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Body Size Measurements as Predictors of Type 2 Diabetes in Aboriginal People

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Abstract

OBJECTIVE: To investigate waist circumference, waist-to-hip ratio, body mass index (BMI), weight and hip circumference as risk factors for type 2 diabetes in Aboriginal Australians.

DESIGN: Community-based cross-sectional study.

SUBJECTS: In total, 915 Australian Aboriginal adults (age: 18-74 y) from a remote Aboriginal community in the Northern Territory of Australia.

MEASUREMENTS: Body size measurements included waist circumference, waist-to-hip ratio, BMI, weight and hip circumference. Diabetes status was determined according to medical history and fasting and 2-h postload plasma glucose values. Logistic regression was used to calculate odds ratio for diabetes associated with 1 standard deviation (s.d.) increase in a body size measurement. The areas under the ROC curves of five body size measurements were calculated and compared.

RESULTS: Risk of diabetes increased with increasing levels of body size. ORs (95% CI) for diabetes with adjustment for age and sex were 2.16 (1.75, 2.66), 1.80 (1.49, 2.17), 1.41 (1.17, 1.71), 1.81 (1.51, 2.19) and 1.84 (1.50, 2.24) associated with 1 s.d. increase in waist circumference, BMI, weight, waist-to-hip ratio, and hip circumference, respectively. The area under the ROC curve for waist circumference was significantly higher than those for other measurements.

CONCLUSION: Waist circumference is the best body size measurement in predicting diabetes in Aboriginal people.

Keywords: diabetes; body mass index; waist circumference; weight; waist-to-hip ratio; Aboriginal

Introduction

A number of obesity-related variables are recognized risk factors for type 2 diabetes. Waist circumference and BMI are perhaps the most commonly used measurements. However, few studies have focused on addressing which one is the best predictor in Aboriginal populations. Several studies in non-Aboriginal populations suggested that waist circumference was the best obesity-related predictor of type 2 diabetes.[1, 2] We found that waist circumference predicted the risk of cardiovascular disease better than body mass index (BMI) and waist-to-hip ratio in an Australian Aboriginal population.[3] There is increasing interest in investigating the separate contributions of waist and hip circumferences to diabetes, demonstrating a protective effect of a large hip circumference in non-Aboriginal populations.[4, 5, 6] The cardiovascular risk profile in Aboriginal people is different from that of the general Australian population.[7] Aboriginal people have higher prevalence of smoking, diabetes and hypertension and lower prevalence of abnormal total cholesterol. Characterised by long-leggedness and low sitting height to stature ratio, Aboriginal Australians have different body shapes from other populations.[8]

It is not known which body size measurement is the best predictor of type 2 diabetes in Aboriginal Australians. In this study, we assessed the associations of BMI, weight, waist circumference, hip circumference and waist-hip ratio with type 2 diabetes in Aboriginal people.

Methods

Study population and measurements

A sample of 915 Aboriginal Australians (442 women and 473 men) aged 18–74 y, from a remote community in the Northern Territory of Australia, were examined during 1992–1995. Among them, 514, 399 and 454 were tested by fasting glucose, OGTT and casual glucose tests respectively. A total of 143 participants were identified as having diabetes during the study period. They were either known to be on treatment for diabetes or diagnosed through plasma glucose measurements using the American Diabetes Association (ADA) cutoffs (fasting glucose ≥7.0 mmol/l, 2-h postload glucose ≥11.1 mmol/l or casual glucose ≥11.1 mmol/l).[9]

Waist circumferences were measured at the narrowest point below the ribs or halfway between the lowest rib and iliac crest using a measuring tape. Hip circumferences were measured at the level of the anterior superior iliac spine, where this could be felt, otherwise at the broadest circumference below the waist. Height was measured to the nearest 0.5 cm without shoes using a stadiometer. Weight was measured to the nearest 0.1 kg with participants wearing light clothes only without shoes. BMI was defined as weight divided by height squared (kg/m^2) and waist-to-hip ratio as waist circumference divided by hip circumference.

Statistical methods

All statistical analyses were performed for men and women separately and for the combined group. To compare the strengths of linear relationships of five body size measurements with diabetes, we calculated odds ratios corresponding to one standard deviation increment in each anthropometric measurement using logistic regressions. A receiver operating characteristic (ROC) curve was generated for each measurement. The global performance of each body size measurement in predicting diabetes was summarized by the area under the ROC curve.[10] Areas under ROC curves were compared using the algorithm suggested by Delong *et al.*[11] Confidence intervals that exclude 0.5 were considered to indicate significant results. All analyses were performed using Stata 8.0.[12]

Results

The body size measurements of the participants are shown in Table 1. Men and women were significantly different in all measurements, even after adjusting for age. Women had higher waist and hip circumferences and BMI, while men had higher total body weight and waist-to-hip ratio. Correlations among body size measurements in this population have been reported elsewhere.[3] All measurements were positively correlated with each other except that hip circumference was negatively correlated with waist-to-hip ratios.

With 143 participants identified as having diabetes, the prevalence of diabetes in the study population was 15.6%. Each body size measurement was significantly associated with diabetes as shown in Table 2. The odds ratios for diabetes associated with one standard deviation increase were all significantly higher than non-effect value 1 for all five parameters. The associations remained after adjustment for age in sex-specific groups and for age and sex in the combined group, except the adjusted value for waist-to-hip ratio in men. The point estimate of odds ratio associated with 1 s.d. increase in waist circumference was higher than those of other measurements in both sex groups and the combined group.

Table 1 Body size measurements in Aboriginal participants: mean (s.d.)[a]

	Women	*Men*
Number	442	473
Age (y)	35.6 (13.2)	32.0 (11.7)
Waist circumference (cm)	91.0 (14.6)	86.0 (13.4)
Hip circumference (cm)	98.2 (14.2)	87.8 (12.1)
Weight (kg)	63.0 (16.1)	67.8 (14.6)
Body mass index (kg/m^2)	24.4 (6.0)	23.0 (4.6)
Waist-to-hip ratio, ×100	92.7 (7.4)	98.0 (6.8)

[a]Men and women were significantly different in all body size measurements.

The ROC curves for three commonly used measurements – waist circumference, BMI and waist-to-hip ratio for the combined group – are presented in Figure 1. Waist circumference tended to perform better in terms of sensitivity and specificity. Choosing a cutoff point to achieve the same level of sensitivity, waist circumference gave a better specificity than other measurements. The discriminating values of the body size measurements in identifying diabetes were presented by the areas under the ROC curve in Table 3. All areas under the ROC curve were significantly higher than the noneffect value 0.5. The area under the ROC for waist circumference was larger than those of other measurements in all groups. The differences between the area under the ROC curve for waist circumference and that for each of other body size measurements were tested.[11] All the differences in the combined group were statistically significant.

Odds ratios of BMI, waist-to-hip ratio, weight and hip circumference for diabetes estimated after adjustment for age, sex and waist circumference are shown in Table 4. Point estimates of ORs for BMI, weight and hip circumference were less than the noneffect value 1, while the value for waist-to-hip ratio was greater than one. None of those measurements were significantly associated with diabetes after adjustment of age, sex and waist circumference. However, the association between waist circumference and diabetes remained significant even after adjustment for age, sex and each of the other measurements.

Discussion

This is the first study comparing the accuracy of the five anthropometric variables in Australian Aboriginal people. The logistic regression analysis and the areas under the ROC curves indicate that waist circumference, BMI, waist-to-hip ratio, hips circumference and weight are useful predictors of diabetes in the Aboriginal population. We found that in both men and women, waist circumference was the most significant predictor in both logistic regressions and the ROC analyses. Our results suggest that waist circumference is the best measure for predicting diabetes. This is consistent with findings from previous studies in other populations.[13] Lean *et al*[14] proposed waist circumference as a simple measurement to indicate the need for weight management. Prospective studies have shown that abdominal obesity is a major risk factor for the development of type 2 diabetes. Wei *et al*[1] conducted a 7-y cohort study on Mexican Americans. They found that body weight, BMI, waist and hip circumferences, and waist-to-hip ratio were all positively predictive of type 2 diabetes independent of age and sex. In their multivariate analysis, waist circumference was the only significant predictor of type 2 diabetes in models that included other anthropometric variables either separately or simultaneously.[1] This increased risk can be largely attributed to the fact that a high accumulation of abdominal adipose tissue, especially of visceral adipose tissue, has been associated with glucose intolerance and with hyperinsulinaemia.[15] It was reported in the Hoorn Study that the waist-to-hip ratio and not BMI was an important independent predictor of diabetes.[16] Although most studies use the waist-to-hip ratio for measuring fat distribution,[2] our results from both the logistic regressions and the areas under the ROC curves showed that a simple measurement of waist circumference was a better indicator of diabetes risk than waist-to-hip ratio. Waist circumference has been recognized as a good measure of abdominal fat. Pouliot *et al*[17] found that waist circumference was a better correlate of abdominal visceral adipose tissue accumulation than waist-to-hip ratio. It may also be more sensitive to weight changes due to exercise, diet, smoking and alcohol consumption.[18] A longitudinal study revealed that the change in waist was a better predictor of the change in visceral adipose tissue.[19] A study in Guadeloupean women suggested that waist circumference had a higher discriminant ability than BMI in identifying the presence of diabetes.[13]

Table 2 Odds ratios with 95% CI for diabetes associated with 1 s.d. increase in body size measurements

	Crude OR	*95% CI*		*Adjusted OR*[a]	*95% CI*	
Women						
Waist circumference	2.09	1.61	2.70	1.98	1.51	2.59
Body mass index	1.46	1.16	1.84	1.49	1.17	1.89
Weight	1.49	1.18	1.87	1.50	1.18	1.90
Waist-to-hip ratio	1.65	1.30	2.10	1.52	1.19	1.94
Hip circumference	1.62	1.28	2.06	1.54	1.20	1.98
Men						
Waist circumference	2.76	2.04	3.73	2.34	1.68	3.26
Body mass index	2.33	1.77	3.08	2.30	1.68	3.15
Weight	2.32	1.77	3.05	2.34	1.72	3.19
Waist-to-hip ratio	1.55	1.18	2.04	1.25	0.92	1.70
Hip circumference	2.56	1.90	3.45	2.31	1.67	3.20
Women and men						
Waist circumference	2.32	1.91	2.82	2.16	1.75	2.66
Body mass index	1.76	1.48	2.10	1.80	1.49	2.17
Weight	1.60	1.34	1.91	1.41	1.17	1.71
Waist-to-hip ratio	1.78	1.50	2.12	1.81	1.51	2.19
Hip circumference	1.94	1.61	2.34	1.84	1.50	2.24

[a]Adjusted for age and sex.

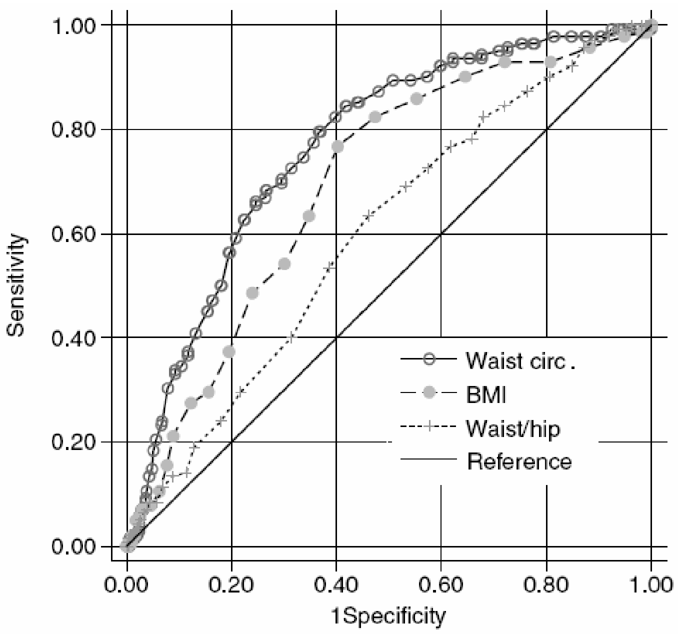

Figure 1. ROC curves for the discrimination of diabetes.

Table 3 Areas under the ROC curve for discriminating diabetes using body size measurements

	Areas under ROC	*95% CI*		*P-value*[a]
Women				
Waist circumference	0.714	0.659	0.769	
Body mass index	0.630	0.570	0.689	<0.0001
Waist-to-hip ratio	0.666	0.603	0.729	0.14
Weight	0.635	0.575	0.696	<0.0001
Hip circumference	0.648	0.591	0.706	<0.0001
Men				
Waist circumference	0.801	0.740	0.863	
Body mass index	0.771	0.710	0.832	0.11
Waist-to-hip ratio	0.625	0.553	0.697	<0.0001
Weight	0.770	0.706	0.834	0.11
Hip circumference	0.776	0.710	0.841	0.041
Men and women				
Waist circumference	0.764	0.724	0.803	
Body mass index	0.696	0.652	0.740	<0.0001
Waist-to-hip ratio	0.599	0.550	0.647	<0.0001
Weight	0.664	0.616	0.712	<0.0001
Hip circumference	0.730	0.689	0.770	0.0015

[a]Compared with the area under ROC curve for waist circumference.

However, our findings are inconsistent with some other studies. Warne *et al*[20] reported that estimates of fat distribution were not significantly better than general estimates of obesity – BMI was the most significant predictor for women in both logistic regression and ROC analyses in Pima Indians. It is not clear whether the inconsistency is due to the variation of the importance of waist circumference in predicting diabetes in different populations.

As in many other studies, waist circumference was highly correlated with weight, BMI, waist-to-hip and hip circumference. They carry similar information about the risk of diabetes. If waist circumference is not available, each of other measurements – BMI, waist-to-hip ratio, weight and hip circumference – is a useful predictor. One previous study using data from different Aboriginal populations showed that elevated BMI was associated with diabetes.[21] However, when waist circumference is available, none of the other four measurements is a major predictor of diabetes.

Table 4 Associations of body size measurements with diabetes after adjustment for age, sex and waist circumference

	Adjusted for age, sex and waist			*For waist*[a]		
	OR	*95% CI*		OR	*95% CI*	
Body mass index	0.84	0.57	1.23	2.56	1.67	3.91
Waist-to-hip ratio	1.13	0.92	1.40	2.10	1.68	2.62
Weight	0.86	0.58	1.28	2.50	1.62	3.85
Hip circumference	0.80	0.53	1.20	2.64	1.72	4.05

[a]Adjusted for age sex and a body size measurement on the row of left column.

There is an increasing interest in investigating the separate contributions of waist and hip circumferences. Using the AusDiab data from the general Australian population, Snijder *et al*[5] found independent and opposite associations of waist and hip circumferences with diabetes. Several earlier studies have demonstrated that a larger waist circumference is associated with increased risk while a large hip circumference is associated with lower risk of diabetes.[4, 6, 22] Our study showed a similar trend. After adjustment for waist circumference, a higher hip circumference was associated with a lower risk of diabetes. However, the independent association did not reach statistical significance. Therefore, the protective effect of large hips in this population remains to be further investigated. It should be noted that without taking waist circumference into consideration, hip circumference is a risk predictor of diabetes. This may be due to the fact that hip circumference carries some information of both overall obesity and abdominal obesity since hip circumference is positively correlated with BMI and waist circumference.

The two widely used measurements waist-to-hip ratio and BMI were independent predictors of type 2 diabetes. However, their predictive abilities disappeared after adjustment for waist circumference. A similar finding was reported in Mexican Americans.[1] Although both health professionals and the general public are familiar with BMI and its acceptable range, most people cannot readily calculate their BMIs. Both BMI and waist-to-hip ratio require two measurements to calculate ratios while waist circumference is only a single measurement. The evidence in this study supports waist circumference as the preferred body size measurement in predicting diabetes in the study population.

One limitation of this study was the use of cross-sectional data to identify predictors of type 2 diabetes. Weight loss resulting from diabetes in some cases could have biased the observed effect estimates of body size measurement on diabetes toward the null effect. Another limitation was that the study sample was not randomly selected from the whole Aboriginal population. Whether the findings can be generalised to other Aboriginal communities remains to be verified. No efforts were made to define waist cutoff points in this study. Lean *et al*[14] suggested that a waist circumference of 94 cm for men and of 80 cm for women should be considered the cutoff for limiting weight gain, whereas 102 cm for men and 88 cm for women should be considered for reducing weight. A nation-wide Australian survey of the prevalence of diabetes, obesity and other cardiovascular risk factors adopted those cutoffs.[23] More Aboriginal people were classified as overweight by the above waist criteria than by BMI criteria.[7] Therefore, health-related cutoffs need to be established for Aboriginal Australians.

In conclusion, waist circumference, BMI, waist-to-hip ratio, weight and hip circumference are associated with diabetes, independent of age and sex. However, waist circumference appears to be the best predictor of diabetes risk in both Aboriginal men and women.

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