Body fat distribution and the risk of non-insulin-dependent diabetes mellitus in the Omani population

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العلاقة بين توزُّع دهنيات الجسم وبين خطر الإصابة بالسكّري غير المعتمد على الإنسولين في المجتمع العُماني

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خلاصة: تمت دراسة القياسات البشرية للسمنة الإجمالية بالجسم والسمنة المركزية باعتبارهما من عوامل التكهن بخطر الإصابة بالسكّري غير المعتمد على الإنسولين. فاستخرجت البيانات الخاصة بأربعة آلاف وسبعمئة وثمانية وعشرين مواطناً عُمانياً من نتائج المسح الوطني للسكّري الذي أجري سنة 1991. وبعد تصحيح البيانات بحسب السن والنوع والتاريخ العائلي للإصابة بالسكّري وممارسة الرياضة وضغط الدم، وجد أن منسب كتلة الجسم كان مقترناً على نحو إيجابي بارتفاع خطر الإصابة بالسكّري. وبعد إجراء التصحيح اللازم إزاء منسب كتلة الجسم وعوامل التشويش المحتملة الأخرى وجد أن نسبة محيط الوسط إلى الأوراك ومحيط الوسط يرتبطان بصورة إيجابية باحتمال الإصابة بالسكري. إن قياس الوسط (وحده أو مع محيط الوركين) هو أداة بسيطة ومستقلة لتقدير خطر الإصابة بالسكّري غير المعتمد على الإنسولين.

ABSTRACT Anthropometric measures of overall and central obesity as predictors of non-insulin-dependent diabetes mellitus (NIDDM) risk were studied. Data for 4728 Omanis were taken from the 1991 National Diabetes Survey. Diabetes mellitus was assessed using a 2-hour post glucose load. After adjusting for age, sex, family history of diabetes, physical activity and blood pressure, body mass index (BMI) was positively associated with increased risk of diabetes mellitus. Controlling for BMI and other potential confounders, waist-to-hip ratio and waist circumference were positively associated with increased risk of diabetes mellitus. Waist measurement (alone or with hip circumference) is a simple and independent tool for assessing the risk of NIDDM.

La répartition des tissus adipeux et le risque de diabète sucré non-insulino-dépendant dans la population omanaise

RESUME Les mesures anthropométriques de l'adiposité générale et centrale comme facteurs prédictifs du risque de diabète sucré non-insulino-dépendant ont fait l'objet d'une étude. Des données pour 4728 Omanais ont été puisées de l'enquête nationale sur le diabète de 1991. Le diabète sucré a été évalué en utilisant l'hyperglycémie provoquée orale avec contrôle deux heures après. Après ajustement en fonction de l'âge, du sexe, des antécédents familiaux de diabète, de l'activité physique et de la tension artérielle, l'indice de masse corporelle (IMC) était associé de manière positive à un risque accru de diabète sucré En contrôlant l'indice de masse corporelle et d'autres facteurs de confusion potentiels, le rapport tour de taille/tour de hanches et tour de taille étaient associés de manière positive à un risque accru de diabète sucré. La mesure du tour de taille (seule ou avec le tour de hanches) constitue un instrument simple et indépendant pour évaluer le risque de diabète non-insulino-dépendant.

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Received: 22/02/98; accepted: 10/05/98

Introduction

Non-insulin-dependent diabetes mellitus (NIDDM) is a major public health problem in Oman. The 1991 National Diabetes Survey, using World Health Organization (WHO) methodology [*1*], showed that 10% of the Omani population over the age of 20 years had diabetes mellitus [*2*]. Furthermore, a similar percentage was shown to have impaired glucose tolerance. Projecting these figures according to the 1993 census, it is estimated that there are more than 60 000 Omanis with overt diabetes mellitus and a similar number with impaired glucose tolerance. Even without an increase in the incidence, the absolute number of people with diabetes mellitus in Oman will increase, due to the increase in the population size. Future projections indicate that there will be about 97 000 people with NIDDM living in Oman by the year 2000 and this figure is expected to increase to 121 000 by the year 2010 [*3*].

Physiological data indicate greater insulin resistance and glucose intolerance among the obese [*4*]; body mass index (BMI) has been found to be a powerful predictor of NIDDM [*5*]. In addition, central obesity has been found to be an important determinant of NIDDM risk. A number of prospective [*6,7*], cross-sectional [*8*] and case–control [*9*] studies suggest that a preponderance of abdominal fat might increase the risk of NIDDM. However, studies on the association of risk factors, especially those related to BMI, waist-to-hip ratio and waist circumference, with diabetes mellitus are scarce for the Arab population and the Arabian peninsula in particular. In this paper, we report on anthropometric measures of overall and central obesity as predictors of NIDDM risk in the Omani population using data from the 1991 National Diabetes Survey.

Materials and methods

Subjects

The National Diabetes Survey was a cross-sectional survey of households, conducted in the period of 1991–1992. More than 4700 people over the age of 20 years were recruited using a multistage cluster sampling scheme [*2*]. Table 1 shows some of the characteristics of the study population. For the purposes of this analysis, pregnant women ($n = 97$) were excluded as their gestational status would bias the anthropometric measurements.

Anthropometric variables

Weight was measured with the person's clothes on, but without footwear. Waist circumference was measured at the lowest point of the costal margins and hip circumference at the widest point of the hips. BMI [weight (kg)/ height^2 (m^2)] was used as an indicator for overweight and obesity and was divided into four categories (BMI < 25 kg/m^2, 25–29.9 kg/m^2, 30–34.9 kg/m^2 and ≥ 35 kg/m^2) [*10,11*]. Waist-to-hip ratio (WHR) and waist circumference were divided into six percentiles (10th, 25th, 50th, 75th, 90th and >90th percentile). The corresponding categories for WHR were < 0.79, 0.79–0.84, 0.84–0.89, 0.89–0.94, 0.94–0.97 and ≥ 0.97 and for the waist circumference were < 68 cm, 68–74.9 cm, 75–83.9 cm, 84–93.9 cm, 94–101.9 cm, ≥ 102 cm respectively.

Confounding variables

Physical activity was dichotomized into active and inactive participation. Inactive subjects were defined as those who do not perform any physical activity or their activity during work or leisure time does not exceed half an hour per week, such as those in clerical jobs. Family history of diabetes was assessed by asking the participants if

Table 1 **Selected characteristics of the study population of the National Diabetes Survey, 1991–1992**

Characteristic	Males		Females		Total	
	No.	%	No.	%	No.	%
Age group (years)						
15–19	15	0.7	4	0.15	19	0.4
20–24	358	17.7	446	16.5	804	17.1
25–29	305	15.1	476	17.7	781	16.6
30–34	247	12.2	382	14.2	629	13.3
35–39	212	10.5	364	13.5	576	12.2
40–44	224	11.1	299	11.1	523	11.1
45–49	202	10.0	213	7.9	415	8.8
50–54	161	8.0	187	6.9	348	7.4
55–59	93	4.6	116	4.3	209	4.4
60–64	105	5.2	113	4.2	218	4.6
65–69	38	1.9	42	1.6	80	1.7
70–74	39	1.9	36	1.3	75	1.6
≥75	22	1.1	17	0.6	39	0.8
Diabetes[a]	188	9.41	267	9.97	455	9.73
Ever smoker	407	20.3	22	0.8	429	9.27
Family history of diabetes	259	12.8	334	12.8	602	12.8
Blood pressure (mmHg)	**Mean**	**±s**	**Mean**	**±s**	**Mean**	**±s**
Systolic	126.9	18.2	127.0	24.46	127.0	22
Diastolic	81.4	19.2	80.7	20.4	80.9	20

[a]*Persons were classified as diabetic using WHO criteria [1]*
s = *standard deviation*

there was anyone in their immediate family (father, mother, siblings and first cousins) with diabetes. Systolic and diastolic blood pressures were recorded in a single reading using a mercury sphygmomanometer, and they were entered as continuous variables.

Diabetes confirmation

All participants were asked to come to a local health centre after fasting and were given an oral glucose tolerance test using 75 g of anhydrous glucose. Diagnosis of diabetes mellitus was confirmed by measuring 2-hour post-load serum glucose. The cut-off value of ≥ 11.1 mmol/L (200 mg/dL) was used to classify subjects as diabetic.

Statistical analysis

Statistical analysis was performed using *Stata* software version 5 (Stata Corporation, College Station, Texas, USA). Univariate and multivariate analysis were carried out using logistic regression to obtain crude and adjusted relative odds, 95% confidence intervals (CI) and *P*-values.

Results

Univariate analysis

Table 2 shows the association of NIDDM with BMI, waist circumference and WHR. Strong positive associations were seen between all measures of obesity and the risk of NIDDM. The lowest risk gradient is seen in model I (BMI < 25 kg/m^2 versus ≥ 35 kg/m^2) giving an odds ratio of 3.5, 95% CI 2.4–4.9. On the other hand, model II for WHR shows the sharpest risk gradient for WHR ≥ 0.97 versus < 0.79, odds ratio = 17.9, 95% CI 7.7–41.3.

Multivariate analysis

Table 3 shows the relative odds derived from models in which adjustments were made for potential confounders of the relation between different measures of obesity and NIDDM. The risk relation between BMI and NIDDM (model IV) remained strong after adjustment for age, sex, physi-

Table 2 **Models of NIDDM odds ratio according to three different anthropometric indices of overall and central obesity: National Diabetes Survey, 1991–1992**

Category	OR (95% CI)	*P*-value
Model I: body mass index (kg/m^2)		
< 25	1.0	
25–29.9	2.3 (1.8–2.9)	< 0.001
30–34.9	3.2 (2.4–4.2)	< 0.001
≥ 35	3.5 (2.4–4.9)	< 0.001
Model II: waist-to-hip ratio		
< 0.79	1.0	
0.79–0.84	5.0 (2.1–11.8)	< 0.001
0.84–0.89	5.7 (2.5–13.2)	< 0.001
0.89–0.94	9.0 (3.9–20.5)	< 0.001
0.94–0.97	13.6 (5.9–31.2)	< 0.001
≥ 0.97	17.9 (7.7 – 41.3)	< 0.001
Model III: waist circumference (cm)		
< 68	1.0	
68–74.9	1.4 (0.6–3.3)	< 0.421
75–83.9	3.3 (1.6–7.0)	< 0.001
84–93.9	5.8 (2.8–12.0)	< 0.001
94–101.9	10.8 (5.2–22.4)	< 0.001
≥ 102	11.4 (5.4–23.8)	< 0.001

NIDDM = non-insulin-dependent diabetes mellitus
OR = odds ratio CI = confidence interval

Table 3 **Multivariate models of NIDDM risk controlling for combinations of anthropometric indices of overall and central obesity and potential confounders: National Diabetes Survey, 1991–1992**

Category	OR (95% CI)	*P*-value
Model IV: body mass index (kg/m^2)		
< 25	1.0	
25–29.9	2.1 (1.6–2.8)	< 0.001
30–34.9	2.8 (2.1–3.9)	< 0.001
≥ 35	3.2 (2.2–4.8)	< 0.001
Model V: body mass index and waist-to-hip ratio		
Body mass index (kg/m^2)		
< 25	1.0	
25–29.9	1.8 (1.3–2.4)	< 0.001
30–34.9	2.3 (1.6–3.2)	< 0.001
≥ 35	2.7 (1.8–4.1)	< 0.001
Waist-to-hip ratio		
< 0.79	1.0	
0.79–0.84	3.9 (1.5–9.7)	0.004
0.84–0.89	3.6 (1.5– 8.9)	0.005
0.89–0.94	4.9 (2.1– 11.9)	< 0.001
0.94–0.97	5.9 (2.4–14.5)	< 0.001
≥ 0.97	5.6 (2.3–14.0)	< 0.001
Model VI: waist circumference		
Body mass index (kg/m^2)		
< 25	1.0	
25–29.9	1.2 (0.9–1.7)	0.191
30–34.9	1.4 (0.9–2.1)	0.155
≥ 35	1.5 (0.95–2.7)	0.074
Waist circumference (cm)		
< 68	1.0	
68–74.9	1.8 (0.7–4.5)	0.217
75–83.9	3.6 (1.6–8.0)	0.003
84–93.9	5.2 (2.3–11.7)	< 0.001
94–101.9	7.7 (3.3–17.9)	< 0.001
≥ 102	6.7 (2.7–16.1)	< 0.001

Confounders in all models include: age, sex, family history of diabetes, physical activity, systolic and diastolic blood pressures
NIDDM = non-insulin-dependent diabetes mellitus
OR = odds ratio CI = confidence interval

cal activity, family history of diabetes and systolic and diastolic blood pressures.

Models V and VI assessed the simultaneous effects of BMI and central obesity measures after controlling for the above-mentioned confounders. The relation of NIDDM and WHR remained highly significant despite adjusting for BMI, with the odds ratios increasing as WHR increased. Model VI shows waist circumference as a highly significant predictor of NIDDM. The significance of BMI was attenuated once data were adjusted simultaneously for WHR (model V) and totally eliminated after adjustment for waist circumference (model VI).

Effect modification

Figures 1 and 2 show prevalence estimates of NIDDM within 4 × 6 cross classifications based on (BMI × WHR) and (BMI × waist circumferance) respectively. Figure 1 shows that for each stratum of BMI (especially at higher BMI categories), the prevalence of NIDDM increased with increasing WHR. Subjects in the highest WHR category had about six times the prevalence of NIDDM compared with subjects of comparable BMI levels in the lowest WHR category. Essentially, a similar relation was seen between waist circumference and NIDDM prevalence, which reached more than 70% for those with a waist circumference of 102 cm or more (Figure 2). A formal test of interaction between BMI and WHR levels and BMI and waist circumference levels gave non-significant *P*-values.

Discussion

Our data support the strong association between BMI, WHR and waist circumference and the risk of NIDDM among the Omani

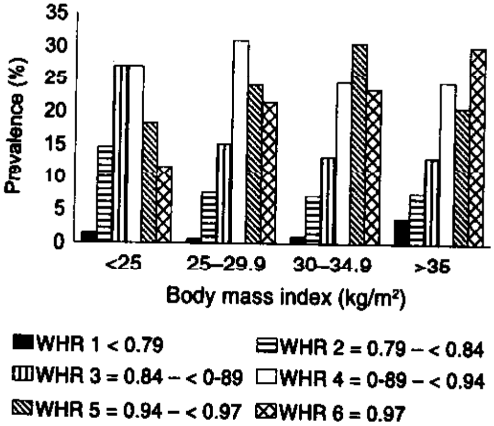

Figure 1 **Prevalence of non-insulin-dependent diabetes mellitus, cross-classified according to body mass index categories (BMI) and waist-to-hip ratio (WHR)**

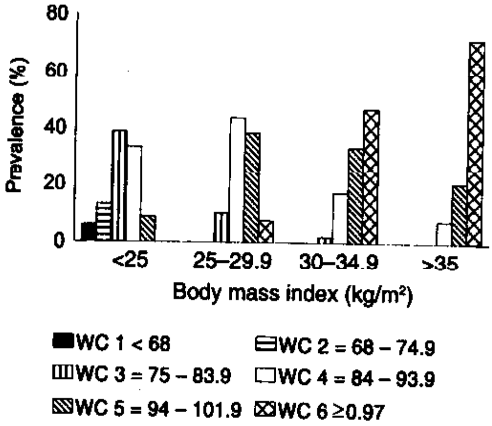

Figure 2 **Prevalence of non-insulin-dependent diabetes mellitus, cross-classified according to body mass index categories (BMI) and waist circumference (WC)**

population after adjustment for several confounders, such as age, sex, physical activity, family history of diabetes and systolic and diastolic blood pressures. Our study also shows that, within different categories of BMI, fat distribution (measured by WHR and waist circumference) was an independent risk factor, with the risk of NIDDM increasing as WHR or waist circumference increased. In our analysis, however, BMI was not a significant independent risk factor once waist circumference was accounted for. This may be due to the higher correlation between waist circumference and BMI ($r = 0.7$; $P < 0.001$) than between WHR and BMI ($r = 0.3$; $P < 0.001$). Other studies have found BMI, WHR and waist circumference all to be independent risk factors for developing NIDDM with the effect of BMI being non-significant at lower cut-off points (BMI ≤ 25 kg/m^2) [*12*].

In line with other studies [*13,14*], our analysis also shows waist circumference to be a stronger predictor of NIDDM than BMI or WHR. This principle could be used in busy clinical settings, where a single measure of waist circumference may suffice for counselling patients about the risk of NIDDM and would avoid the need to measure patients' height, weight or hip circumference to determine BMI or WHR and thus save time for health professionals.

In addition to the association of various anthropometric measures with the risk of NIDDM, our results also show that the prevalence of diabetes mellitus increased with increasing WHR and waist circumference. Similar results on the interaction of BMI, WHR and waist circumference have been found by other researchers [*15*].

Some of the limitations of our analysis are worth noting. First, the study involved all eight administrative regions of Oman. Weight and height measurements were taken using different scales in each region. Interobserver and intraobserver variation were not assessed at the time of the study. This may have led to the possible misclassification of participants. Secondly, ex-smokers were classified as non-smokers and physical activity was dichotomized into active and inactive. A different classification of these covariates might have influenced the main anthropometric measures and made estimation of their significance uncertain.

These data provide strong evidence that measurements of central obesity based on waist circumference and WHR are strong predictors of the risk of NIDDM over and above that of BMI. Body fat distribution seems to be a more important risk factor for NIDDM than overweight *per se*. Free fatty acids (FFAs), derived from the visceral fatty depots, cause insulin resistance in muscles and liver, and increase hepatic gluconeogenesis and lipoprotein production [*16,17*]. It is also suggested that such fractions of FFAs have a low responsiveness to the antilipolytic actions of insulin. Furthermore, they may decrease hepatic clearance of insulin. Together, these alterations cause insulin resistance, which may lead to the development of overt NIDDM.

We conclude that WHR and waist circumference are independent risk factors for the development of NIDDM besides BMI. These measurements could be used by clinicians in counselling patients, with waist circumference being the strongest and simplest predictor of NIDDM risk.

Acknowledgements

We would like to thank Dr Ala'din Alwan, Mr Ahmed Al-Qasimy and Dr Medhat K. El-Sayed for their helpful comments.

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