

Research paper

Is waist circumference a useful screening tool for diabetes mellitus in an overweight multi-ethnic population?

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ABSTRACT

Background Fourteen percent of adults over 60 years may have type two diabetes mellitus, with up to half of these undiagnosed. Screening of high-risk populations is recommended by policymakers, but there is no direct evidence of benefit for those screened. Although abdominal obesity is a recognised risk factor for diabetes, there is controversy regarding its best measure, and its usefulness as a screening measurement is not widely evaluated.

Aim To evaluate the relative performance of waist circumference, body mass index, age and random capillary blood glucose as measurements within a screening programme, in terms of the number of screening tests and diagnostic tests carried out (costs), and the number of cases diagnosed (outcome).

Methods Using national pilot data the study population ($n = 4343$) comprising those eligible for screening (age ≥ 40 years, body mass index ≥ 25 kg/m², no pre-existing diabetes or cardiovascular disease) is described. Threshold analyses by the key variables are displayed in terms of numbers needed

to screen and test per new case. Receiver operating characteristic curve analysis evaluates their usefulness as screening measurements in this context.

Results The area under the curve for waist circumference is 63.4% compared to 61.5% for body mass index and 60.9% for age; with overlapping confidence intervals. Random capillary blood glucose of levels over 6 mmol/l have a significantly greater area under the curve of 73.2%. This difference becomes insignificant when analysed by sex.

Discussion The theoretical advantage of waist circumference over body mass index as a screening measurement is not demonstrated in a real-life screening programme. If, in addition to age, another measure to select and define a high-risk population for screening is required, body mass index is recommended. Direct blood glucose measurement remains the most effective screening tool.

Keywords: diabetes mellitus, waist circumference, screening

How this fits in with quality in primary care

What do we know?

- Clinical guidelines suggest that patients with risk factors for diabetes benefit from screening, but the best way of identifying high-risk patients is uncertain.
- Abdominal obesity is a risk factor for diabetes.
- Of the measures of abdominal obesity, waist circumference is the best predictor of diabetic risk that can be measured routinely in primary care.

What does this paper add?

- The theoretical advantage of waist circumference over body mass index is not demonstrated in a real-life screening programme.
- In selecting a high-risk population for systematic screening, body mass index is probably more practical than waist circumference.
- The impact of varying key parameters in screening inclusion criteria is demonstrated and is useful to estimate potential impact and relative cost-effectiveness of future programmes.

Introduction

The prevalence of undiagnosed type two diabetes mellitus (DM) has been estimated to be between 25% and 100% of that which is diagnosed,^{1,2} suggesting that up to 14% of adults over the age of 60 years may have the condition.³ Systematic screening of high-risk populations is recommended by key organisations,^{4,5} and in the *National Service Framework for Diabetes*,⁶ though the vast majority of DM is currently diagnosed opportunistically. Systematic screening is only widely performed in the UK as part of routine monitoring of patients with cardiovascular disease.

Central or abdominal obesity as a risk factor for DM is well documented.^{7,8} Even after adjusting for body mass index (BMI), the waist-to-hip ratio is positively associated with hyperglycaemia.⁹ Of the several indices used to measure central obesity, a growing body of evidence suggests waist circumference (WC) is the most accurate,^{10,11} and also the best measure in the prediction of diabetic risk,¹² although it has been difficult to quantify in terms of a threshold to apply.¹³ Predictive value is also likely to vary according to ethnicity and sex.^{14,15}

However, little is known about the usefulness of WC as a screening measurement, either as an individual tool, or as an adjunct, used to improve the effectiveness or cost-effectiveness of the programme. Studies so far have produced equivocal results in all but the most obese.¹⁶

In every screening programme, there is a trade-off between sensitivity (and therefore benefit) and specificity (and therefore cost, in terms of subsequent diagnostic testing of those without the condition). The ideal screening programme would use both sensitive and specific measures. We aim to evaluate the relative performance of four potential screening measurements: WC, BMI, age and plasma glucose, in terms of the number of screening and diagnostic tests carried out (costs), and the number of cases diagnosed (benefit or outcome). This will assist clinicians and policy-makers, in estimating the cost-effectiveness of different strategies, and therefore in designing future programmes.

Methods

We used data from the National Screening Committee Diabetes, Heart Disease and Stroke Prevention Pilot Project.¹⁷ This was set up in October 2003, to study the identification and screening of high-risk individuals in relatively high-prevalence, multi-ethnic areas, within primary care.

Pilot practices were funded to provide a cardiovascular risk assessment to all their practice population over 40 years old. Overweight subjects (defined by $BMI \geq 25 \text{ kg/m}^2$) were to be offered diabetic screening and diagnostic testing as appropriate. During screening, additional demographic and anthropometric data were collected, including WC, sex, smoking status and self-reported ethnicity. Twenty general practices from seven primary care trusts submitted data on 16 795 patients over a two-year screening period.

The pilot protocol suggested diabetic screening only for patients who were overweight ($BMI \geq 25 \text{ kg/m}^2$) and over 40 years old without pre-existing DM, using a random capillary blood glucose (RCBG) as a screening tool, and offering diagnostic testing for those whose RCBG was $\geq 6 \text{ mmol/l}$, using a fasting plasma glucose or a standard oral glucose tolerance test, with a confirmatory second test where appropriate. Those with pre-existing cardiovascular disease were assumed to have been screened for DM during routine care for that condition, and were excluded from analysis.

Complete data were only available for those eligible for diabetic screening within the pilot, hence this study population had the following inclusion criteria:

- at least 40 years old at the end of the pilot (December 2005)
- no known pre-existing diabetes
- no known pre-existing cardiovascular disease
- a $BMI \geq 25 \text{ kg/m}^2$
- a known waist circumference in centimetres
- a known screening test (RCBG) result in millimoles per litre.

In order to identify potential bias arising from selecting a subset of individuals with complete data,

the study sample was compared to the remainder of the screened population in terms of age, sex, smoking status, diabetic family history and ethnicity.

The data were analysed using SPSS version 12. New cases of DM were defined by diagnostic test results using WHO criteria.¹⁸ Mean WC of newly diagnosed DM was compared to those not newly diagnosed, using an independent samples *t* test. In order to assess the potential impact of varying the WC used in selection of the sample to be screened, the selected dataset was banded into 5 cm WC intervals and analysed according to:

- the number of patients who would require screening at each interval (those who fitted the study inclusion criteria on whom we have valid data)
- the number of patients who would require diagnostic testing at each interval (those with a positive screening test)
- the number of new cases of DM (who also have a positive screening test).

Results are displayed in cumulative bands with calculation of the numbers needed to screen and test per new case of DM at each band. This analysis was also carried out at different thresholds of BMI (≥ 25 kg/m²), age (≥ 40 years) and RCBG result (≥ 6 mmol/l). To assess the potential usefulness of each of the four potential screening measurements in the subsequent diagnosis of DM, we generated receiver operating characteristic (ROC) curves and used the area under the curve as a comparative measure of predictive performance for all those who received a diagnostic test. This analysis was repeated separately in males and females, because conventionally different thresholds for abdominal obesity have been defined for both. We wished to explore whether there was any additional value in allowing for different thresholds, between men and women for this or the other measures used.

Results

Description of study sample

From the total pilot dataset ($n = 16\,795$), Tables 1 and 2 detail the study sample ($n = 4343$) consisting of patients invited for, and subsequently attending diabetic screening, with the specified inclusion criteria, and about whom we have valid data. There were 163 newly diagnosed cases of diabetes giving an unadjusted prevalence of undiagnosed DM of 3.75%.

Information regarding additional variables (sex, smoking, diabetic family history and ethnicity) was 95–100% complete, compared to 22–80% in the remainder of the pilot population. Unadjusted for missing data, patients in our study were more likely:

- to be younger (mean difference 4 years)
- to be a non-smoker (approximately 3% difference)
- to have a first-degree relative with DM (approximately 8% difference)
- not to be of Pakistani ethnicity (13% difference); however most patients in both groups were white.

Differential analysis of varying key measurements

Thresholds

The mean WC of those with newly diagnosed diabetes was 100.6 cm compared to 92.8 cm in those without new DM. The difference of 7.8 cm was highly significant ($P < 0.001$). The impact of varying WC, BMI, age and RCBG thresholds is shown in Table 3. It is the RCBG result which forms the basis of going on to have a diagnostic test; therefore the impact of the choice of threshold on the number to be screened, and to be tested is the same.

Hence, if only patients with WC equal to or greater than 80 cm had been screened, there would have been 508 fewer patients to screen (3835 rather than 4343,

Table 1 Description of study sample ($n=4343$): continuous variables

Variable	Range	Mean	Standard deviation	Notes
Age (years)	40–96	57.4	11.26	
BMI (kg/m ²)	25.0–57.5	29.9	4.24	
Waist circumference (cm)	59–199	93.1	12.27	
Screening test (mmol/l)	1.7–27.8	5.9	1.62	<6 mmol/l, $n = 2835$ (65.3%); ≥6 mmol/l, $n = 1508$ (34.7%)

Table 2 Description of study sample ($n = 4343$): categorical variables

Variable	Categories	Number	%
Sex	Male	2033	46.8
	Female	2303	53.0
	No data	7	0.2
Smoking status	Non-smoker	3332	76.7
	Smoker	914	21.0
	No data	97	2.2
Family history of DM	Yes	1839	42.3
	No	2265	52.2
	No data	239	5.5
Ethnicity	White	3257	75.0
	Black (Caribbean)	407	9.4
	Pakistani	169	3.9
	Black (African)	138	3.2
	Indian	93	2.1
	Other	226	5.2
	No data	53	1.2

11.7% reduction), with a consequent 127 fewer diagnostic tests to be done (8.4% reduction). The trade-off for imposing this threshold is a loss of three new cases of DM (1.8% of total cases). At this level, 24 patients need to be screened for each new case of DM, and nine need to be tested, per new case.

Differential analysis of varying key measurements

Areas under the ROC curve

The ROC curve for the combined male and female study population is shown in Figure 1. The area under the curve and hence potential usefulness as a screening measurement is 63.4%, compared to 61.5% for BMI and 60.9% for age. The confidence intervals for all three overlap. RCBG over levels of 6 mmol/l have a significantly greater area of 73.2%. When broken down by sex, these patterns remain consistent though all differences become insignificant. These data are shown in Table 4.

Discussion

Summary of findings

This study shows that in an overweight multi-ethnic population being screened for diabetes, the theoretical advantage of waist circumference in prediction of diabetic risk is not demonstrated when compared to BMI or age. Our results also confirm that direct

measurement of blood glucose (RCBG) is the most effective of the four indices under study. The potential impact of varying WC, BMI, age or RCBG threshold has been clearly demonstrated in terms of numbers needed to screen and test per new case of DM, providing valuable information to clinicians and policy-makers when designing future programmes.

Comment

The pilot collected data from real-life clinical practice. Approaches to screening are likely to have varied from practice to practice, and consequently data analysis required a pragmatic approach. Although inter-observer differences in WC measurement are known to affect its accuracy,¹⁹ the significant difference in mean WC between those newly diagnosed with DM, and those not, suggests that WC measured by nurses or healthcare assistants, in day-to-day practice, has the potential to be predictive.

Strengths and weaknesses

The prevalence of undiagnosed DM of 3.75% is slightly lower than those rates suggested in the literature, probably due to incomplete attendance for screening.

It is more difficult to generalise our specific findings to other populations, since the screened population was not randomly selected (or selected to be representative of the national population), and diagnostic testing was only offered to those identified as at risk (on age and BMI criteria) with an RCBG of 6 mmol/l or over.

Table 3 Impact of varying key thresholds within the screening pilot

	Waist circumference (cm)					BMI (kg/m ²)					Age (years)					RCBG result (mmol/l)				
	≥80	≥85	≥90	≥95	≥100	≥105	≥25	≥27.5	≥30	≥32.5	≥50	≥55	≥60	≥65	≥7	≥7.5				
Total	3835	3259	2543	1806	1155	700	4343	2842	1779	929	3031	2327	1650	*	*	*				
Numbers to have screening test	4343	3835	3259	2543	1806	1155	700	4343	2842	1779	929	3031	2327	1650	*	*				
Numbers to have diagnostic test	1508	1381	1224	1002	743	504	314	1508	1070	721	383	1124	910	675	1027	715				
New DM	163	160	146	135	105	80	57	163	131	100	69	140	119	94	142	122				
Numbers needed to screen (per new case)	27	24	22	19	17	14	12	27	22	18	13	22	20	18	*	*				
Numbers needed to test (per new case)	9	9	8	7	7	6	6	9	8	7	6	8	8	7	7	6				

* As the RCBG was the screening test used, and all those in this study population with results over 6 mmol/l were diagnostically tested, varying the RCBG threshold within this analysis only has meaningful influence upon the numbers of new cases and hence numbers needed to test.

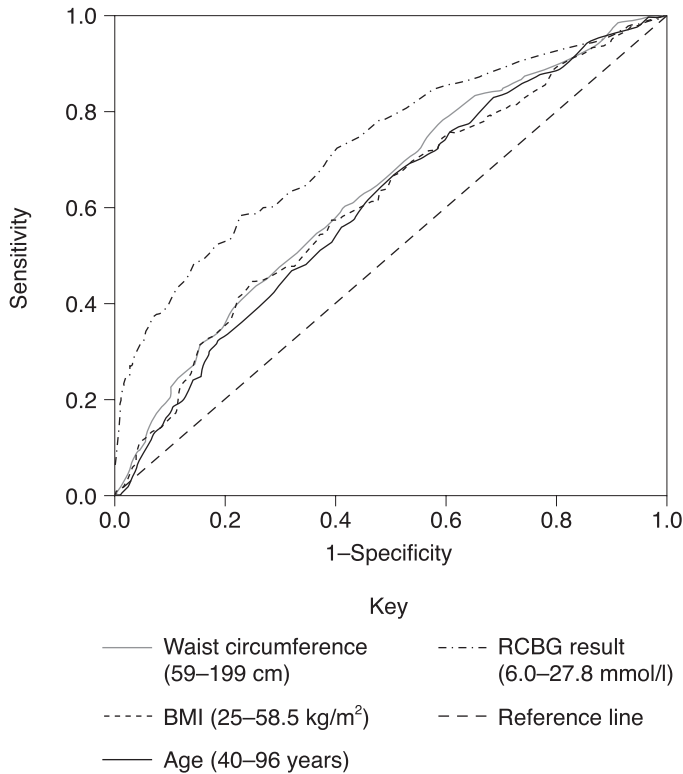


Figure 1 ROC curve in varying key measurements in the detection of new DM

Missing data is a key potential weakness and is more common with data from routine practice than in epidemiological surveys. Of particular note is the low proportion with recorded WC (42.5%) compared to BMI (80.2%). As known WC was a requirement, this considerably reduced our study sample size. WC may be viewed as a more personal and intrusive measurement to take when compared to BMI, with lack of knowledge regarding how to measure it; reluctance to change existing clinical practice; or lack of time and incentive to record additional parameters.

The differences when comparing the study sample with the remainder of the pilot population are likely to reflect selection bias, in which the healthcare professional gathers a more complete dataset on those he deems to be at high risk, or feels more comfortable or inclined to measure the WC of a younger patient or one of white ethnicity, hence leading to inclusion in the study. The consequent relatively low proportion of patients from ethnic minorities (especially South Asians) means that the findings may not be applicable to these populations.

We cannot ascertain true sensitivity as we have no data on the general population. The denominator population is the selected sample with RCBG ≥ 6 mmol/l. Within the study we do not know how many of those with RCBG < 6 mmol/l might have DM, as on the

whole they were not diagnostically tested (according to DHDS protocol). In essence we are assuming 100% sensitivity when the RCBG result is ≥ 6 mmol/l.

In practice, ROC curves are of interest over a small central range, where an optimal threshold can be defined, maximising sensitivity and specificity. The total area under the curve may not be the best measure of effectiveness; however using this, the predictive benefit of WC demonstrated was not statistically significant. Although the literature suggests that the predictive value of WC varies according to sex and ethnicity, when broken down by sex, predictive benefit failed to reach significance. This is either due to real absence of difference, or non-significance through reduced sample size.

Furthermore, the aim of the study was to assess the influence in real-life clinical practice where thresholds are unlikely to be differentially applied. A parallel would be the current use of a BMI over 30 kg/m² to universally define obesity regardless of sex and ethnicity.

Conclusions

As BMI was more completely recorded than WC, and this is likely to reflect normal practice, these results

Table 4 Areas under the ROC curve for key measurements

Test result variable(s)	Combined (<i>n</i> = 1508; 718 male, 789 female, 1 sex missing)		Male (<i>n</i> = 718)		Female (<i>n</i> = 789)	
	Area	95% confidence interval	Area	95% confidence interval	Area	95% confidence interval
Waist circumference (cm)	0.634	0.589–0.678	0.632	0.568–0.695	0.638	0.576–0.700
Observed BMI (kg/m ²)	0.615	0.568–0.661	0.616	0.548–0.684	0.614	0.550–0.677
Age (2006 – year of birth)	0.609	0.565–0.654	0.576	0.510–0.643	0.636	0.576–0.695
RCBG result (mmol/l)	0.732	0.687–0.776	0.759	0.694–0.824	0.711	0.649–0.772

suggest BMI is an appropriate risk marker to use, if an additional measure to age is needed to select a high-risk population for systematic screening.

Further work is needed to practically confirm the theoretical benefit of consistently measured waist circumference as an additional screen for DM before its mandatory inclusion in future programmes can be recommended.

Whilst useful to estimate the cost-effectiveness of future programmes, the data on cumulative thresholds must be considered alongside the cost of screening, and the benefit and cost of early treatment, before the feasibility of future programmes can be fully evaluated. Ideally, future work would seek to estimate a cost per quality-adjusted life year, to allow comparison with competing priorities within the health service.

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CONFLICTS OF INTEREST

None.

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