonwhite groups, the prevalence of diabetes was equivalent to that in white populations at much lower levels of BMI and waist circumference. Using current guidelines to target interventions at

Table 1—Characteristics of study participants by ethnic group and sex

	Women				Men			
	White *n* = 256,806	South Asian *n* = 4,479	Black *n* = 4,596	Chinese *n* = 965	White *n* = 214,368	South Asian *n* = 5,152	Black *n* = 3,353	Chinese *n* = 569
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
Age (years)	60 (52–65)	54 (48–61)	52 (47–59)	54 (48–60)	60 (53–66)	55 (47–62)	52 (46–59)	53 (47–61)
BMI (kg/m^2)	26.1 (23.4–29.6)	26.7 (24.0–30.0)	29.7 (26.1–33.7)	22.9 (21.0–25.4)	27.3 (24.9–30.1)	26.5 (24.4–29.1)	27.9 (25.5–30.6)	24.9 (23.0–27.0)
Weight (kg)	69.1 (61.8–78.6)	65.4 (68.4–74.0)	77.9 (68.4–89.1)	57.2 (52.0–63.4)	84.5 (76.5–94.0)	77.0 (69.7–85.5)	84.2 (76.1–93.9)	70.8 (65.2–77.6)
Body fat (%)	36.7 (32.0–41.3)	38.0 (33.8–42.1)	40.4 (35.6–44.3)	30.1 (25.9–34.2)	25.4 (21.6–29.1)	26.2 (22.9–29.4)	25.6 (21.7–29.0)	21.1 (17.8–24.7)
WC (cm)	83 (75–92)	86 (78–94)	91 (82–100)	75 (70–82)	96 (89–104)	95 (89–102)	94 (87–101)	87 (81–93)
HC (cm)	102 (96–108)	101 (95–107)	107 (100–114)	93 (89–98)	103 (99–107)	100 (95–104)	103 (98–108)	96 (93–100)
WHR	0.81 (0.77–0.86)	0.85 (0.80–0.90)	0.84 (0.79–0.90)	0.81 (0.77–0.86)	0.93 (0.89–0.98)	0.95 (0.91–0.99)	0.91 (0.87–0.95)	0.90 (0.87–0.94)
Physical activity (MET, min/week)	2,533 (1,455–4,547)	2,226 (1,215–4,053)	2,300 (1,299–4,053)	2,314 (1,342–4,485)	2,648 (1,448–5,092)	2,162 (1,158–3,908)	2,415 (1,273–4,938)	2,093 (3,684–1,164)
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Diabetes	8,869 (3.5)	618 (13.8)	475 (10.3)	48 (5.0)	14,014 (6.5)	1,068 (20.7)	431 (12.9)	44 (7.7)
Missing	484	86	43	25	629	123	48	15
Heart diseases	65,603 (25.5)	1,274 (28.4)	1,882 (41.0)	197 (20.1)	74,281 (34.6)	1,902 (36.7)	1,242 (36.9)	139 (24.1)
Missing	452	84	46	12	357	97	34	7
Deprivation								
1 (least)	52,586 (20.5)	454 (9.9)	125 (2.7)	148 (15.0)	44,358 (20.6)	453 (8.6)	91 (2.7)	83 (14.3)
2	52,766 (20.5)	446 (9.8)	212 (4.6)	145 (14.7)	44,009 (20.5)	476 (9.0)	146 (4.3)	95 (16.3)
3	52,837 (20.5)	699 (15.3)	380 (8.2)	165 (16.7)	42,988 (20.0)	734 (14.0)	264 (7.8)	82 (14.1)
4	51,600 (20.1)	1,337 (29.3)	953 (20.5)	254 (25.7)	41,774 (19.5)	1,445 (27.4)	675 (19.4)	146 (25.1)
5 (most)	47,197 (18.4)	1,625 (35.7)	2,964 (64.0)	275 (27.9)	4,1607 (19.4)	2,158 (41.0)	2,210 (65.3)	176 (30.2)
Alcohol frequency								
Never	20,964 (8.15)	2,472 (54.4)	1,125 (24.4)	305 (30.9)	10,989 (5.1)	692 (23.1)	690 (20.4)	123 (21.1)
Daily	43,026 (16.7)	131 (2.9)	184 (4.0)	45 (4.6)	56,287 (26.2)	404 (13.5)	327 (9.7)	60 (10.3)
3–4/week	54,723 (21.3)	202 (4.5)	329 (7.1)	42 (4.3)	57,692 (26.9)	464 (15.5)	446 (13.2)	54 (9.3)
1–2/week	67,868 (26.4)	424 (9.3)	761 (16.5)	108 (10.9)	56,322 (26.2)	667 (22.3)	822 (24.3)	99 (17.0)
1–3/month	33,734 (13.1)	311 (6.8)	648 (14.0)	103 (10.4)	19,019 (8.9)	289 (9.7)	409 (12.1)	69 (11.8)
Occasional	36,807 (14.3)	1,004 (22.1)	1,570 (34.0)	384 (38.9)	14,522 (6.8)	480 (16.0)	696 (20.5)	179 (30.7)

P value $<$0.0001 for all variables. HC, hip circumference; IQR, interquartile range; WC, waist circumference.

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Table 2—Logistic regression analysis of the association between adiposity and diabetes by ethnic group and sex

		Women							Men						
		White	South Asian		Black		Chinese		White	South Asian		Black		Chinese	
	Model	Reference group	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	Reference group	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
BMI	1‡	1.0	4.8 (4.3–5.2)	<0.001	2.1 (1.9–2.3)	<0.001	2.7 (2.0–3.7)	<0.001	1.0	47 (4.4–5.1)	<0.001	2.0 (1.8–2.3)	<0.001	2.0 (1.5–2.7)	<0.001
	2*	1.0	5.4 (4.9–5.9)	<0.001	2.1 (1.9–2.4)	<0.001	3.3 (2.4–4.4)	<0.001	1.0	5.8 (5.4–6.3)	<0.001	2.4 (2.1–2.7)	<0.001	2.6 (1.9–3.6)	<0.001
	3#	1.0	3.7 (3.1–4.5)	<0.001	1.5 (1.3–1.8)	<0.001	1.7 (0.9–3.0)	0.052	1.0	4.2 (3.7–4.8)	<0.001	2.2 (1.8–2.6)	<0.001	3.3 (2.1–5.2)	<0.001
WC	1‡	1.0	4.6 (4.2–5.1)	<0.001	2.1 (1.9–2.4)	<0.001	3.2 (2.4–4.3)	<0.001	1.0	4.6 (4.3–5.0)	<0.001	2.6 (2.3–2.9)	<0.001	2.5 (1.8–3.4)	<0.001
	2*	1.0	5.1 (4.6–5.6)	<0.001	2.2 (2.0–2.4)	<0.001	3.7 (2.8–5.0)	<0.001	1.0	5.4 (5.0–5.8)	<0.001	2.8 (2.5–3.2)	<0.001	3.0 (2.2–4.2)	<0.001
	3#	1.0	3.6 (3.0–4.2)	<0.001	1.6 (1.3–1.9)	<0.001	2.0 (1.2–3.4)	<0.001	1.0	3.9 (3.4–4.4)	<0.001	2.5 (2.1–3.0)	<0·001	3.6 (2.2–5.6)	<0.001
% BF	1‡	1.0	5.3 (4.8–5.8)	<0.001	2.2 (2.0–2.5)	<0.001	3.0 (2.2–4.0)	<0.001	1.0	4.6 (4.3–5.0)	<0.001	2.3 (2.0–2.5)	<0.001	2.3 (1.7–3.1)	<0.001
	2*	1.0	4.5 (4.1–5.0)	<0.001	2.3 (2.0–2.5)	<0.001	3.4 (2.5–4.6)	<0.001	1.0	4.2 (3.9–4.6)	<0.001	2.3 (2.1–2.6)	<0.001	2.5 (1.8–3.4)	<0.001
	3#	1.0	3.1 (2.6–3.7)	<0.001	1.6 (1.3–1.9)	<0.001	1.6 (0.9–2.8)	0.096	1.0	3.2 (2.8–3.6)	<0.001	2.1 (1.8–2.5)	<0.001	3.0 (1.9–4.8)	<0.001
WHR	1‡	1.0	3.3 (3.1–3.7)	<0.001	2.4 (2.2–2.7)	<0.001	1.6 (1.2–2.2)	<0.001	1.0	3.4 (3.2–3.7)	<0.001	2.9 (2.6–3.2)	<0.001	1.8 (1.3–2.5)	<0.001
	2*	1.0	3.6 (3.3–3.9)	<0.001	2.3 (2.1–2.5)	<0.001	1.8 (1.4–2.5)	<0.001	1.0	3.8 (3.6–4.2)	<0.001	2.9 (2.6–3.2)	<0.001	2.1 (1.5–2.9)	<0.001
	3#	1.0	2.5 (2.1–3.0)	<0.001	1.6 (1.4–1.9)	<0.001	1.1 (0.7–2.1)	0.453	1.0	3.0 (2.6–3.4)	<0.001	2.6 (2.2–3.1)	<0.001	2.8 (1.7–4.4)	<0.001

Whites are the referent group. *P* values are in comparison with the white group. Adiposity included as a continuous variable in models. % BF, percentage body fat; OR, odds ratio; WC, waist circumference. ‡Univariate analyses. *Adjusted for age and socioeconomic status. #Adjusted for age, socioeconomic status, physical activity, heart disease, and alcohol consumption.

obese individuals would result in a higher risk threshold for diabetes being applied to nonwhite individuals. The curvilinear relationship between BMI and diabetes contrasts to the U-shaped relationship between BMI and total and cardiovascular mortality, which is not fully understood. This simpler relationship, combined with plentiful evidence that diabetes can be prevented by lifestyle changes, justifies the focus on diabetes in deriving ethnic-specific cutoffs.

Our findings are consistent with previous studies in suggesting that the cutoffs currently recommended by the WHO should be reduced when applied to nonwhite populations (11–16). Whereas the current cutoffs apply equally well to diabetes and cardiovascular disease when applied to white populations, studies in nonwhite populations tend to produce lower ethnic-specific equivalents for diabetes than cardiovascular disease (12,14,18). Our study demonstrated that South Asians had an equivalent prevalence of diabetes at a BMI of 22.0 kg/m^2 in women and 21.6 kg/m^2 in men, which is at the lower end of the normal BMI range for white populations. This is consistent with previous studies. A U.K. study by Gray et al. (12) measuring glycemic risk score produced BMI cutoffs of 21.5 and 22.6 kg/m^2 for South Asian men and women, respectively, as being equivalent to a BMI of 30.0 kg/m^2 in whites, and a similar Canadian study by Razak et al. (13) suggested a BMI cutoff of 21.0 kg/m^2 in South Asians for both men and women. Chiu et al. (14) recommended a higher South Asian cutoff value of 24.0 kg/m^2 based on the adjusted incidence of diabetes, but did not include any confidence intervals to indicate the precision of their cut point estimates. Nyamdorj et al. (10) pooled data from 30 cross-sectional studies (n = 54,467), conducted in 11 Asian and European countries, on the crude prevalence of diabetes and reported an equivalent BMI cutoff of 19.0 kg/m^2 for South Asian groups. Our study cutoffs for BMI of 24.0 kg/m^2 in Chinese women, 26.0 kg/m^2 in Chinese men, and 26.0 kg/m^2 for both black women and men were comparable to the cutoff range of 23.0–26.0 kg/m^2 shown by Nyamdorj et al. (10), Chiu et al. (14), and Stommel et al. (18) based on diabetes.

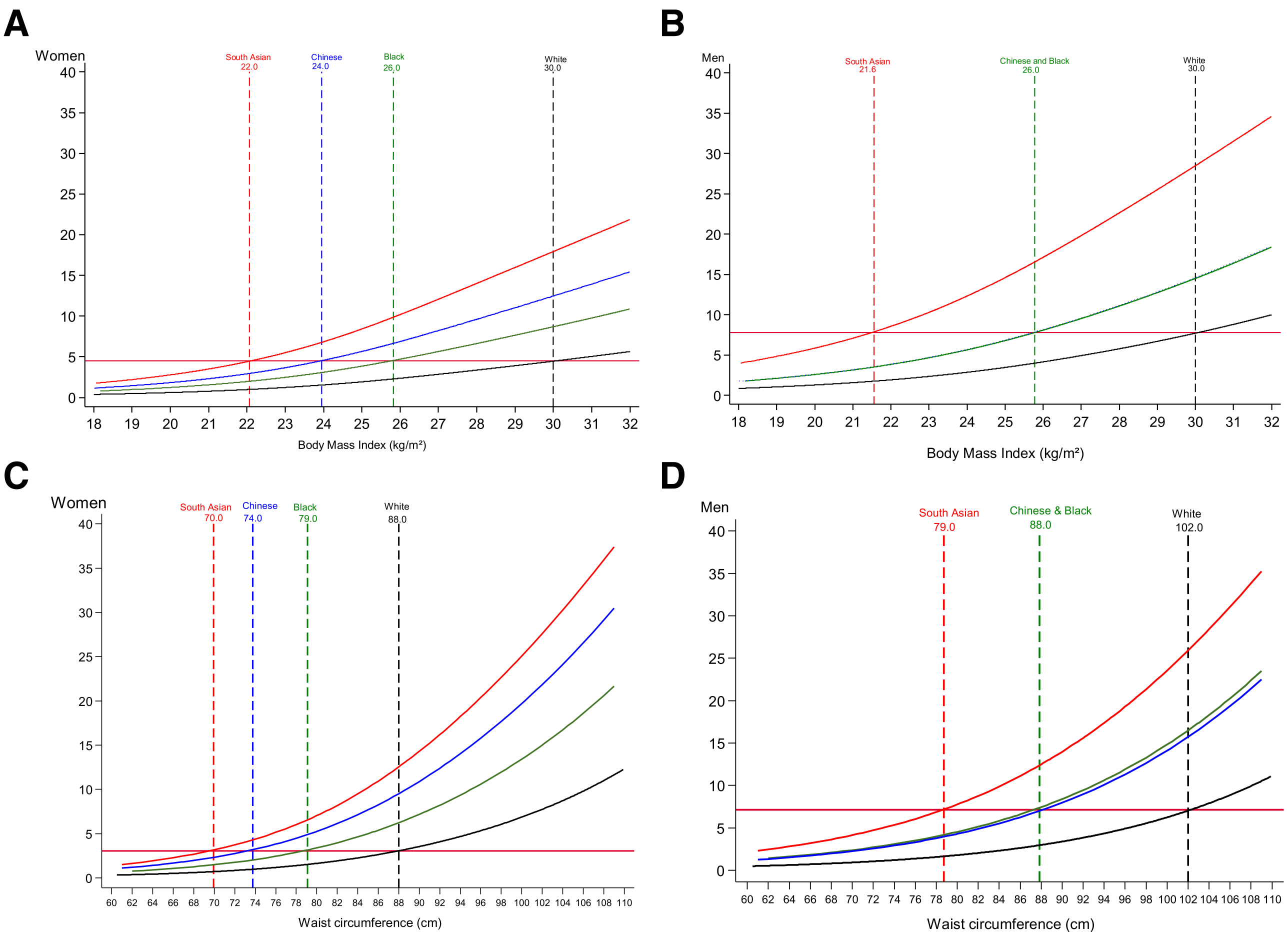

Figure 1—Age-adjusted associations between diabetes prevalence and adiposity. This figure presents the relationship between diabetes prevalence and BMI by ethnic groups in South Asian (solid red line), Chinese (solid blue line), black (solid green line), and white (solid black line) women (*A*) and South Asian (solid red line), Chinese and black (solid green line), and white (solid black line) men (*B*), and the relationship between diabetes prevalence and waist circumference by ethnic groups in South Asian (solid red line), Chinese (solid blue line), black (solid green line), and white (solid black line) women (*C*) and South Asian (solid red line), Chinese and black (solid green line), and white (solid black line) men (*D*), showing the equivalent levels of adiposity in each ethnic group compared with the white ethnic group. Results are adjusted for age and stratified by sex.

In contrast, our study cutoff for Chinese was higher than the value of 21.0 kg/m^2 recommended by Razak et al. (13) based on glycemic risk score. Based on glycemic risk score, rather than diabetes, Gray et al. (12) produced an identical cutoff value of 69 cm for South Asian women but a higher figure of 84 cm for South Asian men, whereas the Nyamdorj et al. (10) study based on diabetes recommended 70 and 73 cm in South Asian women and men,

Table 3—Age-adjusted BMI and waist circumference cutoffs equivalent to conventional obesity thresholds by ethnic group and sex

		White	South Asian	Black	Chinese
		Reference cutoff value	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
Including all participants with diabetes					
Women	BMI (kg/m^2)	30.0	22.0 (21.4–23.0)	26.0 (25.3–27.2)	24.0 (22.3–27.1)
	WC (cm)	88.0	70.0 (66.0–72.0)	79.0 (77.3–81.5)	74.0 (69.5–80.0)
Men	BMI (kg/m^2)	30.0	21.6 (21.0–22.6)	26.0 (25.3–27.3)	26.0 (24.0–28.5)
	WC (cm)	102.0	79.0 (77.0–80.4)	88.0 (86.2–90.3)	88.0 (83.4–94.1)
Including only participants with diabetes diagnosed within last 5 years					
Women	BMI (kg/m^2)	30.0	22.3 (21.4–23.6)	25.3 (24.2–26.7)	23.4 (20.5–28.1)
	WC (cm)	88.0	72.0 (69.5–75.3)	78.0 (75.3–81.3)	74.0 (68.6–82.7)
Men	BMI (kg/m^2)	30.0	23.4 (22.3–25.0)	26.0 (24.8–27.4)	26.0 (23–30.3)
	WC (cm)	102.0	84.0 (77.0–85.2)	88.0 (85.3–91.5)	88.0 (80.3–101.5)

WC, waist circumference.

respectively, and 70 and 82 cm in Chinese women and men.

This study builds on the earlier published findings in a number of important ways. First, with a total of 490,288 participants, including 9,631 South Asians, 1,534 Chinese, and 7,949 blacks, it is ~10 times larger than any other previous investigation on this topic. This allows for a more precise estimate of the equivalent BMI and waist cut points than was previously possible and for robust cut point estimates to be made for men and women separately. We also considered cut points for Indians and Pakistanis separately, within the South Asian group, reporting for the first time that equivalent BMI and waist cut points for diabetes prevalence were slightly lower in Pakistanis than Indians. It is of note that 89.4% of South Asian women and 94.8% of South Asian men in the UK Biobank cohort had BMI values >22.0 and 21.6 kg/m^2, respectively. This suggests that, depending on the nature of the intervention, it may sometimes be more feasible and cost-effective to target all South Asians rather than trying to identify the large majority at high risk. For people with a BMI of ~22 kg/m^2, weight loss interventions may not be the most appropriate mechanism for reducing diabetes risk, but other lifestyle interventions such as dietary modification and increased physical activity could be established for them. Studies have shown that physical activity levels are lower in South Asian groups and that South Asians may need to engage in greater levels of physical activity than whites for an equivalent glycemic risk profile (27,28). Therefore, future research is required to determine whether interventions aimed at increasing physical activity, rather than weight loss per se, may be more appropriate at this level of BMI.

Several hypotheses have been proposed to explain why nonwhite populations have an equivalent risk of diabetes at lower levels of adiposity. Many researchers attribute this to higher insulin resistance among Asian and black populations, as a result of which body fat is deposited in the abdomen and liver at a lower BMI, and that the "thrifty gene" inherited from Asian ancestors enabled them to store calories more efficiently during long periods of famine, but predisposes to weight gain in our obesogenic environment (29,30). Lower birth weight, shorter limbs relative to the trunk, insufficient physical activity, and physiological differences such as low fitness and reduced capacity for fat oxidation have also been suggested as contributory factors (27,30).

UK Biobank is a very large study and provided sufficient numbers in the four main ethnic subgroups. Therefore, a major strength was our ability to compare several ethnic groups living in the same country within the same study. Previous U.K. cross-sectional studies have been smaller overall, recruited smaller numbers of nonwhite participants, and compared fewer ethnic groups; for example, the study by Mckeigue et al. (11) was based on 3,754 participants in total. We had access to several measures of adiposity, all measured by trained staff, using validated methods and standard operating procedures. We were able to adjust for a wide range of potential confounding factors, but residual confounding can never be fully excluded from an observational study. Our results showed that the regression fitted the different models reasonably well, with all producing areas under the curve in excess of 74%. In our cross-sectional study of prevalent cases of diabetes, we could not establish a temporal relationship between obesity and diabetes. However, reverse causation is unlikely to be a major problem since the subgroup analysis that included only recently (within 5 years) diagnosed patients with diabetes produced very similar cutoff values (except for South Asian men, in which the cut point values increased slightly). Diabetes was ascertained by self-report of a physician diagnosis. Therefore, incomplete ascertainment is possible but unlikely to introduce a systematic error. Indeed, Bays et al. (31) reported that the prevalence of diabetes was similar when based solely on self-report in the SHIELD (Study to Help Improve Early evaluation and management of risk factors Leading to Diabetes) screening survey compared with clinical and laboratory corroboration of self-reports in the National Health and Nutrition Examination Survey. Schneider et al. (32) also showed that self-reported diabetes was >92% reliable and 83% sensitive. We were unable to differentiate between type 1 and type 2 diabetes. However, in the age-group studied, the majority of cases (>90%) will be type 2 (7), and the cutoffs were very similar in the subgroup analysis limited to participants with recently diagnosed diabetes, who are much less unlikely to be type 1. In due course, follow-up of UK Biobank participants will provide data on incident cases of diabetes, which can be used to verify the cutoffs derived from the baseline data. This study was conducted in the U.K. From migration studies, we know that ethnic groups who emigrate differ from those remaining in their native countries in terms of metabolic risk and that this is due to changes in their lifestyle (33–37). However, we believe that the underlying relationship between adiposity and diabetes in a given ethnic group should be unaffected by country of residence, and therefore the results should be generalizable to people of the same ethnic group who live outside of the U.K., including their country of origin. However, further studies should be conducted to corroborate this.

Defining a threshold value for BMI or waist circumference is necessary to target diabetes screening and prevention, including weight reduction interventions. Our study adds to the growing evidence that nonwhite groups face a greater burden of diabetes at lower levels of adiposity. Therefore, applying the same adiposity thresholds in nonwhite and white populations introduces inequality in terms of disease risk. There is now overwhelming evidence of the need for lower ethnic-specific cutoffs for intervention in nonwhite populations. Although the precise cutoffs varied slightly between studies, the rankings of ethnic groups has been consistent, with South Asians having the lowest cutoff values and Chinese having values either equal to or below those of black groups. Lower obesity thresholds should be applied to nonwhite groups, and should be specific to each ethnic group, in order to ensure an equitable approach based on equivalent risk. In particular, the present data show that Asians should not be treated as a single group when considering obesity thresholds, an approach that has been adopted in some previous recommendations (15,19,21), with South Asians requiring a substantially lower obesity cutoff than Chinese. Moreover, these findings, which will aid future guidelines in this area, could help to promote better public education and health measures to attenuate obesity risks in high-risk ethnic populations.

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References

1. WHO. Burden: mortality, morbidity and risk factors. In *Global status report on noncommunicable diseases 2010*. Geneva, World Health Org., 2011, p. 9–31
2. Vazquez G, Duval S, Jacobs DR Jr, Silventoinen K. Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis. Epidemiol Rev 2007;29:115–128
3. Colditz GA, Willett WC, Stampfer MJ, et al. Weight as a risk factor for clinical diabetes in women. Am J Epidemiol 1990;132:501–513
4. Banegas JR, López-García E, Gutiérrez-Fisac JL, Guallar-Castillón P, Rodríguez-Artalejo F. A simple estimate of mortality attributable to excess weight in the European Union. Eur J Clin Nutr 2003;57:201–208
5. Sicree R, Shaw J, Zimmet P. The global burden. Diabetes and impaired glucose tolerance [article online], 2011. Available from http://www.idf.org/sites/default/files/The_Global_Burden.pdf. Accessed 14 June 2013
6. Morgan L, Dent M. The economic burden of obesity [article online], 2010. Available from http://www.noo.org.uk/NOO_pub/briefing_papers. Accessed 9 May 2013
7. Diabetes UK. Diabetes in the UK 2011/12: key statistics on diabetes [article online], 2011. Available from http://www.diabetes.org.uk/documents/reports/diabetes-in-the-uk-2011-12.pdf. Accessed 9 May 2013
8. Clarke P, Gray A, Legood R, Briggs A, Holman R. The impact of diabetes-related complications on healthcare costs: results from the United Kingdom Prospective Diabetes Study (UKPDS Study No. 65). Diabet Med 2003;20:442–450
9. Tillin T, Hughes AD, Godsland IF, et al. Insulin resistance and truncal obesity as important determinants of the greater incidence of diabetes in Indian Asians and African Caribbeans compared with Europeans: the Southall And Brent REvisited (SABRE) cohort. Diabetes Care 2013;36:383–393
10. Nyamdorj R, Pitkäniemi J, Tuomilehto J, et al.; DECODA and DECODE Study Groups. Ethnic comparison of the association of undiagnosed diabetes with obesity. Int J Obes (Lond) 2010;34:332–339
11. McKeigue PM, Shah B, Marmot MG. Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. Lancet 1991;337:382–386
12. Gray LJ, Yates T, Davies MJ, et al. Defining obesity cut-off points for migrant South Asians. PLoS ONE 2011;6:e26464
13. Razak F, Anand SS, Shannon H, et al. Defining obesity cut points in a multiethnic population. Circulation 2007;115:2111–2118
14. Chiu M, Austin PC, Manuel DG, Shah BR, Tu JV. Deriving ethnic-specific BMI cutoff points for assessing diabetes risk. Diabetes Care 2011;34:1741–1748
15. Misra A, Chowbey P, Makkar BM, et al.; Concensus Group. Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. J Assoc Physicians India 2009;57:163–170
16. Kim CH, Kim HK, Kim EH, Bae SJ, Park JY. Impact of body mass index on the predictive ability of body fat distribution for type 2 diabetes risk in Koreans. Diabet Med 2012;29:1395–1398
17. Resnick HE, Valsania P, Halter JB, Lin X. Differential effects of BMI on diabetes risk among black and white Americans. Diabetes Care 1998;21:1828–1835
18. Stommel M, Schoenborn CA. Variations in BMI and prevalence of health risks in diverse racial and ethnic populations. Obesity (Silver Spring) 2010;18:1821–1826
19. Expert Consultation WHO; WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157–163
20. World Health Organization. *Waist circumference and waist-hip ratio report of a WHO expert consultation, Geneva, 8-11 December 2008*. Geneva, World Health Org., 2011
21. International Diabetes Federation. The IDF consensus worldwide definition of the metabolic syndrome [article online], 2005. Available from http://www.idf.org/webdata/docs/MetSyndrome_FINAL.pdf. Accessed 5 May 2013
22. Qiao Q, Hu G, Tuomilehto J, et al.; DECODA Study Group. Age- and sex-specific prevalence of diabetes and impaired glucose regulation in 11 Asian cohorts. Diabetes Care 2003;26:1770–1780
23. Allen N, Sudlow C, Downey P, et al. UK Biobank: current status and what it means for epidemiology. Health Policy and Technology 2012;1:123–126
24. Biobank UK. UK Biobank: rationale, design and development of a large-scale prospective resource. Resources [article online], 2007. Available from http://www.ukbiobank.ac.uk/resources/. Accessed 8 April 2013
25. Office for National Statistics. Ethnic group [article online], 2013. Available from http://www.ons.gov.uk/ons/guide-method/measuring-equality/equality/ethnic-nat-identity-religion/ethnic-group/index.html. Accessed 2 March 2013
26. Akaike H. A new look at the statistical model identification. IEEE Transactions on Automatic Control 1974;19:716–723
27. Hall LM, Moran CN, Milne GR, et al. Fat oxidation, fitness and skeletal muscle expression of oxidative/lipid metabolism genes in South Asians: implications for insulin resistance? PLoS ONE 2010;5:e14197
28. Celis-Morales CA, Ghouri N, Bailey ME, Sattar N, Gill JM. Should physical activity recommendations be ethnicity-specific? Evidence from a cross-sectional study of South Asian and European men. PLoS ONE 2013;8:e82568
29. Wagner DR, Heyward VH. Measures of body composition in blacks and whites: a comparative review. Am J Clin Nutr 2000;71:1392–1402
30. Bhopal RS. A four-stage model explaining the higher risk of type 2 diabetes mellitus in South Asians compared with European populations. Diabet Med 2013;30:35–42
31. Bays HE, Bazata DD, Clark NG, et al. Prevalence of self-reported diagnosis of diabetes mellitus and associated risk factors in a national survey in the US population: SHIELD (Study to Help Improve Early evaluation and management of risk factors Leading to Diabetes). BMC Public Health 2007;7:277
32. Schneider AL, Pankow JS, Heiss G, Selvin E. Validity and reliability of self-reported diabetes in the atherosclerosis risk in communities study. Am J Epidemiol 2012;176:738–743
33. Wild SH, Fischbacher C, Brock A, Griffiths C, Bhopal R. Mortality from all causes and circulatory disease by country of birth in England and Wales 2001-2003. J Public Health (Oxf) 2007;29:191–198
34. Marmot MG, Syme SL, Kagan A, Kato H, Cohen JB, Belsky J. Epidemiologic studies of coronary heart disease and stroke in Japanese men living in Japan, Hawaii and California: prevalence of coronary and hypertensive heart disease and associated risk factors. Am J Epidemiol 1975;102:514–525
35. Bhatnagar D, Anand IS, Durrington PN, et al. Coronary risk factors in people from the Indian subcontinent living in west London and their siblings in India. Lancet 1995;345:405–409
36. Adelstein AM, Marmot MG, Bulusu L. Migrant studies in Britain. Br Med Bull 1984;40:315–319
37. Harding S, Rosato M, Teyhan A. Trends for coronary heart disease and stroke mortality among migrants in England and Wales, 1979-2003: slow declines notable for some groups. Heart 2008;94:463–470