An Evaluation of the Diagnostic Utility of Anthropometric and Body Composition cut-off Values in Assessing Elevated Fasting Blood Sugar and Blood Pressure

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ABSTRACT

Objective: *High blood pressure and diabetes mellitus account for over 50% of annual visits to health facilities in Trinidad and Tobago. This study investigates the ability of various absolute and relative body composition variables to predict elevated fasting blood sugar (FBS) and blood pressure (BP).*
Subjects and Methods: *Participants had overnight fasting finger-stick blood glucose analysed with a hand-held automated glucometer (Basic One-touch Ultra). Two blood pressure tests were taken on the right arm after ten minutes of rest in the sitting position using an automated blood pressure (Omron HEM 712C). Participation in the study was voluntary. Waist, height and weight circumferences were measured using standard procedure. Percentage body fat (%BF) was measured with a foot-to-foot bioelectric body fat analyser (Tanita UM026).*
Results: *One hundred and fifty-seven persons (90 females and 67 males) participated in the investigation. Approximately 23% of participants had BP, FBS and waist circumference levels that were above recommended cut-offs. In correlation, analyses controlling for ethnicity and age-adjusted FBS were significantly positively correlated with waist circumference, BMI, weight, fat mass and %BF. Receiver-operator curve analyses suggest that cut-off values based on BMI, waist circumference and waist-height ratio were significant predictors of elevated FBS among females while those based on waist circumference and %BF were significant predictors of elevated FBS among males.*
Conclusion: *The findings suggest similar predictive ability among the various absolute and relative body composition measures in predicting FBS and BP.*

Keywords: Anthropometry, blood pressure, body composition, fasting blood glucose

Evaluación de la Utilidad Diagnóstica de los Valores Límites de Composición Corporal y Antropométrica a la Hora de Evaluar la Glucosa alta en Ayunas y la Presión Sanguínea

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RESUMEN

Objetivo: *La presión arterial alta y diabetes mellitus constituyen la causa de más de 50% de visitas anuales a los centros de salud en Trinidad y Tobago. Este estudio investiga la capacidad de varias variables de composición corporal absolutas y relativas para predecir la glucosa en sangre en ayunas (GSA) y la presión arterial (PA) altas.*
Sujetos y Métodos: *Se analizó la glucosa en sangre de los participantes tras una noche en ayunas mediante punción de la yema del dedo usando un glucómetro automático portable (Basic One Touch Ultra). Se hicieron dos tests de presión arterial en el brazo derecho luego de diez minutos de reposo en posición sentada, usando un monitor de presión arterial de inflado automático Omron HEM-712C. La participación en el estudio fue voluntaria. Las circunferencias de cintura, altura y peso fueron medidas usando procedimientos estándar. Se midió el índice de grasa corporal (IGC) mediante un monitor Tanita UM026 para el análisis bioeléctrico de grasa corporal de pie a pie.*

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Resultados: *Ciento cincuenta y siete personas (90 hembras y 67 varones) participaron en la investigación. Aproximadamente 23% de los participantes tenían PA, GSA, y niveles de circunferencia de cintura por encima de los límites recomendados. En la correlación, los análisis que controlan la etnicidad, y la GSA ajustada por edad, guardaron una correlación significativamente positiva con la circunferencia de cintura, el IMC, el peso, la masa grasa y el IGC. Los análisis de la curva receptor-operador sugieren que los valores límites basados en el IMC, la circunferencia de cintura y el índice cintura/altura fueron predictores significativos de GSA elevada entre las hembras, en tanto que los basados en la circunferencia de cintura y el IGC fueron predictores significativos de GSA elevada entre los varones.*

Conclusión: *Los hallazgos sugieren una capacidad predictiva similar entre las diversas medidas de composición corporal absoluta y relativa a la hora de predecir la GSA y la PA.*

Palabras claves: Antropometría, presión arterial, composición corporal, glucosa en ayunas

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INTRODUCTION

Hypertension, diabetes mellitus and their co-morbid conditions are major contributors to adult illness and death, as well as, hospitalization in the Caribbean region. In Trinidad and Tobago, both conditions are quite prevalent and place tremendous economic burden on healthcare as they account for a large percentage of annual healthcare visits (1–3). The association of these diseases with overweight and obesity are major risk factors which suggest that body composition might be important in their pathogenesis (4). Several anthropometric measures and body composition measures have been used to assess adiposity. These include body mass index, body fat, percentage body fat and waist circumference to name a few. Recent studies suggest that abdominal fat as assessed by waist and waist-to-hip ratio is a better index for predicting the development of diabetes mellitus than measures such as BMI (5, 6). Other studies suggest that the ability of these indicators to predict disease outcome such as diabetes or cardiovascular disease is dependent on age, ethnicity and gender (7–9). There is an urgent need for a quantitative and practical evaluation of the various indices in predicting the risk of diabetes and hypertension in the population. In this study, we investigated the diagnostic utility of standard anthropometric and body composition measurements on fasting blood sugar (FBS) and blood pressure (BP).

SUBJECTS AND METHODS

The study was conducted in Government Ministries in Trinidad and Tobago. The study was confined to four branch offices, one each located in Port-of-Spain, Arima, San Fernando and Tobago. At the initial meeting, the aim and objectives of the study were explained. Those persons who gave both oral and written consent were enrolled in the study. All participants were volunteers. Participants were advised to refrain from eating any foods and drinking any liquids except water after 10:00 pm on the night prior to their FBS measurements. On the day of interview, finger-stick fasting blood glucose (FBS) was measured using blood from the middle finger with a hand-held glucose meter (Basic One Touch Ultra). This device has been shown to have acceptable validity and reliability in measuring blood sugar from serum (10, 11). In fact, the results of multi-centre study showed that the accuracy of blood sugar measurement taken yearly over a four-year period with this device exceeded the International Organization for Standardization (ISO) criteria (12).

Finger-stick blood sugar measurements require only a very small drop of blood and is feasible and reliable under routine clinical conditions (13). Participants were then seated for five to ten minutes and two BP readings were taken two minutes apart with the Omron HEM 712C. This automated blood pressure monitor has met the criteria established for home blood pressure monitoring (14). The Omron HEM 712C device records brachial BP oscillometrically. Systolic and diastolic blood pressure and heart rate are displayed on a LCD read-out. The inflation is performed using a fuzzy-logic electric pumping system and the deflation by an automatic pressure release valve. Adult cuffs which fit both standard and large arm circumferences were used. The subjects were seated in a quiet room and BP measurements started after a 10-minute rest period. Upper mid-arm circumference was measured and the appropriate brachial BP cuff size was placed on the arm as recommended. All measurements were made on the left arm at the level of the heart. The average of two readings was recorded as the BP for the individual. Standard recommended procedures were used for the selection of the position and size of cuffs used (15). Participants then had weight, height and waist circumference measured using standard procedure (16). Percentage body fat (%BF) was estimated using a foot-to foot body fat analyzer (Tanita UMO26) according to the manufacturer's procedure manual. Percentage BF estimated by these monitors for groups are comparable to those estimated by the established gold standards (17–19). All measurements were taken by HC who underwent training sessions to ensure proper technique before and during the data collection phase. The entire study took approximately two months to be completed. Participants then filled out a questionnaire consisting of socio-demographic items. Elevated blood pressure was defined as blood pressure ≥ 130/85 mmHg and elevated fasting blood glucose ≥ 100 mg/dL (20, 21). Body mass index (BMI) was calculated as the weight in kilogram divided by the height in metres squared. Fat mass Index (FM) was calculated as the fat mass in kilogram divided by height in metres squared. Also, fat-free mass index was calculated as the fat-free in kilogram divided by the height in meters squared. Waist-to-height ratio was calculated as the waist circumference in centimetres divided by height in centimetres (22, 23).

Statistical analyses were performed by using SPSS for Windows (version 10; SPSS Inc., Chicago, IL, USA). The t-test was used to determine differences in anthropometric and physiological variables by gender. Correlation analyses were used to assess the strength of the associations between anthropometric and physiological variables of interest. In addition, the sensitivities, specificities and likelihood ratio values were determined for these cut-offs. A positive likelihood ratio > 10 suggests that persons with anthropometric values greater than and equal to the recommended cut-off value are 10 times more likely to have elevated levels of FBS or BP, than a person with anthropometric values below the recommended cut-off value (24, 25).

Receivers operating characteristic (ROC) curves were used to assess the performance of the various recommended anthropometric and body composition cut-off values in detecting elevated fasting blood sugar and blood pressure. Cut-off values of interest were as follows: percentage body fat (% BF) ≥ 25% in males and ≥ 30% in females, BMI ≥ 25 (overweight) and ≥ 30 (obese), waist circumference ≥ 88 cm in females and ≥ 102 cm in males and waist circumference to-height ratio ≥ 0.5 (23, 26, 27). The ROC curve tests the ability of a variable to predict an outcome by plotting sensitivity against 1-specificity. Sensitivity and specificity were computed assuming that each variable was positively related to the FBS and BP. The area under the curve represents the probability of being able to identify an individual with elevated FBS and BP based on established anthropometric and body composition cut-offs. For anthropometric and body composition cut-offs that positively predict elevated FBS and BP, areas under the ROC curve vary from > 0.5 to 1.0 (with 1.0 representing perfect prediction). An area of 0.5 (50% of the AUC) indicates that the recommended anthropometric and body composition cut-off values cannot predict elevated FBS and BP. A value of < 0.5 indicates that the recommended anthropometric and body composition cut-off values negatively predict elevated FBS and BP (28, 29). Age-adjusted FBS was computed as a person's observed FBS *minus* predicted FBS (from the regression of age on FBS) *plus* the mean FBS 87.5 mg/dL for female or 96.6 mg/dL for males). That is, a person's age-adjusted FBS is his residual from the regression of age on FBS *plus* the mean gender-specific FBS.

Table 1 shows the characteristics of participants by gender. Males had significantly higher weight, height, waist circumference, FBS and blood pressure than females. Females had significantly higher adiposity than their male counterparts. Table 2 shows the results of correlation analyses between body composition and anthropometry variables with age-adjusted fasting blood sugar and blood pressure. In correlation, analyses controlling for ethnicity, age-adjusted FBS were significantly positively correlated with waist circumference, BMI, weight, fat mass and %BF. The correlation between waist circumference and adjusted FBS became non-significant after controlling for either, BMI, %BF or Fatmass index. These variables were significantly associated with systolic and diastolic BP among females. Among males, diastolic blood pressure was significantly associated with weight, waist circumference, fat mass and %BF.

Table 1: Characteristics of participants by gender

Variable	**Females n= 90 Mean (SD)**	**Males n = 67 Mean (SD)**	**p-value**
Age (years)	34.0 (11.6)	36.7 (13.2)	0.18
Height (cm)	162.8 (8.2)	176.6 (9.0)	**< 0.01**
Weight (kg)	69.7 (15.6)	84.6 (17.5)	**< 0.01**
Waist circumference (cm)	84.6 (13.2)	95.1 (15.0)	**< 0.01**
Fat mass (kg)	52.9 (24.0)	47.9 (30.0)	0.25
Body fat (%)	33.1 (10.1)	24.5 (12.6)	**< 0.01**
Fat mass index (kg/m^2)	9.1 (4.2)	7.0 (4.5)	**< 0.01**
Body mass index (kg/m^2)	26.3 (6.0)	27.1 (5.4)	0.50
Waist-to-height ratio	0.52 (.09)	0.39 (0.19)	**< 0.01**
Fasting blood sugar (mg/dL)	87.5 (22.2)	96.6 (27.4)	**< 0.05**
Systolic blood pressure (mmHg)	123.1 (19.4)	134.1 (17.3)	**< 0.01**
Diastolic blood pressure (mm Hg)	77.0 (12.0)	81.9 (15.5)	**< 0.05**

SD = standard deviation

Table 2: Correlation coefficients for anthropometric measures with age-adjusted fasting blood sugar and blood pressure

		Females n= 90			**Males n = 67**		
		SBP	DBP	FBS	SBP	DBP	FBS
Height	*r*	0.07	-0.16	-16	-0.09	-0.08	-0.06
	p	0.53	0.14	0.14	0.48	0.54	0.66
Weight	*r*	0.49	0.32	0.26	0.13	0.06	0.30
	p	**< 0.01**	**0.002**	**0.01**	0.27	0.61	**0.01**
Waist circumference	*r*	0.46	0.33	0.34	0.11	0.30	0.28
	p	**< 0.01**	**< 0.01**	**< 0.01**	0.37	**0.01**	**0.02**
Fat mass	*r*	0.57	0.42	0.30	0.09	0.24	0.32
	p	**< 0.01**	**< 0.01**	**< 0.01**	0.50	**0.05**	**< 0.01**
Body Mass Index	*r*	0.52	0.40	0.35	0.18	0.09	0.36
	p	**< 0.01**	**< 0.01**	**< 0.01**	0.16	0.48	**< 0.01**
Fat Mass Index	*r*	0.59	0.46	0.36	0.10	0.24	0.35
	p	**< 0.01**	**< 0.01**	**< 0.01**	0.40	**0.05**	**< 0.01**
Body fat	*r*	0.48	0.38	0.31	0.21	0.33	0.18
	p	**< 0.01**	**< 0.01**	**< 0.01**	0.80	< **0.01**	0.14

SBP = Systolic blood pressure; DBP = Diastolic blood pressure

Waist circumference was significantly associated with weight, per cent body fat, fat mass BMI and FMI in both male confidence interval CI (0.77, 0.80) and females CI (0.68, 0.86). There were no gender differences in the magnitude of the correlation coefficient in these analyses. This relation between waist circumference and fasting blood sugar became non-significant after controlling for adiposity as measured by any of the absolute or relative body composition variables. Results of the diagnostic tests suggest that among females %BF > 30, waist-to-height ratio < 0.5 and BMI > 25 had excellent sensitivities in detecting elevated waist circumference while BF > 30 and BMI > 25 had excellent sensitivities in detecting elevated waist circumference adiposity among males (Table 3). Persons with BMI ≥ 25 were significantly more likely than those with BMI < 25 to have elevated systolic (Odds ratio (OR) = 5.5, 95% (CI): 2.0, 15.0) and diastolic blood pressures (OR = 4.0, 95% CI: 1.4, 11.2). Persons with waist circumferences above the cut-off were significantly more likely than their counterparts with normal waist circumference to have fasting blood sugar ≥ 100 mg/dL (38% vs. 6.5%; $p < 0.001$).

Table 3: Diagnostic ability of absolute and relative body composition measures in detecting the presence of excess visceral adiposity (waist circumference).

	Sensitivity	**Specificity**	**Area under the receiver-operator curve**
% Body Fat (BF)			
Male (BF > 25%)	92 (62, 100)	63 (48, 75)	78 (65, 90)
Female	97 (84, 100)	60 (45, 73)	79 (69, 88)
Waist-to-height ratio (< 0.5)			
Male	69 (39, 90)	72 (58, 83)	70 (55, 87)
Female	100 (88, 100)	66 (51, 78)	83 (75, 92)
Body Mass Index (BMI > 25)			
Male	100 (72, 100)	53 (40, 67)	77 (66, 88)
Female	97 (87, 100)	69 (55, 81)	86 (75, 92)
BMI > 30			
Male	84 (53, 97)	89 (76, 95)	86 (74, 99)
Female	59 (42, 75)	96 (86, 99)	78 (67, 89)

Table 4: Diagnostic utility of various anthropometric and body composition recommended BMI cut-offs in assessing fasting blood sugar (FBS) and blood pressure (BP) by gender

	SEX	**BMI ≥ 25**	**BMI ≥ 30**	**Waist Circumference Male >102 cm Females > 88 cm**	**Waist-Height Ratio < 0.5**	**% body fat Males ≥ 25 Females ≥ 30%**
FBS						
Se	**M**	69 (39, 90)	53 (26, 80)	58 (29, 84)	61 (32, 85)	85 (53, 97)
	F	100 (78, 100)	61 (32, 84)	92 (62, 99)	100 (71, 100)	100 (78, 100)
Sp	**M**	46 (32, 60)	81 (68, 90)	88 (75, 95)	70 (56, 82)	61 (46, 73)
	F	49 (35,58)	79 (68, 87)	68 (55, 77)	45 (34, 57)	42 (31, 54)
AUC	**M**	55 (41, 69)	64 (48, 81)	**71 (54, 89)**	61 (46, 76)	**64 (51, 78)**
	F	**63 (51, 74)**	63 (49, 77)	**65 (53, 77)**	**62 (51, 73)**	69 (46, 91)
+LR	**M**	1.3 (0.8, 2.0)	2.9 (1.4, 6.1)	5.0 (2.0, 12.1)	2.1 (1.1, 3.8)	2.2 (1.4, 3.3)
	F	1.9 (1.5, 2.3)	3.0 (1.6, 5.5)	2.8 (2.0, 4.1)	1.8 (1.5, 2.2)	1.7 (1.4, 2.1)
BP						
Se	**M**	72 (50, 88)	40 (21, 63)	35 (16, 59)	45 (25, 67)	63 (41, 82)
	F	100 (77, 100)	52 (28, 76)	82 (55, 95)	40 (21, 630)	94 (69, 100)
Sp	**M**	51 (36, 66)	82 (67, 91)	86 (71, 94)	68 (53, 81)	60 (44, 74)
	F	49 (37, 61)	79 (68, 87)	68 (56, 79)	82 (67, 91)	43 (31, 55)
AUC	**M**	62 (48, 76)	62 (47,77)	62 (48, 76)	57 (42, 72)	62 (48, 76)
	F	**75 (64, 85)**	**66 (51, 82)**	**66 (51, 82)**	**70 (59, 82)**	**69 (56, 81)**
+LR	**M**	1.6 (1.0, 2.20)	2.3 (1.0, 5.1)	2.5 (1.0, 6.5)	1.4 (0.8, 2.7)	1.6 (1.0, 2.6)
	F	2.0 (1.6, 2.5)	2.6 (1.4, 4.9)	1.7 (1.4, 2.3)	2.0 (1.0, 5.1)	1.7 (1.3, 2.1)

SE = Sensitivity, SP = Specificity, AUC = Area under the receiver operator curve, +LR = Positive Likelihood Ratio

Area under the ROC curve and 95% CI suggest that cut-off values based on BMI > 25, waist circumference and waist-height ratio were significant predictors of elevated FBS among females while waist circumference and %BF were significant predictors of elevated FBS among males. Among females, cut-off values based on all of the anthropometric and body composition variables were better than chance at predicting elevated blood pressure. For males, all of the 95% confidence intervals of AUC for BP based on the cut-off values for the anthropometric indices included 0.5. The 95% confidence intervals for AUC for the various anthropometric and body composition cut-off values suggest that there was significant difference in the predictive ability of the various measures in this group.

DISCUSSION

In this investigation, the ability of established cut-off values based on absolute and relative body fat measurements to predict elevated FBS and BP were gender dependent. Among females, BMI > 25, waist circumference and waist-height ratio were significant predictors of elevated FBS while waist circumference and %BF were significant predictors of elevated FBS in males. These findings suggest that cut-off values based on these relative and absolute body fat measurements may be useful in screening for elevated risk of FBS in this population (30). The findings also point to the need for developing population specific cut-off values based on empirical data (31, 32). The results of ROC analyses among males were notable in which none of the established cut-off values based on absolute and relative body composition measurement were significant predictors of elevated BP. This has been demonstrated in other studies and may reflect the cut-off values in the components of body composition between genders that predict BP (33). This becomes especially important with the clustering of chronic noncommunicable diseases and the increasing probability of metabolic syndrome.

It is important to note that almost all of the absolute and relative measures were significantly correlated with FBS in both males and females. Also, many of the positive likelihood ratios approach 2.0. This reinforces the need to use a variety of diagnostic tests when assessing candidate variables for use in screening. This is also supported by the fact that there was considerable overlap in many of the 95% confidence intervals for the positive likelihood ratios. Also, many of the positive likelihood ratios approach 2.0. Notwithstanding, there were no significant differences in the AUC for the various cut-off values. This suggests that waist circumference might not be superior to other relative and absolute body composition measures in screening for elevated FBS in this population (34–37). In fact, waist circumference was highly related to all of the absolute and relative body composition measures. Moreover, controlling for any of these absolute and relative body composition measures in correlation analyses rendered the association between glucose and waist circumference non-significant. Fat free mass was not significantly associated with fasting blood sugar levels (38). Taken together, these might reflect impaired glucose tolerance with total adiposity rather than regional adiposity. In this study, waist circumference was strongly correlated with BMI in both males (r = 0.7) and females (r = 0.9). Similar correlation coefficient values have been observed in studies using more sophisticated methods of assessing FBS (39, 40).

This study has several limitations. The fact that participation was voluntary precludes generalization of the results to the targeted population. Secondly, the cross-sectional nature of the study suggests that simple cause-effect relations between relative and absolute body composition and FBS and BP cannot be imputed. Thirdly, the sample size might not be representative of the population. Notwithstanding these limitations, the correlation coefficients between absolute and relative measures of body composition and FBS and BP are similar to those observed in studies using more sophisticated measures of these variables. Clearly, there is a need to investigate these associations in a larger and more representative population.

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