Comparison of Anthropometric Characteristics in Predicting the Incidence of Type 2 Diabetes in the EPIC-Potsdam Study

Matthias B. Schulze, drph
Christin Heidemann, msc
Anja Schienkiewitz, mph
Manuela M. Bergmann, phd
Kurt Hoffmann, phd
Heiner Boeing, phd

Obesity is a well-established risk factor for type 2 diabetes (1–3). However, while several studies (4–10) suggest that anthropometric measurements that describe central fat distribution are superior in predicting type 2 diabetes compared with measurements of general adiposity, this issue remains controversial (11–14). The aim of this study was to compare different anthropometric measurements and derived estimates of body composition, in particular BMI, waist-to-height ratio, waist-to-hip ratio (WHR), metric index, and percentage body fat, in their ability to predict risk of type 2 diabetes in a large prospective cohort study of men and women.

RESEARCH DESIGN AND METHODS — The European Prospective Investigation into Cancer and Nutrition (EPIC)-Potsdam study includes 27,548 subjects, 16,644 women aged mainly 35–65 years and 10,904 men aged mainly 40–65 years, from the general population of Potsdam, Germany, recruited between 1994 and 1998 (15). The baseline examination included anthropometric measurements (16,17) as well as a personal interview and a questionnaire on prevalent diseases and sociodemographic and lifestyle characteristics. Follow-up questionnaires have been administered every 2–3 years. Response rates for follow-up rounds 1, 2, 3, and 4 were 96, 95, 91, and 90% (31 August 2005), respectively. All potential incident cases of diabetes were verified by the diagnosing physician using ICD-10.

After exclusion of participants with any history of diabetes at baseline, with self-reported diabetes during follow-up but without physician confirmation, with missing follow-up time, and with missing confounder information and missing information on anthropometric measurements at baseline, 9,711 men and 15,402 women remained for analyses. Informed consent was obtained from all participants of the study, and approval was given by the ethical committee of the state of Brandenburg, Germany.

We estimated the relative risk (RR) for each quintile of anthropometric characteristics compared with the lowest quintile using Cox proportional hazards analysis and compared the predictive power through receiver-operator characteristic curve analysis (18) and through likelihood ratio tests. All statistical analyses were performed with SAS release 9.1 (SAS Institute, Cary, NC).

RESULTS — During 176,780 person-years of follow-up, we observed 849 incident cases of type 2 diabetes (492 men and 357 women). All anthropometric measures, including estimates of body composition, were significantly positively associated with diabetes risk in men and women independent of age and other individual characteristics (Table 1); however, height was inversely associated with risk among men, whereas no significant association was observable among women. The strongest associations of single anthropometric measures were observed for waist circumference (RRs for extreme quintiles: men 11.5 [95% CI 7.19–18.5], women 25.7 [11.3–58.4]), chest depth (men 10.3 [6.33–16.7], women 13.1 [6.88–25.0]), and subscapular skin fold (men 9.47 [6.40–14.0], women 14.9 [8.27–26.8]) and of estimates of body composition for the waist-to-height ratio for both men (31.2 [14.6–66.5]) and women (23.3 [10.2–53.1]).

We calculated receiver-operator characteristic area under the curve to compare different anthropometric measures regarding their predictive power for risk of type 2 diabetes. Among men, differences across anthropometric measures appeared to be rather small, with the waist-to-height ratio having the highest area under the curve (waist-to-height ratio = 0.77, waist = 0.76, BMI = 0.75, and WHR = 0.74). Among women, waist-to-height ratio (0.83) appeared to be similar to waist circumference alone (0.83) but was somewhat better compared with WHR (0.81) and BMI (0.80). Generally, the predictive value of anthropometric measures, in addition to waist circumference, BMI, WHR, or the waist-to-height ratio, measured as changes in receiver-operator characteristic area under the curve were rather small, with the largest changes observed for models that included waist or waist-to-height ratio in addition to BMI or WHR.

Inclusion of metric index, WHR, or percentage body fat, in addition to waist circumference, did improve overall model fit; however, inclusion of BMI did not significantly improve model fit among men, although it did among women. Similarly, models including waist-to-height ratio were significantly improved including

From the Department of Epidemiology, German Institute of Human Nutrition Potsdam-Rehbruecke, Nuthetal, Germany.
Address correspondence to Matthias B. Schulze, German Institute of Human Nutrition Potsdam-Rehbruecke, Department of Epidemiology, Arthur-Scheunert-Allee 114-116, 14558 Nuthetal, Germany. E-mail: mschulze@mail.dife.de.
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Abbreviations: EPIC, European Prospective Investigation into Cancer and Nutrition; WHR, waist-to-hip ratio.
A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.
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Table 1—*Risk* of type 2 diabetes by quintiles of anthropometric measurements and estimates of body composition: the EPIC-Potsdam study*

	Men (n = 9,711)					Women (n = 15,402)				
	Quintiles of anthropometric characteristics					Quintiles of anthropometric characteristics				
	1	2	3	4	5	1	2	3	4	5
Anthropometric measurements										
Weight (kg)	1.00	1.75 (1.13–2.73)	2.83 (1.87–4.27)	3.70 (2.48–5.54)	7.57 (5.17–11.1)	1.00	0.98 (0.52–1.83)	1.65 (0.94–2.87)	2.62 (1.57–4.39)	8.50 (5.29–13.7)
Height (cm)	1.00	0.74 (0.57–0.95)	0.63 (0.48–0.83)	0.72 (0.55–0.94)	0.71 (0.53–0.95)	1.00	0.90 (0.66–1.23)	1.16 (0.86–1.57)	0.84 (0.59–1.18)	1.10 (0.78–1.55)
Waist circumference (cm)	1.00	2.03 (1.18–3.50)	2.91 (1.74–4.87)	5.19 (3.18–8.46)	11.5 (7.19–18.5)	1.00	1.18 (0.43–3.26)	4.88 (2.05–11.6)	5.59 (2.39–13.1)	25.7 (11.3–58.4)
Hip circumference (cm)	1.00	1.38 (0.92–2.05)	2.13 (1.47–3.11)	3.13 (2.20–4.45)	5.36 (3.82–7.53)	1.00	2.03 (1.08–3.81)	2.50 (1.37–4.59)	4.52 (2.56–7.98)	9.67 (5.58–16.7)
Chest depth (cm)	1.00	1.74 (0.99–3.07)	4.46 (2.70–7.37)	5.02 (3.04–8.30)	10.3 (6.33–16.7)	1.00	1.07 (0.47–2.40)	3.00 (1.50–6.03)	4.76 (2.44–9.27)	13.1 (6.88–25.0)
Chest breadth (cm)	1.00	1.68 (1.12–2.50)	2.43 (1.67–3.54)	2.83 (1.95–4.11)	4.52 (3.17–6.43)	1.00	1.23 (0.71–2.14)	2.01 (1.23–3.29)	2.89 (1.81–4.61)	6.01 (3.88–9.31)
Biceps skinfold (cm)	1.00	1.63 (1.12–2.37)	2.01 (1.31–3.10)	3.54 (2.50–5.01)	6.18 (4.40–8.67)	1.00	2.15 (1.20–3.84)	3.00 (1.72–5.25)	4.53 (2.70–7.62)	8.86 (5.35–14.7)
Triceps skinfold (cm)	1.00	1.23 (0.89–1.70)	1.37 (0.97–1.94)	1.87 (1.35–2.58)	2.93 (2.17–3.95)	1.00	1.47 (0.95–2.26)	1.18 (0.73–1.92)	2.07 (1.38–3.11)	4.61 (3.16–6.72)
Subscapular skinfold (cm)	1.00	1.85 (1.17–2.92)	3.47 (2.28–5.29)	4.36 (2.89–6.59)	9.47 (6.40–14.0)	1.00	1.37 (0.65–2.90)	3.20 (1.68–6.08)	7.59 (4.16–13.9)	14.9 (8.27–26.8)
Suprailiac skinfold (cm)	1.00	1.74 (1.18–2.57)	2.20 (1.50–3.23)	3.63 (2.52–5.23)	5.45 (3.83–7.75)	1.00	1.69 (0.85–3.34)	3.21 (1.70–6.06)	5.65 (3.08–10.4)	12.4 (6.86–22.3)
Estimates of body composition										
BMI (kg/m^2)	1.00	2.47 (1.38–4.39)	3.86 (2.23–6.66)	5.95 (3.51–10.1)	14.6 (8.79–24.3)	1.00	1.11 (0.51–2.40)	1.93 (0.97–3.86)	4.12 (2.17–7.83)	11.8 (6.38–21.9)
WHR	1.00	1.67 (1.00–2.77)	2.30 (1.43–3.71)	3.74 (2.38–5.90)	8.56 (5.53–13.3)	1.00	0.58 (0.22–1.51)	2.36 (1.15–4.84)	5.38 (2.77–10.4)	13.7 (7.16–26.1)
Waist-to-height ratio	1.00	5.62 (2.53–12.5)	7.76 (3.55–17.0)	13.8 (6.39–29.7)	31.2 (14.6–66.5)	1.00	0.74 (0.24–2.31)	2.81 (1.15–6.88)	7.12 (3.06–16.6)	23.3 (10.2–53.1)
Metric index	1.00	2.32 (1.23–4.39)	4.75 (2.63–8.58)	7.21 (4.05–12.8)	13.7 (7.76–24.1)	1.00	0.93 (0.38–2.25)	3.11 (1.50–6.43)	4.02 (1.97–8.17)	13.7 (6.94–27.1)
Percentage body fat	1.00	1.64 (1.06–2.56)	2.52 (1.67–3.80)	3.41 (2.28–5.09)	7.49 (5.15–10.9)	1.00	2.76 (1.18–6.43)	4.41 (1.98–9.83)	9.40 (4.34–20.4)	20.2 (9.47–43.2)

Data are RR (95% CI). *Adjusted for age, education (in or no training, vocational training, technical school, or technical college or university degree), occupational activity (light, moderate, or heavy), sport activity (0, 0.1–4.0, or >4.0 h/week), biking (0, 0.1–2.4, 2.5–4.9, or ≥5 h/week), smoking (never, past, current <20 cigarettes/day, or current ≥20 cigarettes/day), and alcohol consumption (0, 0.1–5.0, 5.1–10.0, 10.1–20.0, 20.1–40.0, or >40.0 g/day). Tests for trend were all significant at $P < 0.0001$, except for height among men ($P = 0.009$) and women ($P = 0.78$).

other measures of body fat distribution, except for BMI among men.

CONCLUSIONS— We found that among men and women, waist circumference appeared to be a better predictor than any other single direct measure. Among men, the waist-to-height ratio further improved the predictive power compared with waist circumference. Among women, waist circumference and waist-to-height ratio were similarly predictive and stronger predictors of risk than BMI and WHR.

Several previous cohort studies (4–10,19,20) that compared different anthropometric measurements with regard to diabetes risk prediction suggest that anthropometric measurements that describe central fat distribution, in particular waist circumference, may be superior to measurements of general adiposity. However, other studies (8,11–14) did not confirm these observations. Similar to our study, the waist-to-height ratio was a similar or better predictor compared with other anthropometric measures among Jamaican men and women (19) and Pima Indians (13).

All potential cases in our study were verified through the treating physician, and the remaining misclassification (nonidentified cases) should not have biased the estimated risk (21). Furthermore, we considered only clinically apparent type 2 diabetes. We did not screen our study population for diabetes at baseline; thus, it is possible that prevalent but undiagnosed cases of diabetes remained in our analyses. A further limitation is in regards to a potential surveillance bias. Because obesity is a well-known risk factor for diabetes, obese subjects may be more likely to be tested for diabetes, which would lead to an overestimation of the association between obesity and diabetes risk.

In conclusion, waist circumference was a better predictor of incident diabetes than BMI among women in this German cohort, although no difference was found among men. The waist-to-height ratio was the strongest anthropometric predictor among men. Generally, measurement of anthropometric characteristics beyond waist circumference and height added little predictive information.

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