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Determining the waist circumference that predicts pre-diabetes (insulin resistance) in Eastern Cape Province of South Africa

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Abstract

Background. *In South Africa, type 2 diabetes (T2DM) accounts for 58 deaths per day and is the fifth highest cause of death largely because of the overweight and obesity tsunami that can easily be prevented. Almost 74% of the subjects were either overweight or obese with, over 10% being morbidly obese. On the basis of the close association of abdominal obesity with both waist circumference and insulin resistance, the purpose of this study was to determine the optimal waist circumference that predicts insulin resistance/pre-diabetes) in Eastern Cape Province of South Africa for use in monitoring overweight/obesity in rural and economically disadvantaged communities. Design and methods. Four hundred and fifty one (451) nondiabetic adult subjects attending community health centers in Eastern Cape Province, who had not eaten any breakfast participated in the study. Anthropometric measures were performed under trained supervision. Blood samples were collected for estimation of fasting insulin and fasting blood glucose levels. The following surrogate measures of insulin resistance were used: Homeostasis model assessment of insulin resistance (HOMA-IR) and Quantitative Insulin sensitivity Check Index (QUICKI). Results. The optimal waist circumference cutoff that predicts insulin resistance was ≥ 90 cm for men and ≥ 100 cm for women. The IDF cutoffs are ≥ 94 cm for men and ≥ 80cm for women. The study was a convenience sample consisting of individuals seeking medical attention at a health center. Thus, findings may not be representative of the Eastern Cape Province population. (Perhaps, a stratified random sample of the Province is needed). The limitations, notwithstanding, the significance of the study lies in the fact that we have identified a simple and affordable method (optimal cutoff waist circumference) that Eastern Cape residents can use to monitor and control the propensity to gain weight, and take the necessary steps to forestall the concomitant on set of type 2 diabetes by reducing insulin resistance.*

Keywords: International Diabetes Federation (IDF) body mass index (BMI), waist circumference (WC), insulin resistance (IR), fasting glucose and fasting insulin levels, homeostasis model assessment of insulin resistance (HOMA-IR), quantitative insulin sensitivity Check Index (QUICKI), obesity, diabesity, Youden index, area under the curve (AUC), optimal sensitivity, specificity and diabesity.

Introduction.

The 2005 report by the World Health Organization estimated that the 2% of all deaths worldwide were diabetes-related, WHO (1). Based on global projections T2DM prevalence is expected to double from 285 million in 2010 to 592 million in 2035, WHO (1). Of these estimates sub-Saharan African region is the most affected with South Africa in the lead the lead (Guariguata, et al. (2); where type 2 diabetes (T2DM) accounts for 58 deaths per day and is now the fifth highest cause of death (Pillay, et al 2016 (3). Dominant to this alarming T2DM epidemic is the diabesity (connection of obesity to T2DM) crisis. High adiposity is independently linked to T2DM, (Mbanya et al. (4), Tuei et al. (5), Peer et al. (6), Motala et al. (7). Abdominal obesity as assessed by waist circumference, independent of the overall adiposity in adult population, is a significant predictor of cardiovascular disease and T2DM. Lee et al. (8). Waist circumference independently predicts total and abdominal adiposity as well as metabolic profiles. Lee et al. (8). Waist circumference is an independent predictor of insulin resistance, Lee et al. (8). On the basis of the close association of abdominal obesity with both waist circumference and insulin resistance, the purpose of this study was to determine the waist circumference that predicts insulin resistance (pre-diabetes) in Eastern Cape Province of South Africa. Measuring insulin resistance/pre-diabetes involves collecting blood samples and measuring both insulin and glucose levels, at a cost that is prohibitive for economically disadvantaged communities. Waist circumference measurements are easily affordable in these communities. South Africa is undergoing rapid epidemiological and economic transition and now has the highest prevalence of obesity in sub-Saharan Africa. Sartorius et al. (9). If waist circumference predicts insulin resistance/per-diabetes, health workers can encourage and promote monitoring of one's waist as an important step in preventing onset of type 2 diabetes.

Design and Methods

Patients attending Community Health Centers located in the King Sabata Dalindyebo Municipality and Buffalo City Metropolitan Municipality Districts of the Eastern Cape Province of South Africa were invited to participate in the study. The Walter Sisulu University Ethics Committee and the Buffalo City Metro Health District, Eastern Cape Province approved the study. Only nondiabetic patients (451 in number),who had not eaten breakfast and were above 20 years of age signed, were selected. All of them signed informed consent in this 2013 study. Pregnant women and diagnosed diabetics were excluded from the study. Both demographic and anthropometric data were collected. Weight was measured to the nearest 0.01Kg and height was measured to the nearest 0.01m using a meter rule with subject standing upright against the wall and barefooted without headdress or headgear. Waist circumference was measured using a normal tailoring tape to the nearest 0.5cm, at the level of the umbilicus and the superior iliac crest. The subject was made to stand upright, feet together and arms hanging freely at the sides. The BMI was calculated as weight (kg)/height^2 (m^2). The BMI categories for body weight were based IDF and WHO as follows: underweight <18kg, normal weight, 18-25kg, overweight 25.1 - 30, Class I obesity 30.1 – 35, Class II obesity 35.1 – 40, Class III obesity >40kg.

Serum Insulin levels were estimated using the Enzyme-Linked-Immuno-Assay (ELISA) method with DX-EIA-2935 Insulin kit, 96 wells purchased from AEC-Amersham (PTY) Ltd. Fasting insulin levels are a measure of insulin resistance.

Two validated indices of insulin resistance were utilized, viz., (i) Homeostasis model assessment of insulin resistance (HOMA-IR) = {fasting glucose in mmol/l x fasting insulin in µU/ml}/22.5 and (ii) Quantitative Insulin sensitivity Check Index (QUICKI) = inverse of the sum of fasting glucose plus the log of fasting insulin level as surrogate indices of insulin resistance. QUICKI is among the best surrogate indices in terms of the predictive power for the onset of type 2 diabetes (Gungor et al. 2004(10), Hanley, et al 2003 (11), Katz, et al. 2000 (12). Individuals were considered as insulin resistant when HOMA-IR $\geq$ 2.0, QUICKI $\leq$ 0.330, fasting glucose; and $\geq$ 5.5 mmol/l, and fasting insulin $\geq$ 12.0, McAuley et al. 2001(13), Hettihewa et al. 2006) (14).

Statistical analysis.

Statistical analysis was performed using the SPSS (version 23.0; SPSS, Chicago, IL, USA). Variables (numerical) were expressed as means ± S.D. The Student *t*-test was used in bivariate analysis. Categorical variables were analyzed using the Chi squared. A test was considered significant if $P < 0.05$ or at 95% Confidence Interval.

Results.

Basic characteristics of the subjects

The basic characteristics of the subjects are shown on Table 1.

Table 1. General Characteristics of the Study Population (Mean measurements)

	N	Age (Yrs.)	Body Weight (Kg)	Body Height (cm)	BMI (Kg/m^2)	Waist Circumference (cm)
Total	385	42.3	75.5	163.0	28.7	91.2
Female	282	43.9 ±16.0	78.8 ±18.9	159.7 ±7.0	30.9 ±7.5	95.2 ±17.8
Male	103	37.8 ±15.2	66.3 ±14.2	172.1 ±7.6	22.3 ±4.4	80.5 ±12.0

Table 1 shows that the characteristics of main interest to this study, body weight (kg) and BMI of males and females differ, in that females are heavier than males in both measurements.

Table 2. IDF weight classifications by gender

	Females		Males	
Weight class	N	%	N	%
Underweight	2	0.7	17	16.5
Normal weight	72	25.5	65	63.1
Overweight	66	23.4	14	13.6
Class 1 obese	67	23.8	6	5.8
Class 2 obese	37	13.1	1	1.0
Severely obese	38	13.5	0	0
Total	282	100.0	103	100.0

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Volume 04 Issue 10
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Table 2 shows that among men 20.4% were within the categories of overweight to Class 2 obese, and 63.1% were of normal weight. On the other hand, among females, 73.8% were within the classes from overweight to severely obese, and only 25.5% were of normal weight, with all classifications measured according to IDF criteria. Although the IDF criteria which utilizes BMI is normally used as a measurement of weight classification in general populations, we examine more complex statistics in order to determine a cutoff point of WC which predicts insulin resistance in this population. WC is a measure that is both simpler and easier to use in the context of a rural and disadvantaged geographic areas.

Receiver operating characteristic (ROC) curve analysis

ROC was used to determine optimal cutoffs of waist circumference (WC) that predict insulin resistance using the surrogate indices of HOMA-IR ≥ 2.0 (Hanley, et al. 2003) (10), QUICKI ≤ 0.330 (Katz et al. 2000) (11). The true-positive rate (sensitivity) was plotted against the false-positive rate (1-specificity) to calculate the optimal cutoff values of waist circumference that predict insulin resistance.

Optimal waist circumference cutoffs were determined on the basis of the maximum values of the Youden index (*J*), calculated by [sensitivity + specificity – 1] and the minimum values of the square root of [(1-sensitivity)^2 + (1-specificity)^2, which is the maximum distance from the upper left corner to the point on the ROC curve (15) Medical Biostistics.com www.medicalbiostatistics.com/roccurve.pdf)

WC as predictor of insulin resistance using HOMA-IR as index

For men a single WC (≥ 90cm) had the highest *J* value with a Youden index of .47. The area under the curve (AUC) was .751. (Figure 1). The prediction of insulin resistance at this WC had a sensitivity of 77% and specificity of 30%. This WC ≥ 90cm had the highest diagnostic accuracy and positive predictive value (Sumner, et al. 2008)(16). A WC ≥ 99cm for women, had the highest *J* value with a Youden index of .30. The AUC was .682 (Figure 2). The prediction of insulin resistance at this WC had a sensitivity of 59% and specificity of 29%. The AUC was .682 (Figure 2).

WC as predictor of insulin resistance using QUICKI as index

For men a single WC (≥ 90cm) had the highest *J* value with a Youden index of .42 (Figure 3). The prediction of insulin resistance at this WC had a sensitivity of 75% and specificity of 33%. Thus WC ≥ 90cm had the highest diagnostic accuracy and positive predictive value (Sumner, et al. 2008). The AUC was .757. A single WC ≥ 99cm for women had the highest *J* value with a Youden index of .30 (Figure 4). The prediction of insulin resistance at this WC had a sensitivity of 59% and specificity of 29%. The AUC was .667, (Figure 4).

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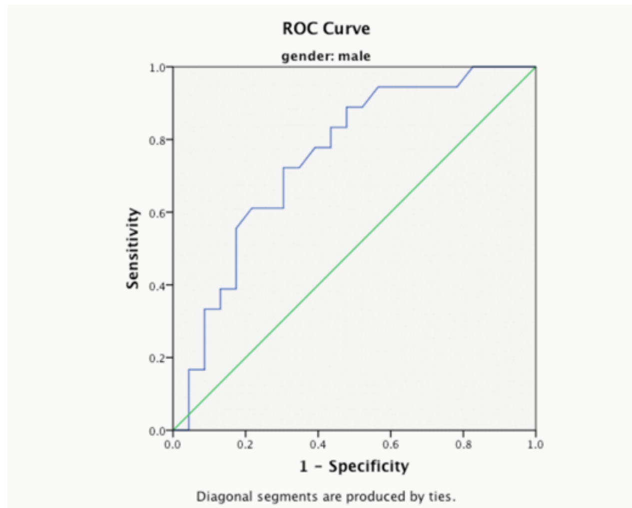
ROC illustrating what WC predicts IR in males using HOMA-IR

WC	Sensitivity	1-specificity
84.75	0.833	0.435
87.00	0.778	0.435
88.25	0.778	0.391
89.25	0.772	0.348
90.00	0.772	0.304
91.25	0.667	0.304
92.50	0.611	0.304
93.25	0.611	0.261
93.75	0.611	0.217
94.25	0.556	0.174



AUC	Sig (p value)	Lower	Upper
.751	.006	.601	.902

Figure 1. ROC curve for waist circumference that predicts insulin resistance in males using HOMA-IR as surrogate index. The area under the curve (95% Confidence Interval) was 0.751 (0.601 – 0.902) and ($p \leq$ 0.006). The optimal waist circumference that predicts insulin resistance in males is ≥ 90cm using HOMA-IR.

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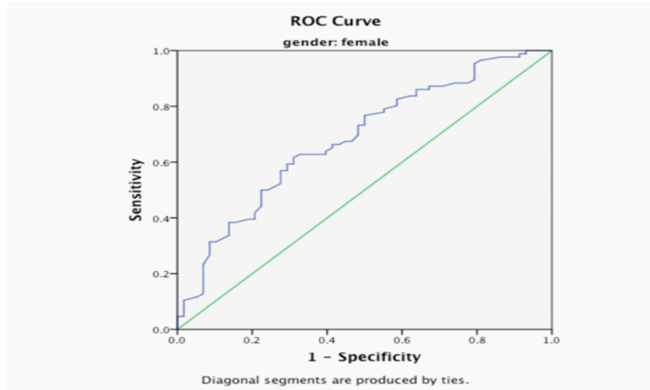
ROC illustrating what WC predicts IR in females using HOMA-IR

WC	Sensitivity	1-Specificity
96.25	0.628	0.397
96.75	0.628	0.379
97.25	0.628	0.362
97.75	0.628	0.345
98.25	0.628	0.328
98.75	0.616	0.310
99.20	0.593	0.310
99.45	0.593	0.293
99.75	0.570	0.293
100.25	0.570	0.276

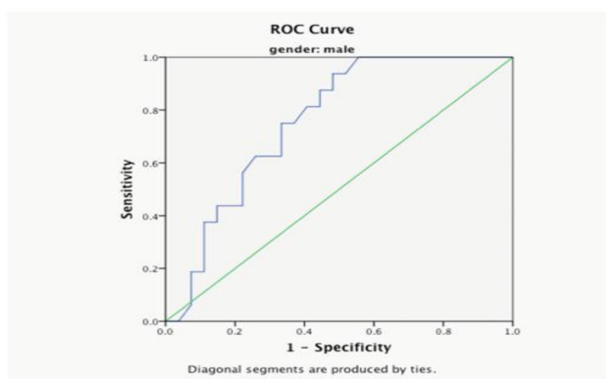


AUC	Sig (p value)	Lower	Upper
.682	.000	.594	.770

Figure 2. ROC curve for waist circumference that predicts insulin resistance in females using HOMA-IR as surrogate indices. The area under the curve (95% Confidence Interval) was 0.682 (0.594 – 0.770) and ($p \leq$ 0.000). The optimal waist circumference that predicts insulin resistance in females is ≥ 99cm using HOMA-IR.

ROC illustrating what WC predicts IR in males using QUICKI

WC	Sensitivity	1-Specificity
84.75	0.875	0.444
87.00	0.813	0.444
88.25	0.813	0.407
89.25	0.750	0.370
90.00	0.750	0.333
91.25	0.688	0.333
92.50	0.625	0.333
93.25	0.625	0.296



AUC	Sig (p value)	Lower	Upper
.757	.005	.615	.899

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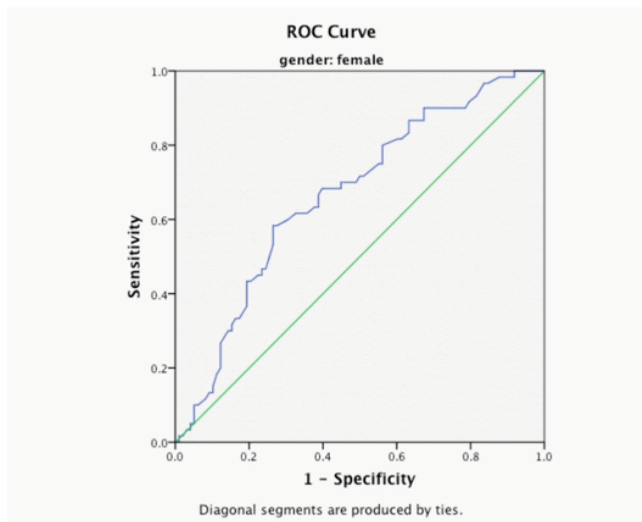
Figure 3. ROC curve for waist circumference that predicts insulin resistance in males using QUCKI as surrogate indices. The area under the curve (95% Confidence Interval) was 0.757 (0.615 – 0.899) and ($p \leq$ 0.005). The optimal waist circumference that predicts insulin resistance in males is ≥ 90cm using QUICKI.

ROC illustrating what WC predicts IR in females using QUICKI

WC	Sensitivity	1-Specificity
100.25	0.617	0.347
100.65	0.617	0.337
100.90	0.617	0.327
101.25	0.600	0.306
101.65	0.583	0.276
101.90	0.583	0.265
102.50	0.533	0.265
103.50	0.500	0.255



AUC	Sig (p value)	Lower	Upper
.667	.000	.581	.753

Figure 4. ROC curve for waist circumference that predicts insulin resistance in females using QUCKI as surrogate index. The area under the curve (95% Confidence Interval was 0.667 (0.581 – 0.753) and ($p \leq 0.000$). The optimal waist circumference that predicts insulin resistance in females is ≥ 101cm using QUICKI.

Discussion.

Our study targeted South Africans of Xhosa descent in Eastern Cape Province of South Africa. We report the optimal cutoff points for waist circumference that predicts insulin resistance/pre-diabetes. The highest value of Youden index obtained for a HOMA-IR cutoff WC for men was ≥ 90 cm, and WC for women ≥ 99 cm. The highest value of Youden index for a QUICKI cutoff WC for men was ≥ 90cm and ≥101cm for women. Both the HOMA-IR and QUICKI estimates for optimal cutoff for men was ≥90 cm.

Combining the HOMA-IR and QUICKI values for women gives a mean optimal cutoff waist circumference of ≥100cm. There is a strong linear relationship between WC and insulin resistance (Tabata, et al 2009) (17). In this study population, overweight and obesity are serious health risk issues that require major attention. Insulin resistance is strongly associated with other components of metabolic syndrome that contribute to making type diabetes deaths number 5 in South Africa. Thus there is great concern with not only early detection of insulin resistance/pre-diabetes but also with other metabolic syndrome in the Eastern Cape Province of South Africa. To determine insulin resistance requires measuring blood/serum insulin and glucose levels. The cost of this is prohibitive in developing countries. However, measuring waist circumference is extremely affordable for individual use and self-monitoring of waist circumference. In this study, we report that for men the waist circumference of 90 cm and above identifies insulin resistance status. For women, the mean waist circumference is 100 cm and above.

Limitations

This study was a convenience sample consisting of individuals seeking medical attention at a health center. The findings may not be representative of the Eastern Cape Province population. Perhaps, a stratified random sample of the entire Province is needed. These limitations, notwithstanding, the study reveals troublesome findings that include the fact that nearly 74% of the 451 subjects were either overweight or obese with 10% being morbidly obese. The significance of the study is that it has identified a simple and affordable method, viz., waist circumference measurement that residents of the Province can use to monitor and control the propensity to gain weight; and take the necessary steps to forestall the concomitant on set of type 2 diabetes by reducing insulin resistance.

Conclusion

Determining waist circumference offers a simple tool to measure insulin resistance and therefore metabolic risk factors. Measuring waist circumference involves a single measurement with no calculation and therefor has reduced potential for error. One's waist can be easily and well measured and monitored, both at home by patients (Rimm et al, 1990) (18) and in clinical practice. Thus, use of HOMA-IR and QUICKI surrogate measures of insulin resistance/pre-diabetes can easily (and cheaply) be substituted with measuring waist circumference. We strongly encourage implementation of health education campaign to inform the public about insulin resistance as a pre-diabetic condition that can easily be controlled by any individual who is determined to forestall onset of type-2 diabetes.

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Contributions. Each author made a significant contribution to the study.

Conflict of Interest: the authors declare no potential conflict of interest

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