Differences in Body Composition Convey a Similar Risk of Type 2 Diabetes Among Different Ethnic Groups With Disparate Cardiometabolic Risk—The HELIUS Study

Diabetes Care 2021;44:1692–1698 | https://doi.org/10.2337/dc21-0230

Marleen Zethof,[1,2]
Charlotte M. Mosterd,[1,3] Didier Collard,[2]
Henrike Galenkamp,[1] Charles Agyemang,[1]
Max Nieuwdorp,[2]
Daniël H. van Raalte,[3] and
Bert-Jan H. van den Born[1,2]

CARDIOVASCULAR AND METABOLIC RISK

OBJECTIVE

Studies have shown a disparate association between body composition and the risk of type 2 diabetes. We assessed whether associations between differences in body composition and type 2 diabetes vary among ethnic groups with disparate cardiometabolic risk.

RESEARCH DESIGN AND METHODS

We used data from the Healthy Life in an Urban Setting (HELIUS) study, including individuals aged 18–70 years of African Surinamese (*n* = 3,997), South Asian Surinamese (*n* = 2,956), Turkish (*n* = 3,546), Moroccan (*n* = 3,850), Ghanaian (*n* = 2,271), and Dutch (*n* = 4,452) origin living in Amsterdam. Type 2 diabetes was defined using the World Health Organization criteria. Logistic regression was used to assess the relation between body composition and type 2 diabetes. Waist-to-hip ratio (WHR), waist circumference, BMI, and body fat percentage by bioelectrical impedance were used to estimate body composition.

RESULTS

Per unit change in BMI, only Ghanaian (odds ratio [OR] 0.94 [95% CI 0.89–0.99]) and Moroccan (0.94 [0.89–0.99]) women had a smaller increase in type 2 diabetes compared with the Dutch population, whereas the ORs for body fat percentage were 0.94 (0.89–1.00) for Ghanaian, 0.93 (0.88–0.99) for Moroccan, and 0.95 (0.90–1.00) for South Asian Surinamese women. There was no interaction between WHR and ethnicity on the risk of type 2 diabetes, and there were no differences in men. WHR had the highest precision in predicting type 2 diabetes in both men (C statistic = 0.78) and women (C statistic = 0.81).

CONCLUSIONS

The association between differences in body composition and type 2 diabetes is roughly the same in all ethnic groups. WHR seems the most reliable and consistent predictor of type 2 diabetes regardless of ethnic background.

It has been well established that large differences exist in body composition among ethnic minority groups and that these differences have an important impact on the

[1]Department of Public and Occupational Health, Amsterdam University Medical Centers, Academic Medical Center, University of Amsterdam, Amsterdam, the Netherlands
[2]Department of Vascular Medicine, Amsterdam University Medical Centers, University of Amsterdam, Amsterdam, the Netherlands
[3]Diabetes Center, Department of Internal Medicine, Amsterdam University Medical Centers, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands

Corresponding author: Bert-Jan H. van den Born, b.j.vandenborn@amsterdamumc.nl

Received 27 January 2021 and accepted 16 April 2021

This article contains supplementary material online at https://doi.org/10.2337/figshare.14447988.

risk of type 2 diabetes (1–3). The Northern Manhattan study showed that Hispanic and non-Hispanic Black individuals had a higher risk of diabetes than White individuals (4). In the U.K., the prevalence of type 2 diabetes is approximately three to five times higher in ethnic minorities compared with the White British population, and the onset of type 2 diabetes also occurs 10–12 years earlier (5).

We previously reported that the odds of type 2 diabetes are three to five times higher in individuals of South Asian descent living in the Amsterdam area compared with native Dutch, two to four times higher in migrants of Turkish and Moroccan descent, and two to three times higher in sub-Saharan Africans (1). Additionally, migration history seems to contribute to the unequal burden of type 2 diabetes among ethnic groups: Ghanaians who migrated directly to the Netherlands from sub-Saharan Africa had a higher prevalence and higher odds of type 2 diabetes compared with men of African Surinamese origin, who are also of West African descent but have migrated via Suriname (2). The underlying mechanisms of the increased risk of type 2 diabetes in migrants are complex and not fully understood.

Adiposity, in particular central adiposity, is known to be the most important risk factor for developing type 2 diabetes by dysregulating adipokine secretion, subclinical inflammation, and an increased release of fatty acids into the circulation (6–9). Population studies have shown that waist circumference and the waist-to-hip ratio (WHR) are the best discriminators for type 2 diabetes among different ethnic groups (10,11), whereas relationships with body fat percentage and BMI vary. This may be due to differences in body composition, such as central versus peripheral fat depots, differences in appendicular skeletal muscle, and body build. Asian individuals, for example, have a higher tendency toward abdominal obesity compared with non-Asian populations, and health risks associated with obesity occur at a lower BMI compared with Europeans (12–15). In contrast, Mexican Americans have a higher risk of developing type 2 diabetes for a given WHR compared with American Indians. These differences have led to ethnicity-specific cutoffs for overweight, as recommended by the World Health Organization (WHO) and International Diabetes Federation (16–18). However, to what extent, for a given difference in body anthropometric characteristics, the risk of type 2 diabetes differs among ethnic groups is still unclear.

The aim of the current study was to examine the extent to which the association between the different parameters of body composition and type 2 diabetes is different among ethnic minority groups participating in a large multiethnic population based study living in Amsterdam.

RESEARCH DESIGN AND METHODS

We used the Healthy Life in an Urban Setting (HELIUS) study to investigate the association between anthropometric measurements (BMI, WHR, waist circumference, and body fat percentage) and type 2 diabetes among different ethnic groups. The rationale, conceptual framework, design, and methodology of the HELIUS study have been described elsewhere (19). In brief, the HELIUS study is a large-scale prospective multiethnic cohort study on health and health care use conducted in Amsterdam, the Netherlands.

Baseline data collection took place between January 2011 and June 2015 and included people aged between 18 and 70 years of African Surinamese, South Asian Surinamese, Turkish, Moroccan, Ghanaian, and Dutch origin. These ethnic groups were chosen because they comprise the largest ethnic minority groups in Amsterdam, where 35% of inhabitants have a non-Western origin. On the basis of their migration background, which traces back to West Africa (Ghanaians and African Surinamese), Northern India (South Asian Surinamese), Morocco, and Turkey, they are among the main ethnic minority groups in Europe outside of the European Union (20). Details on sociopolitical background and migration history are described by Snijder et al. (21). All participants were randomly selected through the municipality registry of Amsterdam and stratified for ethnic background to generate comparable group sizes.

All data were collected through questionnaires, a physical examination, and fasting venous blood sampling. Study protocols were approved by the Amsterdam University Medical Centers Institutional Review Board, location Academic Medical Center. All participants provided written informed consent.

For this study, we excluded all individuals with unknown or different ethnic background and missing information on anthropometric measurements and data on the presence of type 2 diabetes. The analysis included 21,072 participants, including African Surinamese (n = 3,997), South Asian Surinamese (n = 2,956), Turkish (n = 3,546), Moroccan (n = 3,850), Ghanaian (n = 2,271), and Dutch (n = 4,452) origin (Supplementary Fig. 1).

Information on ethnic origin was obtained by questionnaire. The definition of non-Dutch ethnic origin was being born outside of the Netherlands and having at least one parent born abroad (first generation) or being born in the Netherlands with both parents born outside the Netherlands (second generation). People were considered Dutch when they were born in the Netherlands, and their parents were born in the Netherlands. Participants of Surinamese ethnic origin were further classified according to self-reported ethnic origin (obtained by questionnaire) into "African," "South Asian" or "other."

Following WHO criteria, individuals were classified as having type 2 diabetes if they had a fasting plasma glucose level $\geq$7.0 mmol/L, had self-reported diabetes, or were treated with glucose-lowering medication (22). Participants were asked to bring their medication for verification. Self-reported diabetes was present if participants responded positively to the question of whether they were diagnosed with diabetes by a health care professional. Glucose was measured by enzymatic colorimetric spectrophotometry in fasting blood samples. The concentration of HbA_{1c} was determined on whole blood using high-performance liquid chromatography technology (Tosoh, Tokyo, Japan).

Fat mass was measured by arm-leg bioimpedance taken with a Bodystat 1500 analyzer (Bodystat Ltd, Isle of Man, U.K.). The body fat percentage was calculated by applying the formula of Kyle et al. (23) on the Bodystat output. Weight and height were measured in duplicate while the individual was barefoot and wearing light clothes on a Seca 877 scale and a Seca 217 stadiometer, respectively. BMI was calculated as weight (kg) divided by height squared (m^2).

Waist circumference was measured at the level midway between the lower rib margin and the iliac crest. Hip circumference was measured at the widest point measured over the trochanter major. WHR was calculated as waist circumference divided by hip circumference. Measurements of waist and hip circumference were performed twice, and the average was used for further analysis.

Statistical analysis was performed by using R 3.65.1 software (The R Foundation for Statistical Computing, 2018). Given the well-known sex differences in body composition, baseline characteristics were stratified by both sex and ethnicity and are presented as means with SDs for normally distributed continuous data or as median and interquartile range (IQR) if data were skewed. Age-adjusted logistic regression analysis was performed to study the relation between body composition, defined by BMI, WHR, waist circumference, or body fat percentage, and diabetes. Standardizing of the measurements was obtained by dividing the anthropometric measurements by the SD. Analyses were performed separately for men and women. We assessed the influence of ethnicity on the relation between type 2 diabetes and the anthropometric measurements by adding an interaction term to the logistic regression model, and subsequently estimated ethnicity-specific odds ratios (ORs) using the same models. In addition we depicted the interaction term taking the people with Dutch origin as the reference population.

The primary objective was to assess the association between body composition and the prevalence of diabetes. The receiver operating characteristic (ROC) curve and the corresponding area under the ROC curve (AUC) were calculated using WHR, waist circumference, BMI, or fat percentage as a predictor for type 2 diabetes. Secondly, we assessed the diagnostic accuracy of the different anthropometric measurement in clinical practice by using the WHO-recommended cutoffs taking ethnicity into account, including separate values for BMI, waist circumference, and WHR for South Asian Surinamese men and women (16,17). WHR was depicted as percentage and therefore multiplied by 100. Ethnicity- and sex-specific criteria were not used to assess the relation between body fat percentage and type 2 diabetes because a previous study from our group showed that in a subset of the current study, specific cutoff values did not improve the relation between fat distribution and type 2 diabetes (2).

RESULTS

Baseline characteristics of the study subjects stratified by ethnicity and sex are reported in Table 1. Turkish and Moroccan men and women were, on average, younger than the other ethnic groups. Turkish men and Ghanaian women had the highest BMI and waist circumference, whereas South Asian Surinamese men and women had the highest WHR. Of all measures of body composition, Dutch men and women had the most favorable measures. Type 2 diabetes was highest in South Asian Surinamese men and women, with an overall prevalence of 22.1%, whereas

Table 1—Characteristics of the study population by sex and ethnicity

	Dutch	South Asian Surinamese	African Surinamese	Ghanaian	Turkish	Moroccan
Men						
n	2,034	1,323	1,554	873	1,602	1,498
Age (years)	46.85 (13.81)	44.73 (13.64)	48.01 (12.89)	46.90 (11.46)	40.80 (12.12)	42.06 (12.72)
Diabetes	112 (5.5)	312 (23.6)	217 (14.0)	155 (17.8)	197 (12.3)	198 (13.2)
Age at diabetes onset (years)	44.26 (19.27)	43.76 (13.54)	44.77 (15.30)	45.05 (10.85)	41.96 (12.61)	41.87 (16.08)
Use of diabetes medication	44 (2.2)	205 (15.5)	111 (7.1)	66 (7.6)	95 (5.9)	109 (7.3)
Height (cm)	182.58 (7.18)	172.11 (6.42)	176.16 (6.81)	171.68 (6.47)	172.94 (6.83)	174.76 (6.46)
Body weight (kg)	84.06 (13.35)	76.71 (13.82)	81.80 (15.28)	79.03 (12.62)	83.16 (13.51)	81.63 (13.70)
BMI (kg/m^2)	25.22 (3.78)	25.85 (4.18)	26.31 (4.43)	26.78 (3.75)	27.82 (4.34)	26.69 (3.99)
Waist circumference (cm)	93.90 (11.73)	93.96 (12.15)	92.23 (12.50)	92.07 (11.16)	97.19 (11.87)	95.01(11.19)
WHR	0.93 (0.07)	0.97 (0.08)	0.93 (0.07)	0.94 (0.07)	0.96 (0.07)	0.94 (0.07)
Body fat percentage (%)	24.06 (5.72)	25.70 (6.23)	24.23 (6.35)	24.20 (5.96)	25.94 (5.86)	25.46 (5.82)
Fasting glucose (mmol/L)	5.50 (0.79)	6.00 (1.54)	5.60 (1.29)	5.59 (1.44)	5.64 (1.12)	5.76 (1.40)
HbA_{1c} (%)	5.46 (0.47)	6.06 (0.97)	5.80 (0.85)	5.81 (0.94)	5.70 (0.76)	5.74 (0.81)
HbA_{1c} (mmol/mol)	36.22 (5.13)	42.70 (10.57)	39.86 (9.26)	40.02 (10.29)	38.84 (8.28)	39.18 (8.83)
Women						
n	2,418	1,633	2,443	1,398	1,944	2,352
Age (years)	45.60 (14.19)	46.10 (13.17)	47.85 (12.25)	43.50 (10.67)	39.94 (12.13)	39.50 (12.92)
Diabetes	63 (2.6)	342 (20.9)	352 (14.4)	174 (12.4)	204 (10.5)	278 (11.8)
Age at diabetes onset (years)	49.39 (14.48)	43.20 (14.30)	45.03 (13.64)	44.34 (12.30)	42.47 (10.86)	41.17 (13.31)
Use of diabetes medication	35 (1.4)	212 (13.0)	232 (9.5)	93 (6.7)	116 (6.0)	172 (7.3)
Height (cm)	169.53 (6.68)	158.21 (6.09)	163.78 (6.32)	161.57 (5.76)	159.01 (5.97)	161.02 (6.06)
Body weight (kg)	69.98 (12.79)	66.94 (13.94)	77.34 (16.56)	77.39 (14.70)	73.43 (15.75)	72.89 (14.78)
BMI (kg/m^2)	24.38 (4.48)	26.74 (5.28)	28.83 (5.91)	29.63 (5.34)	29.14 (6.51)	28.16 (5.75)
Waist circumference (cm)	85.46 (12.57)	90.09 (13.43)	93.54 (14.78)	94.10 (13.07)	92.25 (15.26)	92.05 (14.61)
WHR	0.84 (0.08)	0.90 (0.08)	0.88 (0.08)	0.88 (0.08)	0.87 (0.09)	0.86 (0.09)
Body fat percentage (%)	32.98 (6.07)	37.03 (6.15)	37.14 (6.24)	37.84 (6.09)	37.23 (6.37)	37.50 (6.15)
Fasting glucose (mmol/L)	5.13 (0.68)	5.63 (1.49)	5.41 (1.35)	5.25 (1.05)	5.32 (1.19)	5.36 (1.25)
HbA_{1c} (%)	5.44 (0.42)	5.98 (0.90)	5.84 (0.88)	5.74 (0.82)	5.66 (0.78)	5.66 (0.77)
HbA_{1c} (mmol/mol)	35.98 (4.59)	41.86 (9.85)	40.28 (9.64)	39.25 (9.01)	38.39 (8.47)	38.34 (8.39)

Data are presented as mean (SD) for continuous variables and as *n* (%) for categorical variables. All differences, except age, onset of diabetes, and use of diabetes medication were significant at $P < 001$.

Dutch men and women had the lowest prevalence of type 2 diabetes (3.9%).

ROC curves of BMI, WHR, fat percentage, and waist circumference as predictors of type 2 diabetes in men and women are shown in Fig. 1. The overall accuracy of measures of body composition to predict type 2 diabetes was better in women than in men, with ROC curves ranging between 0.71 and 0.82 in women and between 0.64 and 0.80 in men. In both men and women, WHR had the highest accuracy to predict type 2 diabetes. This was also true for all the individual ethnic groups, although the AUC was generally lower in Ghanaian men (AUC, 0.71; sensitivity, 0.88; specificity, 0.31) and women (AUC, 0.80; sensitivity, 0.91; specificity, 0.37) (Supplementary Table 1).

Figure 2 shows the age-adjusted change in OR per unit increase in BMI, WHR, fat percentage, and waist circumference stratified by sex and ethnic group. There were significant differences in the risk of type 2 diabetes and the association with BMI and body fat percentage in women, with Dutch women having the highest OR of type 2 diabetes per unit change in BMI and body fat percentage, whereas Ghanaian and Moroccan women had the lowest OR per change in BMI or body fat percentage. For waist circumference and WHR, the association with type 2 diabetes was the same among women of different ethnic groups. For men, there was no significant difference in measures of body composition and type 2 diabetes. Results were the same when standardized coefficients were used to explore the association between changes in measures of body composition and type 2 diabetes (Supplementary Fig. 2). After standardization for the differences in distribution of the anthropometric measures, we found the strongest association for WHR and waist circumference, with ORs ranging between 1.29 and 3.53, while we found weaker associations with BMI and fat percentage, ranging between 1.06 and 2.92.

In men, we did not find a significant interaction between measures of body composition and the risk of type 2 diabetes. In women, however, we found a significant interaction in the association between both BMI (*P* = 0.01) and body fat percentage (*P* = 0.03) and the risk of type 2 diabetes. The odds of type 2 diabetes for a given increase in WHR and waist circumference did not differ between ethnic groups (Table 2).

CONCLUSIONS

We show that the association between body composition and type 2 diabetes is comparable across ethnic groups, despite large differences in the prevalence of type 2 diabetes and despite the use of ethnicity-specific cutoffs for body composition. Only in women statistically significant variations in the association between BMI, body fat percentage, and the risk of type 2 diabetes were present across ethnic groups, but not in waist circumference or WHR. In both men and women, WHR and waist circumference were superior in predicting type 2 diabetes compared with BMI or body fat percentage. The ROC curves and reported SDs show that WHR was more accurate and precise in predicting type 2 diabetes compared with waist circumference. In line, after standardization, we observed the highest ORs for WHR and waist circumference for the presence of type 2 diabetes.

Many studies have demonstrated that the relation between BMI and the percentage of body fat not only depends on age and sex but also differs across ethnic groups, in particular in Asian populations (17,24). For example, populations of South Asian descent in the U.K. and U.S. tend to have a higher percentage of body fat at a given BMI and have more features of the metabolic syndrome at a given waist circumference (3,25,26). In addition, rates of coronary artery disease and cardiovascular mortality are higher among South Asians (27,28), while the prevalence of impaired glucose tolerance and diabetes is up to six times higher (3,21,29). Because BMI systematically underestimates the percentage of body fat and cardiovascular disease risk among Asian populations, the WHO has recommended separate classification criteria for overweight, obesity, and abdominal obesity in Asian populations to improve early identification of individuals at increased cardiometabolic risk (17). Using the ethnicity-specific WHO cutoffs, we show that the diagnostic accuracy for the different measures of body composition was roughly the same in the different ethnic groups, except for Ghanaian men and women. This confirms previous findings that different criteria need to be applied for individuals of South Asian descent, but also points towards possibilities for improvement in creating cutoffs in other populations, in particular those with African ethnicities.

There are different theories to explain the increased risk of type 2 diabetes between ethnic groups. It has been suggested that exposure to several ecological stressors is creating a variability within metabolism and body size and composition (30). Moreover, the long-term exposure of specific diseases might have altered the metabolic profile of adipose tissue within each ethnic group. Despite large differences in the overall risk of type 2 diabetes and different cutoffs for BMI and waist circumference, our study shows that there are

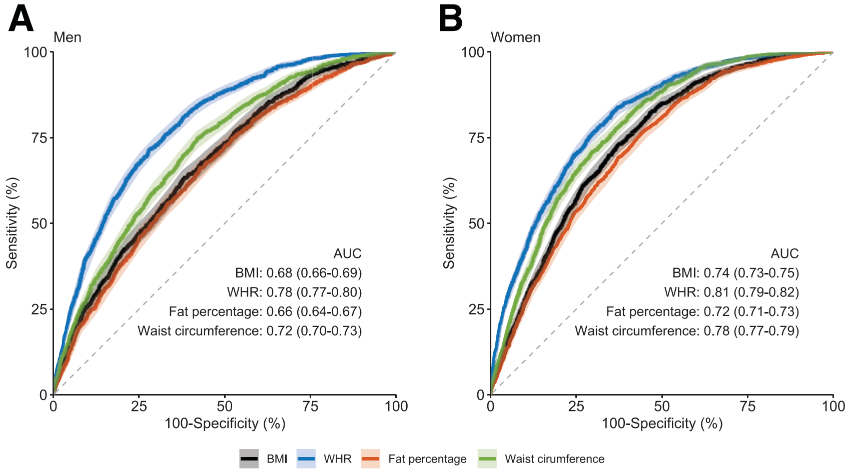

Figure 1—ROC curve of BMI, WHR, fat percentage, and waist circumference as a predictor of type 2 diabetes with corresponding AUC.

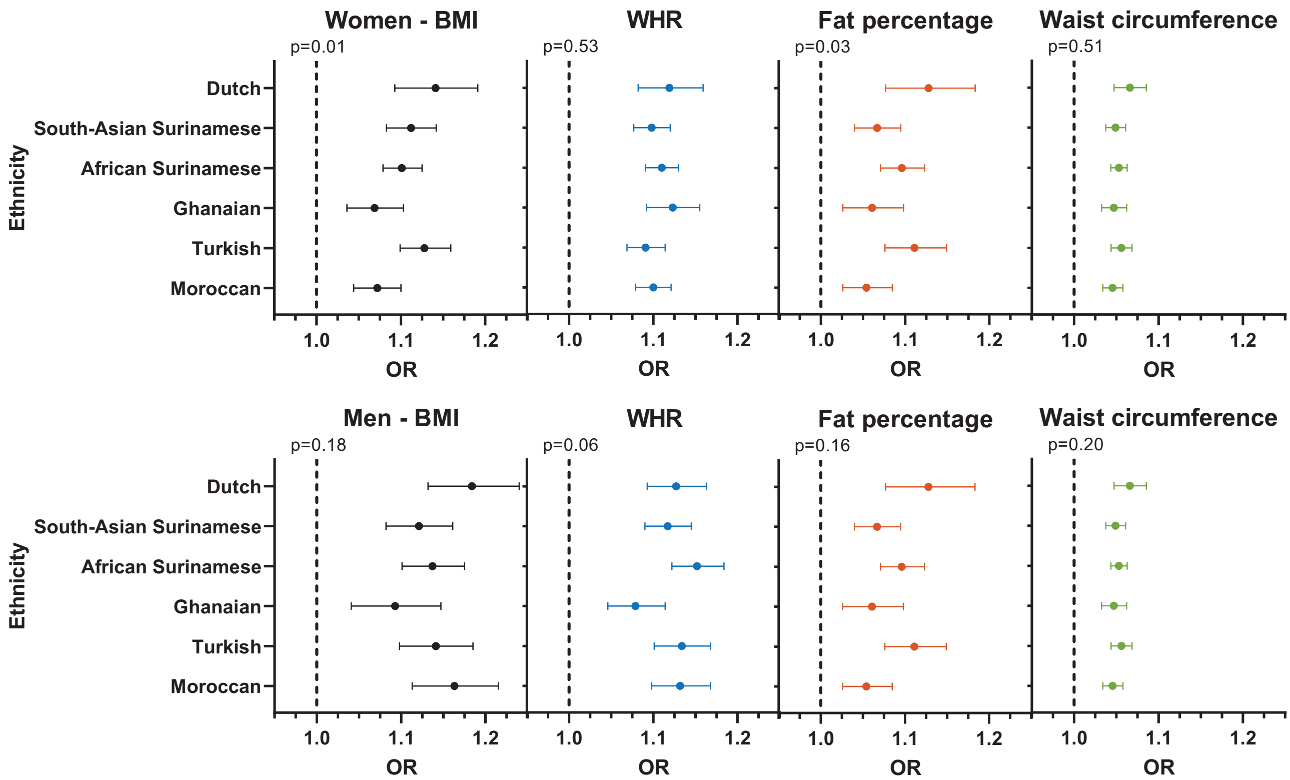

Figure 2—Age-adjusted ORs for the relation between the presence of type 2 diabetes and changes in BMI, WHR, fat percentage, and waist circumference taking the interaction between ethnicity and anthropometric measures into account; WHR was multiplied by 100.

no important ethnic differences in the relation between type 2 diabetes and changes in body composition.

Because there are no important ethnic differences in the associations between changes in body composition and the risk of type 2 diabetes, our results suggest that regardless of ethnic origin, the risk of the development of type 2 diabetes for a given increase in body fat is the same. These findings are supported by a recent publication that used aggregated data from the Multi Ethnic Study in Atherosclerosis (MESA) and the Mediators of Atherosclerosis in South Asians Living in America (MASALA) study showing that the point estimates of the association between different fat deposits are comparable among different ethnic groups (3).

Table 2—OR for the interaction between body composition measures and ethnicity on type 2 diabetes, adjusted for age, the Dutch as reference group, stratified by ethnicity and sex

	BMI		WHR		Fat percentage		Waist circumference	
Ethnicity	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Men								
Overall significance		0.18		0.06		0.16		0.20
Dutch	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
South Asian Surinamese	0.94 (0.89–1.00)	0.05	0.99 (0.95–1.03)	0.65	0.97 (0.93–1.02)	0.24	1.02 (0.96–1.08)	0.52
African Surinamese	0.96 (0.91–1.01)	0.14	1.02 (0.98–1.07)	0.29	0.99 (0.95–1.04)	0.69	0.95 (0.89–1.00)	0.07
Ghanaian	0.92 (0.86–0.98)	0.02	0.96 (0.92–1.00)	0.05	0.94 (0.89–0.99)	0.01	0.96 (0.91–1.02)	0.20
Turkish	0.96 (0.91–1.02)	0.19	1.01 (0.96–1.05)	0.79	0.97 (0.93–1.02)	0.29	0.92 (0.86–0.99)	0.02
Moroccan	0.98 (0.92–1.04)	0.53	1.00 (0.96–1.05)	0.84	0.98 (0.93–1.03)	0.49	0.98 (0.92–1.04)	0.43
Women								
Overall significance		0.01		0.53		0.03		0.51
Dutch	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
South Asian Surinamese	0.98 (0.93–1.03)	0.32	0.98 (0.94–1.02)	0.33	0.95 (0.90–1.00)	0.04	0.98 (0.96–1.01)	0.14
African Surinamese	0.97 (0.92–1.01)	0.15	0.99 (0.95–1.03)	0.67	0.97 (0.92–1.02)	0.29	0.99 (0.97–1.01)	0.23
Ghanaian	0.94 (0.89–0.99)	0.02	1.00 (0.96–1.05)	0.90	0.94 (0.89–1.00)	0.04	0.98 (0.96–1.00)	0.12
Turkish	0.99 (0.94–1.04)	0.66	0.97 (0.94–1.01)	0.21	0.99 (0.93–1.04)	0.61	0.99 (0.97–1.01)	0.38
Moroccan	0.94 (0.89–0.99)	0.01	0.98 (0.94–1.02)	0.37	0.93 (0.88–0.99)	0.02	0.98 (0.96–1.00)	0.07

WHR was multiplied by 100. Ref, reference group.

Although we found similar ORs for the association between the different anthropometric measurements and type 2 diabetes, there was a significant interaction between type 2 diabetes and either BMI or body fat percentage in women of Ghanaian and Moroccan descent. This could point toward ethnic disparities in the relation between type 2 diabetes and BMI and body fat percentage and type 2 diabetes in these women, but may also suggest differences in the distribution of fat and muscle mass. BMI is a reflection of both muscle and fat mass, whereas body fat percentage is susceptible to differences in the amount of visceral and subcutaneous fat. In contrast, the interaction with waist circumference and WHR was consistent among men and women of all ethnic groups in our study, and both measures also had a much smaller individual and ethnic variation compared with BMI and body fat percentage. In line with previous recommendations, our study thereby confirms that waist circumference and WHR may be preferred to estimate cardiometabolic risk, especially in multiethnic populations with large differences in body composition (31).

An important strength of the present population-based study is that different ethnic groups were studied with large disparities in cardiometabolic risk. Additional strengths include the relatively large number of well-characterized participants from six different ethnic groups living in the same geographic environment. Furthermore, we investigated the strength of the interaction between BMI, fat percentage, and WHR in relation to the development of type 2 diabetes between ethnicities instead of comparing the prevalence of type 2 diabetes at a certain value of anthropometric measure. This enabled us to compare the risk of type 2 diabetes that can be attributed to body composition among the ethnic groups.

Limitations of this study included the cross-sectional design, which renders it impossible to make causal inferences on the role of ethnic differences in body composition in the development of diabetes. Anthropometric measurements were performed by trained nurses according to standardized procedures. However, measurements of waist circumference and WHR can be affected by interobserver variations. Finally, body fat percentage was measured using bioelectrical impedance, which is less accurate compared with the gold standard of DEXA. Also, sex- and ethnicity-specific algorithms to convert bioelectrical impedance analysis measurements into estimates of body fat might have improved the performance of body fat as a predictor of type 2 diabetes (32).

Conclusion

Despite large differences in the prevalence of type 2 diabetes between ethnic groups, the association between the different measures of body composition and type 2 diabetes is roughly the same. These results imply that despite the variations in body build that exist among ethnic groups, the risk of type 2 diabetes is similar. Compared with the other measures of body composition, WHR had the highest accuracy and precision in predicting type 2 diabetes across the different ethnic groups. The results of this study further support previous findings that have demonstrated that overweight is an important problem among ethnic minority populations and is likely responsible for most of the discrepancies in type 2 diabetes. The reasons behind the high prevalence of obesity among ethnic minority populations need further exploration to improve programs that are aimed at reducing ethnic disparities in obesity and type 2 diabetes.

Acknowledgments. The authors are grateful to the participants of the HELIUS study and the management team, research nurses, interviewers, research assistants, and other staff who have taken part in gathering the data in this study. Prof. Aeilko H. Zwinderman (Department of Clinical Epidemiology, Biostatistics and Bioinformatics, Amsterdam University Medical Centers, University of Amsterdam) contributed to the statistical analysis of the work.

Funding. The HELIUS study is conducted by the Academic Medical Center (AMC) Amsterdam and the Public Health Services (GGD) of Amsterdam. Both organizations provided core support for HELIUS. The HELIUS study is also funded by the Dutch Heart Foundation, the Netherlands Organization for Health Research and Development (ZonMw), and the European Union Seventh Framework Programme.

Duality of Interest. No potential conflicts of interest relevant to this article were reported.

Author Contributions. M.Z. drafted the manuscript. M.Z., C.M.M., and B.-J.H.v.d.B. contributed to the conception of the work. C.M.M., D.C., H.G., C.A., M.N., D.H.v.R., and B.-J.H.v.d.B. critically revised the manuscript. D.C. and H.G. contributed to the statistical analysis. All authors contributed to the design of the work. B.-J.H.v.d.B. 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.

References

1. Meeks KAC, Freitas-Da-Silva D, Adeyemo A, et al. Disparities in type 2 diabetes prevalence among ethnic minority groups resident in Europe: a systematic review and meta-analysis. Intern Emerg Med 2016;11:327–340
2. Meeks KAC, Stronks K, Beune EJAJ, et al. Prevalence of type 2 diabetes and its association with measures of body composition among African residents in the Netherlands–The HELIUS study. Diabetes Res Clin Pract 2015;110:137–146
3. Flowers E, Lin F, Kandula NR, et al. Body composition and diabetes risk in South Asians: findings From the MASALA and MESA Studies. Diabetes Care 2019;42:946–953
4. Kulick ER, Moon YP, Cheung K, Willey JZ, Sacco RL, Elkind MSV. Racial-ethnic disparities in the association between risk factors and diabetes: the Northern Manhattan Study. Prev Med 2016;83:31–36
5. Goff LM. Ethnicity and Type 2 diabetes in the UK. Diabet Med 2019;36:927–938
6. Bindraban NR, van Valkengoed IGM, Mairuhu G, et al. Prevalence of diabetes mellitus and the performance of a risk score among Hindustani Surinamese, African Surinamese and ethnic Dutch: a cross-sectional population-based study. BMC Public Health 2008;8:271
7. Gregg EW, Cheng YJ, Narayan KMV, Thompson TJ, Williamson DF. The relative contributions of different levels of overweight and obesity to the increased prevalence of diabetes in the United States: 1976-2004. Prev Med 2007;45:348–352
8. McKeigue PM, Pierpoint T, Ferrie JE, Marmot MG. Relationship of glucose intolerance and hyperinsulinaemia to body fat pattern in south Asians and Europeans. Diabetologia 1992;35:785–791
9. Stefan N. Causes, consequences, and treatment of metabolically unhealthy fat distribution. Lancet Diabetes Endocrinol 2020;8:616–627
10. Hardy DS, Stallings DT, Garvin JT, Gachupin FC, Xu H, Racette SB. Anthropometric discriminators of type 2 diabetes among White and Black American adults. J Diabetes 2017;9:296–307
11. Alperet DJ, Lim W-Y, Mok-Kwee Heng D, Ma S, van Dam RM. Optimal anthropometric measures and thresholds to identify undiagnosed type 2 diabetes in three major Asian ethnic groups. Obesity (Silver Spring) 2016;24:2185–2193
12. Rush EC, Goedecke JH, Jennings C, Micklesfield L, Dugas L, Lambert E V, et al. BMI, fat and muscle differences in urban women of five ethnicities from two countries. Int J Obes (Lond) 2007;31:1232–1239
13. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev 2002;3:141–146
14. Ramachandran A, Snehalatha C, Viswanathan V, Viswanathan M, Haffner SM. Risk of noninsulin dependent diabetes mellitus conferred by obesity and central adiposity in different ethnic groups: a comparative analysis between Asian Indians,

Mexican Americans and Whites. Diabetes Res Clin Pract 1997;36:121–125
15. 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
16. World Health Organization. The Asia Pacific Perspective: Redefining Obesity and its Treatment, 2000. World Health Organization Western Pacific Region, International Association for the Study of Obesity & International Obesity Task Force. Accessed 27 January 2021. Available from https://iris.wpro.who.int/bitstream/handle/10665.1/5379/0957708211_eng.pdf
17. Barba C, Cavalli-Sforza T, Cutter J, et al.; WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 2004;363:157–163
18. Alberti KGMM, Zimmet P, Shaw J. Metabolic syndrome–a new world-wide definition. a consensus statement from the International Diabetes Federation. Diabet Med 2006;23:469–480
19. Stronks K, Snijder MB, Peters RJG, Prins M, Schene AH, Zwinderman AH. Unravelling the impact of ethnicity on health in Europe: the HELIUS study. BMC Public Health 2013;13:402
20. Eurostat Statistical books. Migrants in Europe: A statistical portrait of the first and second generation. 2011. Accessed 27 January 2021. Available from: https://ec.europa.eu/eurostat/documents/3217494/5727749/KS-31-10-539-EN.PDF/bcf27a60-7016-4fec-98c5-e8488491ebbd
21. Snijder MB, Galenkamp H, Prins M, et al. Cohort profile: the Healthy Life in an Urban Setting (HELIUS) study in Amsterdam, The Netherlands. BMJ Open 2017;7:e017873
22. World Health Organization. Definition and diagnosis of diabetes mellitus and intermediate hyperglycemia: Report of a WHO/IDF Consultation, 2006. Geneva, Switzerland, 2006
23. Kyle UG, Genton L, Karsegard L, Slosman DO, Pichard C. Single prediction equation for bioelectrical impedance analysis in adults aged 20-94 years. Nutrition 2001;17:248–253
24. Lear SA, Chockalingam A, Kohli S, Richardson CG, Humphries KH. Elevation in cardiovascular disease risk in South Asians is mediated by differences in visceral adipose tissue. Obesity (Silver Spring) 2012;20:1293–1300
25. Eastwood SV, Tillin T, Dehbi H-M, et al. Ethnic differences in associations between fat deposition and incident diabetes and underlying mechanisms: the SABRE study. Obesity (Silver Spring) 2015;23:699–706
26. Bodicoat DH, Gray LJ, Henson J, et al. Body mass index and waist circumference cut-points in multi-ethnic populations from the UK and India: the ADDITION-Leicester, Jaipur heart watch and New Delhi cross-sectional studies. PLoS One 2014;9:e90813
27. Allender S, Scarborough P, Peto V, et al. European Cardiovascular Disease Statistics, 2008 Edition. European Heart Network, 2008. Accessed 27 January 2021. Available from: https://www.bhf.org.uk/informationsupport/publications/statistics/european-cardiovascular-disease-statistics-2008
28. Charles A, van Oeffelen A, Bots M, Stronks K, Vaartjes I. Socioeconomic inequalities in acute myocardial infarction incidence in migrant groups: Has the epidemic arrived? Analysis of nation-wide data. Heart 2014; 100:239–246
29. Khunti K, Hanif W, Karet B, Mughal S, Patel K. A practical approach to managing type 2 diabetes in the UK south Asian population. Diabetes Primary Care 2011;13:47–55
30. Wells JCK. Body composition and susceptibility to type 2 diabetes: an evolutionary perspective. Eur J Clin Nutr 2017;71:881–889
31. Neeland IJ, Turer AT, Ayers CR, et al. Dysfunctional adiposity and the risk of prediabetes and type 2 diabetes in obese adults. JAMA 2012;308:1150–1159
32. Stevens J, Truesdale KP, Cai J, Ou F-S, Reynolds KR, Heymsfield SB. Nationally representative equations that include resistance and reactance for the prediction of percent body fat in Americans. Int J Obes (Lond) 2017;41:1669–1675