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Evaluation of several anthropometric indices of obesity as predictors of metabolic syndrome in Jordanian adults

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Abstract

Introduction: **anthropometric indices have all been tested for their relation to metabolic syndrome (MetS), but with no consistent cut-off points are yet established among different population group.**

Objective: **this study aims to evaluate the predictive power of several anthropometric indices of central obesity as predictors of MetS in a group of Jordanian adults.**

Methods: **in this cross sectional study, 630 adult subjects (308 men and 322 women) aged between 20-70 years were recruited at the King Hussein Medical Center in Amman (Jordan). The diagnosis of MetS was defined by the International Diabetes Federation criteria. Anthropometric measurements (waist circumference [WC]; waist to hip ratio [WHpR]; waist to height ratio [WHtR]; body mass index [BMI]) were performed and recorded following standard procedures. Receiver operating characteristic (ROC) curves were used to determine the efficacy of anthropometric measurements as predictors of MetS.**

Results: **the results indicated that, in men for identifying subjects with MetS risk, area under curve (AUC) from the ROC curves for WC was 0.851, AUC for WHpR was 0.842, AUC for WHtR was 0.85, and AUC for BMI was 0.83. In women, AUC for WC, WHpR, WHtR, and BMI were 0.866, 0.871, 0.872, and 0.831, respectively.**

Conclusion: **it could be concluded that among anthropometric indices, both WHtR and WC had the strongest predictive power for identifying subjects with MetS in men and women. WHtR appears to be the best indicator of central obesity in women and individuals of short stature.**

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Key words: *Metabolic syndrome*. *Anthropometric measurements*. *ROC curves*.

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EVALUACIÓN DE VARIOS ÍNDICES ANTROPOMÉTRICOS DE LA OBESIDAD COMO PREDICTORES DEL SÍNDROME METABÓLICO EN ADULTOS DE JORDANIA

Resumen

Introducción: **han sido probados diversos índices antropométricos por su relación con el síndrome metabólico (SM), pero sin establecer puntos de corte entre diferentes grupos de población.**

Objetivo: **este estudio tiene como objetivo evaluar el poder predictivo de varios índices antropométricos de obesidad central como predictores del síndrome metabólico en un grupo de adultos jordanos.**

Métodos: **en este estudio transversal, 630 sujetos adultos (308 hombres y 322 mujeres) de edades comprendidas entre 20 a 70 años fueron reclutados en el Centro Médico Rey Hussein en Amman (Jordania). El diagnóstico de síndrome metabólico fue definido por los criterios de la Federación Internacional de Diabetes. Las medidas antropométricas (circunferencia de la cintura [WC]; relación cintura-cadera [WHpR]; relación cintura-altura [RCEst]; índice de masa corporal [IMC]) se realizaron y registraron siguiendo los procedimientos estándar. Se utilizaron curvas características del receptor (ROC) para determinar la eficacia de las medidas antropométricas como predictores de SM.**

Resultados: **los resultados indican que, en los hombres, para identificar a los sujetos con riesgo de SM el área bajo la curva (AUC) de la curva ROC para WC era 0.851, AUC para WHpR era 0,842, AUC para RCEst fue de 0,85 y el AUC del IMC fue de 0,83. En las mujeres, el AUC para WC, WHpR, RCEst y el IMC fueron: 0,866, 0,871, 0,872 y 0,831, respectivamente.**

Conclusión: **se puede concluir que entre los índices antropométricos, tanto RCEst como WC tenían el poder predictivo más fuerte para identificar a los sujetos con síndrome metabólico en hombres y mujeres. RCEst parece ser el mejor indicador de la obesidad central en mujeres y personas de baja estatura.**

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Palabras clave: *Síndrome metabólico*. *Medidas antropométricas*. *Curvas ROC*.

Abbreviations

ATP III: Adult Treatment Panel III.
AUC: Area under curve.
BMI: Body mass index.
CDC: Centers for Disease Control and Prevention.
CVD: Cardiovascular diseases.
Diastolic BP: Diastolic Blood Pressure.
FBG: Fasting Blood Glucose.
HDL-C: High Density Lipoprotein Cholesterol.
HOMA: Homeostasis Model Assessment.
IDF: International Diabetes Federation.
J: Youden index.
MetS: metabolic syndrome.
NCEP: National Cholesterol Education Program.
ROC: Receiver operating characteristic.
Systolic BP: Systolic Blood Pressure.
T2DM: Type 2 diabetes mellitus.
TG: Triglycerides.
WC: Waist circumference.
WHO: World Health Organization.
WHpR: waist to hip ratio.
WHtR: waist to height ratio.

Introduction

Metabolic syndrome (MetS) is a cluster of interrelated metabolic risk factors that increase the risk of cardiovascular morbidity and mortality[1-3]. MetS is currently thought to be the underlying major cause of diabetes and cardiovascular disease epidemics worldwide; resulting in premature morbidity and mortality, in addition to increased economic strain on the health systems of most countries[3-5].

There is no universally agreed definition for MetS. Despite the use of the same index for central obesity assessment, the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) and International Diabetes Federation (IDF) differed in the waist circumference (WC) cut-off points. ATPIII proposed WC more than or equals 102 cm for men and more than or equals 88 cm for women, whereas IDF proposed WC cut-off points based on population estimates. Body mass index (BMI), WC, and waist to hip ratio (WHpR) has all been tested for their relation to MetS, but with no consistent results across the globe[1]. Differences in age, sex, and ethnic origin and varying MetS definitions may account for such controversy. Short stature has been shown to be associated with increased MetS risks[6]. Several investigators proposed waist circumference to height ratio (WHtR) as a more sensitive index for the prediction of central obesity and thus MetS[7-9]. It has been documented that WHtR can be used for the identification of metabolic risks even with normal and overweight persons, independent of age, sex, and ethnicity[9]. However, no consistent cut-off points are yet established among different population groups. The description of the nature of body fat distribution has developed over time to express acceptably the ratio of visceral to subcutaneous fat[10], thus reflecting the degree of central obesity present in an individual. These measures of central adiposity included WHpR, BMI, WC, and WHtR[11]. The first definition of MetS by World Health Organization (WHO) used BMI and WHpR. Subsequent definitions relied on WC as a more accurate measure of central obesity for the clinical diagnosis and in various definitions of MetS[11,12]. In subsequent studies, WC was found to be superior to BMI and WHpR as a measure of visceral adiposity, and is widely used to quantify central obesity in clinical practice as it is considered to correlate better with the risk of type 2 diabetes mellitus (T2DM) and cardiovascular diseases (CVD)[13-15]. However, WC has no global standard for it; the cut-off values differ with sex, ethnic origin, and geographic location[9,13].

An association between human heights and MetS risks has been documented[6,16]. Short stature has been associated with increased cardiovascular risks, impaired glucose tolerance and obesity[11,17]. Several studies have shown that WHtR to be superior to BMI, WC, and WHpR in predicting central obesity, cardiovascular risk factors and related health conditions in both men and women[7-9,18-24]. Average WHtR of more than or equals 0.5 can be used for the identification of metabolic risks even with normal and overweight persons[9,25]. A meta-analysis, including data on more than 88,000 subjects from different populations, has shown that WHtR may be a better indicator of metabolic risks than BMI, WC, or WHpR[11]. A study from Jordan, involving 1128 men and 3462 women, also found that WHtR a better predictor of CVD risk factors than BMI, WC, and WHpR[23].

Waist-to-height ratio may reflect visceral fat more accurately than WHpR, since the latter indicator does not reflect visceral fat properly as it may stay the same because WC and hip circumference can increase or decrease proportionately. On the other hand, WHtR will change only when there is a change in waist, as height remains constant in adults[11]. Furthermore, compared with other anthropometric indices, WHpR is more susceptible to measurement errors. However, one study from Iran demonstrated that increased WHpR was a better predictor for CVD risk factors than BMI, WC and WHtR, in all age groups[26].

Studies dealing with WHtR as an index of central obesity in Jordanians are limited. Specificity and sensitivity of WHtR as predictors of MS have not been evaluated. Accepted cut-off points for WHtR have yet to be established. There is still a need to find a simple, practical, specific, and sensitive diagnostic and clinical tool to define those at greater risk of MetS. Therefore, the aims of this study were to evaluate the predictive power of several anthropometric indices of central obesity (WC, WHpR, BMI and WHtR) and the risk factor accumulation as defined by the existence of two or more disorders among hypertension, high triglycerides, low high-density-lipoprotein cholesterol (HDL-C) levels and fasting hyperglycemia; each of which is a component of MetS in an adult Jordanian group.

Methods

Study subjects

This study was carried out in the endocrinology clinics at King Hussein Medical Center (KHMC) in Amman, Jordan. In this study, 630 adult subjects (308 men and 322 women) aged between 20-70 years were recruited from the clinics visitors, their companions, and other volunteers. Pregnant and lactating women, subjects below 20 years or over 70 years of age, women with polycystic ovary syndrome, and subjects with type I diabetes mellitus were excluded. This study was approved by the Institutional Review Board of the Royal Medical Services. Informed consent was obtained from each participant at the start of the study by signing their own information sheets.

Measurements

The diagnosis of MetS was made according to the IDF criteria-2005[27]; subjects were considered to have MetS if WC was ≥ 94 cm for men, and ≥ 80cm for women, plus any two of the following risk factors: 1) TG ≥ 150 mg/dL, 2) HDL-C < 40 mg/dL for men, and < 50 mg/dL for women, 3) blood pressure (BP) ≥ 130 mm Hg systolic BP or ≥ 85 mmHg diastolic BP, and 4) fasting blood glucose (FBG) ≥ 100 mg/dL.

Anthropometric measurements were performed and recorded following standard procedures[28,29]. The following anthropometric classifications were used: 1) BMI: underweight < 18.5 kg/m^2, normal 18.5-25 kg/m^2, overweight 25-29.99 kg/m^2, obese class I 30-34.99 kg/m^2, obese class II 35-39.99 kg/m^2, obese class III ≥ 40 kg/m^2 [30], 2) WHpR: normal < 0.90 for men and < 0.85 for women, or high ≥ 0.90 for men, and ≥ 0.85 for women[30], 3) WC: normal < 94cm for men, and < 80cm for women, or high ≥ 94 cm for men, and ≥ 80cm for women[27], and 4) WHtR: normal < 0.5, or high ≥ 0.5[27].

Blood pressure was measured by a standard mercury sphygmomanometer (Riester, Germany), after seating the subjects for at least 15 min. BP was considered normal if systolic BP < 130 mmHg and diastolic BP < 85 mmHg, or high if systolic BP ≥ 130 mmHg and/or diastolic BP ≥ 85 mmHg[27]. Blood samples were collected after 10-12 hours overnight fasting and serum was obtained for biochemical analysis of blood variables by using standard biochemical kits at Princess Iman Center for Laboratory Research and Science / KHMC. The following laboratory measurements were performed and recorded for each subject and their values were taken in subsequent calculations: FBG; fasting blood insulin (FBI); TG; and HDL-C. The insulin sensitivity was then calculated using Homeostasis Model Assessment (HOMA) according to the following formula: HOMA = FBG (mmol/L) × FBI (μU/ml)/22.5[31].

Statistical analysis

Statistical analyses were performed using Statistical Program for Social Studies (SPSS), version 15 for Windows (SPSS Inc., Chicago, USA). Partial correlations were performed between the study variables and were expressed as correlation coefficients and probabilities, after controlling for age. Receiver operating characteristic (ROC) curves were used to determine the efficacy of anthropometric indices as screening measures for correctly identifying subjects with MetS and to select appropriate cut-off points for variables[32,33]. The optimal cut-off point for each index for men and women was determined using Youden index (J), calculated as: J = maximum (sensitivity + specificity −1)[33]. Levels of statistical significance were set at p-values of < 0.05.

Results

Age, anthropometric, clinical and biochemical indices characteristics by gender for the study group

Table I shows means and standard error of mean of anthropometric and clinical indices by gender for the study group. The age of the study subjects ranged from 20 to 70 years, with a mean age of 43.26 ± 0.54 years (42.19 ± 0.75 in men and 44.28 ± 0.79 in women). Men had significantly (p < 0.05) higher values of weight, height, WC, WHpR, and TG. On the other hand, women had significantly (p < 0.05) higher values of BMI, WHtR, diastolic BP, TC, and HDL-C. Age, systolic BP, FBG, and HOMA index were all not statistically significant between men and women.

Association between anthropometric indices and metabolic syndrome components

Partial correlation coefficients between anthropometric indices and metabolic syndrome risk factors are illustrated in table II. After controlling for age, partial correlation coefficients were significantly correlated (with almost the same value) for WC, WHtR, and WHpR for all MetS components in both men and women. BMI had lower correlation coefficient for MS risk factors in men and had no significant relation to TG in women. HDL-C only showed negative correlations with anthropometric indices, while other parameters revealed positive correlations.

Determining the efficacy and optimal cut-off points of anthropometric, clinical and biochemical indices in identifying subjects with metabolic syndrome

Table III demonstrates optimal cut-off points, AUC, sensitivity, specificity, and P value for identifying metabolic syndrome risk factors. Also, ROC curves of

Table I
Age, anthropometric, clinical and biochemical indices characteristics by gender for the study group

Indices	*Mean ± Standard Error of Mean (SEM)*		
	Men (N=308)	*Women (N=322)*	*Total (N=630)*
Age (Years)	42.19 ± 0.75	44.28 ± 0.79	43.26 ± 0.54
Weight (Kg) ***	90.34 ± 1.16	81.30 ± 1.21	85.72 ± 0.86
Height (cm) ***	172.18 ± 0.35	158.89 ± 0.35	165.38 ± 0.36
WC (cm) **	101.79 ± 0.83	97.76 ± 1.09	99.73 ± 0.70
BMI (Kg/m^2) **	30.40 ± 0.36	32.24 ± 0.47	31.34 ± 0.30
WHpR ***	0.94 ± 0.01	0.85 ± 0.01	0.89 ± 0.00
WHtR **	0.59 ± 0.00	0.62 ± 0.01	0.60 ± 0.00
Systolic BP (mmHg)	132.69 ± 1.73	136.96 ± 1.42	134.87 ± 1.12
Diastolic BP (mmHg) ***	79.58 ± 0.68	83.80 ± 0.61	81.74 ± 0.46
FBG (mg/dl)	124.30 ± 3.39	119.15 ± 3.25	121.67 ± 2.35
FBI (μU/ml)	11.20 ± 0.72	10.43 ± 0.47	10.80 ± 0.43
HDL-C (mg/dl) ***	46.23 ± 0.75	50.66 ± 0.83	48.50 ± 0.57
TG (mg/dl) **	172.45 ± 4.47	153.91 ± 4.96	162.97 ± 3.37
HOMA	0.40 ± 0.02	0.36 ± 0.02	0.38 ± 0.01

*Significant at p-value < 0.05; ** Significant at p-value < 0.01; *** Significant at p-value < 0.001
Results are expressed as mean ± SEM.
WC: Waist Circumference; BMI: Body Mass Index; WHpR: Waist-to-Hip Ratio; WHtR: Waist to Height Ratio; Systolic BP: Systolic Blood Pressure; Diastolic BP: Diastolic Blood Pressure; FBG: Fasting Blood Glucose; HDL-C: High Density Lipoprotein Cholesterol; TG: Triglycerides; HOMA: Homeostasis Model Assessment.
HOMA: Homeostasis Model Assessment, calculated as[31]; FBG (mmol/L) × FBI (μU/ml)/22.5.

anthropometric, clinical and biochemical indices for determining the efficacy in identifying subjects with MetS are shown in Figures 1-4. Regarding men with MS, AUC from the anthropometric indices ROC curves was highest for WC (0.851), followed by WHtR (0.850), WHpR (0.842) and BMI (0.830). Whereas, AUC from the clinical and biochemical indices ROC curves was highest for HDL-C (0.913), followed by FBG (0.869), systolic BP (0.853), diastolic BP (0.842), HOMA (0.841), TG (0.796). As for women with MS, AUC from the anthropometric indices ROC curves was highest for WHtR (0.872), followed by WHpR (0.871), WC (0.866) and BMI (0.831). While, AUC from the clinical and biochemical indices ROC curves was highest for systolic BP (0.930), followed by diastolic BP (0.920), FBG (0.826), TG (0.823), HOMA (0.776), and HDL (0.744).

The optimal cut-off points (*J*) of anthropometric indices, for identifying MetS in this study, were as follows: for WC 98.5 cm in men and 86.7 cm in women, for BMI 28.97 kg/m^2 in men and 30.14 kg/m^2 in women, for WHpR 0.94 in men and 0.86 in women, and for WHtR 0.56 in men and 0.52 in women. On the other hand, the optimal cut-off points (*J*) of clinical and biochemical indices, for identifying MetS, were as follows: for systolic BP 135 mmHg in men and 125 mmHg in women, for diastolic BP 82.5 mmHg both in men and women, for TG 181 mg/dl in men and 143 mg/dl in women, for FBG 102.5 mg/dl in men and 100.5 mg/dl in women, for HDL-C 51.5 mg/dl in men and 49.5 mg/dl in women, for HOMA 2.56 in men and 2.98 in women. Comparisons of the optimal cut-off points for metabolic syndrome risk factors between the current study and international organization's cut-off points are shown in table IV.

Discussion

There is a strong connection between central obesity and MetS risk factors, which led the NCEP/ATP III to define MetS essentially as a clustering of metabolic complications of obesity[1,34,35]. In the IDF definition for MS, central obesity (increased WC) is a pre-requisite criterion in addition to two or more of the other major risk factors[27]. The IDF definition was adopted in this study for identifying subjects with MS and studying the relation between different risk factors.

Different measures of central obesity have been developed over time including WHpR, BMI, WC, and WHtR[10,11]. The first definition of MetS by WHO used BMI and WHpR[30]. The ATPIII used BMI and WC to indicate central obesity[34], whereas the IDF only used WC in their MetS criteria[27]. This disparity in the definition

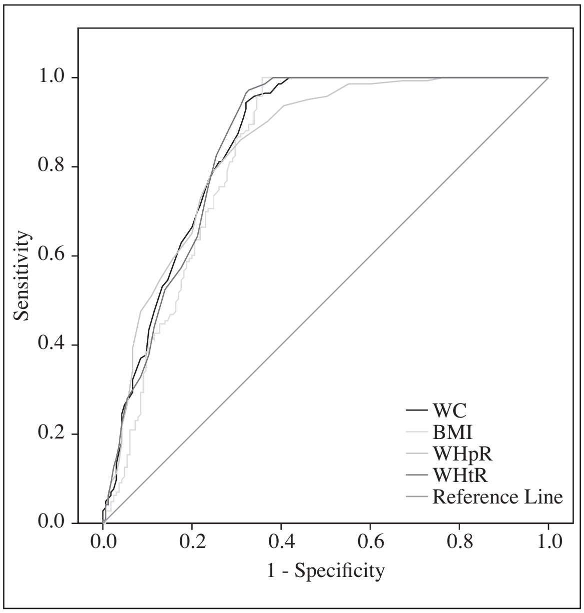

Fig. 1.—Receiver operating characteristic curves of anthropometric indices for identifying subjects with MS in men. WC: Waist Circumference; WHpR: Waist to Hip Ratio; WHtR: Waist to Height Ratio; BMI: Body Mass Index.

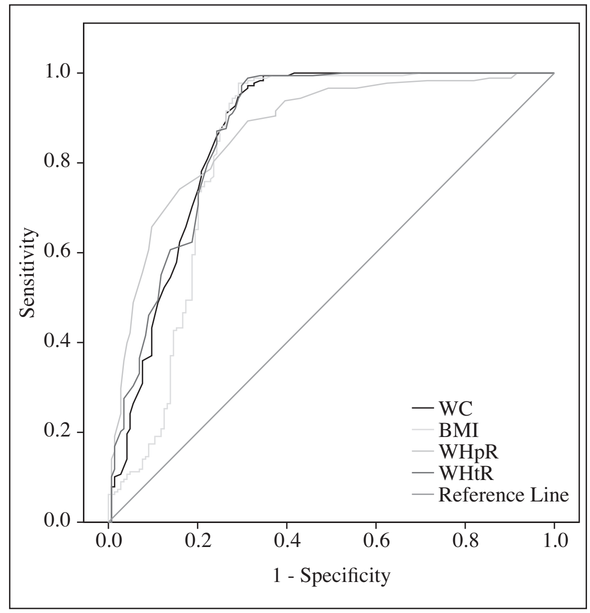

Fig. 2.—Receiver operating characteristic curves of anthropometric indices for identifying subjects with MS in women. WC: Waist Circumference; WHpR: Waist to Hip Ratio; WHtR: Waist to Height Ratio; BMI: Body Mass Index.

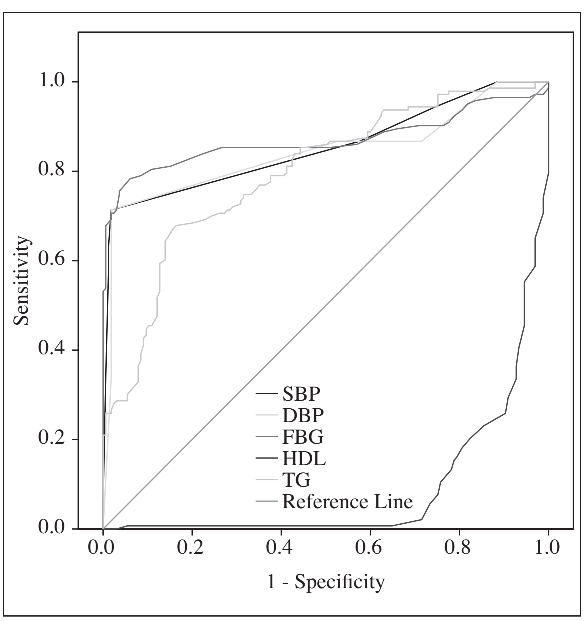

Fig. 3.—Receiver operating characteristic curves of clinical and biochemical indices for identifying subjects with MS in men. SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; FBG: Fasting Blood Glucose; HDL: High Density Lipoprotein; TG: Triglycerides.

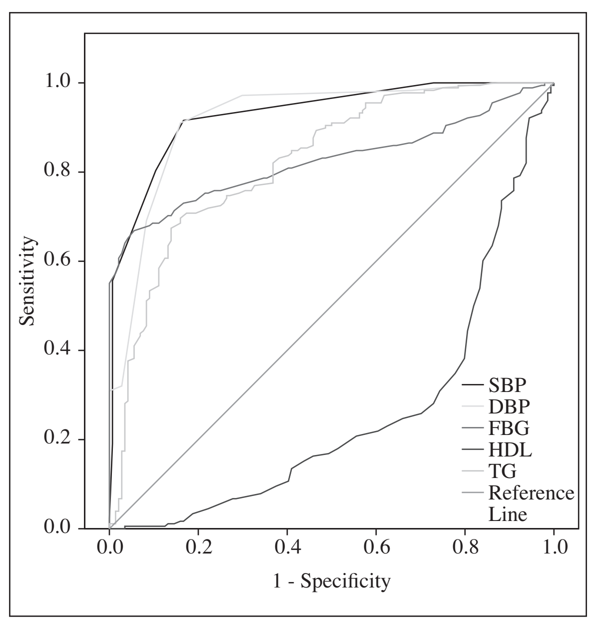

Fig. 4.—Receiver operating characteristic curves of clinical and biochemical indices for identifying subjects with MS in women. SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; FBG: Fasting Blood Glucose; HDL: High Density Lipoprotein; TG: Triglycerides.

of central obesity outlines the lack of a consistent and reliable measure of visceral fat adiposity; necessitating researchers to continue the search for that measure. In the current study, men had significantly ($p<0.05$) higher values of weight, height, WC, and WHpR than women; whereas women had significantly higher values of hip circumference, BMI, and WHtR than men (Table I). This difference in anthropometric indices between men and women may be explained by gender variation in body composition and fat distribution within the body.

After controlling for age, WC, WHtR, and WHpR were significantly ($p<0.05$) correlated (with close va-

Table II
Partial correlation coefficients between anthropometric indices and metabolic syndrome risk factors controlled for age

Indices		Correlation Coefficients (r)			
		WC	BMI	WHpR	WHtR
Systolic BP	Men	0.348***	0.297***	0.358***	0.343***
	Women	0.533***	0.510***	0.460***	0.527***
	Total	0.412***	0.391***	0.329***	0.418***
Diastolic BP	Men	0.372***	0.339***	0.378***	0.372***
	Women	0.640***	0.620***	0.497***	0.635***
	Total	0.465***	0.487***	0.299***	0.507***
FBG	Men	0.359***	0.322***	0.337***	0.333***
	Women	0.286***	0.243***	0.259***	0.304***
	Total	0.322***	0.264***	0.295***	0.298***
HDL-C	Men	-0.556***	-0.566***	-0.501***	-0.535***
	Women	-0.265***	-0.190**	-0.201***	-0.250***
	Total	-0.383***	-0.302***	-0.358***	-0.314***
TG	Men	0.219***	0.248***	0.183**	0.198***
	Women	0.176**	0.079	0.186**	0.182**
	Total	0.220***	0.143***	0.223***	0.186***
HOMA	Men	0.511***	0.515***	0.383***	0.505***
	Women	0.387***	0.369***	0.302***	0.395***
	Total	0.441***	0.413***	0.336***	0.417***

* Significant at p-value < 0.05; ** Significant at p-value < 0.01; *** Significant at p-value < 0.001
WC: Waist Circumference; BMI: Body Mass Index; WHpR: Waist-to-Hip Ratio; WHtR: Waist to Height Ratio; Systolic BP: Systolic Blood Pressure; Diastolic BP: Diastolic Blood Pressure; FBG: Fasting Blood Glucose; HDL-C: High Density Lipoprotein Cholesterol; TG: Triglycerides; HOMA: Homeostasis Model Assessment.

lues) with all MetS components in both men and women, table II. Several studies found that WC was superior to BMI and WHpR as a measure of central obesity, and is considered to correlate better with the risk of T2DM and CVD[13-15,36,37]. In the current study, WC had the highest correlation coefficients compared to other anthropometric indices with FBG in men; and with systolic BP, diastolic BP, and HDL-C in women. Similar findings were reported by other researchers. In a study involving 2183 men and 2698 women aged 20-59 years randomly selected from the Netherlands Civil Registry, Han et al[38] found that all anthropometric indices had a positive correlation with blood pressure, TC, and HDL-C with WC having the highest correlation coefficient. Dobbelsteyn et al[13] also suggested that WC as the best single indicator for all cardiovascular risk factors (hypertension, dyslipidemia, diabetes, smoking and sedentary lifestyle) because of its simplicity and its high correlation with CVD risk factors. In her study, Al-Odat et al[39] reported that WC had the highest correlation with diastolic BP only. In contrast, Esmaillzadeh et al[26] found that WC, albeit significant, had less correlation coefficient than WHpR with MS components in men, but WC was the best indicator of cardiovascular risk factors in Iranian women.

In this study, BMI had the highest correlation compared to other anthropometric indices with HDL-C, TG, and HOMA index in men only. It had a significant positive correlation with other risk factors in both men and women but less than other anthropometric indices. However, it had no significant relation to TG in women. Similar to WC, Esmaillzadeh et al[26] found that BMI, albeit significant, had less correlation coefficient than WHpR with MS components. A meta-analysis found that BMI was the poorest discriminator for CVD risk factors compared to other anthropometric indices[11], with similar conclusions by Al-Odat et al[39] who found that BMI has the weakest correlation coefficients with MS components.

In the present study, WHpR had the highest correlation compared to other anthropometric indices with systolic BP and diastolic BP in men; and with TG in women. Dobbelsteyn et al[13] reported that WHpR had similarly high correlation coefficients with CVD risk factors as those of WC. In their study of adult Iranian men, Esmaillzadeh et al[26] concluded that WHpR is the best indicator for CVD risk factors as it had the highest correlation with FBG, HDL-C, TG, TC, LDL-C, systolic BP and diastolic BP. Al-Odat et al[39], reported that WHpR had the highest correlation with FBG, HDL-C, TG, and systolic BP.

The results of the current study showed that WHtR had the highest correlation compared to other anthropometric indices with FBG and HOMA in women. Although WHtR did not always have the highest correlation coefficient values, it had values very close to those of anthropometric indices with the highest values in each metabolic risk factor in both men and women, table II. These findings are in accordance with the findings of Ho et al[18] who studied the relation between different anthropometric indices and various cardiovascular risk factors. In contrast to the current study, several studies have shown that WHtR to be superior to BMI, WC, and WHpR in predicting central obesity, CVD risk factors in both men and women[7-9,18-24]. A meta-analysis, including data on more than 88,000 subjects, has shown that WHtR may be a better indicator of hypertension, diabetes, and dyslipidemia than BMI, WC, or WHpR in both genders[11]. Similarly, Khader et al[23] from Jordan found that among all anthropometric indices, WHtR had the strongest association with each MetS component in men and women. In another study from Jordan, Al-Odat et al[39] found that WHtR had significant correlation with all risk factors, but she did not find WHtR to have the highest correlation with any MetS component. This coincides with the findings of the current study, where WHtR had a positive correlation with all MetS components, and had the highest correlation only with FBG and HOMA in women.

The fact that WHtR did not have the highest correlation with all MetS components in the current study and the study by Al-Odat et al[39] points out the possibility that this anthropometric index may be more important in Asian populations where people have shorter stature, in general, and that WHtR reflects central obesity better in these populations where short stature has an important role in the pathogenesis of MetS[18].

In the current study, AUC from the ROC curves, for identifying subjects with MetS using IDF criteria, show that all anthropometric indices had a good predictive value and that AUC was highest for WC in men and for WHtR in women, table III. BMI had the weakest predictive power in both genders. Value of AUC from the anthropometric indices ROC curves in men was highest for WC (0.851), followed by WHtR

Table III

Optimal cut-off points (using Youden Index; J), area under the curve, sensitivity, specificity, and probability for identifying metabolic syndrome risk factors in the study group by gender

MetS Risk Factors	*Gender*	*Optimal Cut-Off Point*	*AUC*	*Sensitivity*	*Specificity*	*P-value*
WC (cm)	Men	98.50	0.851	0.944	0.679	<0.001
	Women	86.70	0.866	0.972	0.688	<0.001
BMI (Kg/m^2)	Men	28.970	0.830	1.000	0.642	<0.001
	Women	30.14	0.831	0.978	0.708	<0.001
WHpR	Men	0.94	0.842	0.860	0.691	<0.001
	Women	0.86	0.871	0.742	0.840	<0.001
WHtR	Men	0.56	0.850	0.972	0.673	<0.001
	Women	0.52	0.872	0.989	0.688	<0.001
Systolic BP (mmHg)	Men	135.00	0.853	0.713	0.982	<0.001
	Women	125.00	0.930	0.916	0.833	<0.001
Diastolic BP (mmHg)	Men	82.50	0.842	0.713	0.982	<0.001
	Women	82.50	0.920	0.910	0.840	<0.001
FBG (mg/dl)	Men	102.50	0.869	0.783	0.939	<0.001
	Women	100.50	0.826	0.669	0.944	<0.001
HDL-C (mg/dl)	Men	51.5	0.913	0.979	0.715	<0.001
	Women	49.50	0.744	0.719	0.729	<0.001
TG (mg/dl)	Men	181	0.796	0.678	0.836	<0.001
	Women	143	0.823	0.697	0.840	<0.001
HOMA Index	Men	2.564	0.841	0.783	0.770	<0.001
	Women	2.977	0.776	0.573	0.875	<0.001

MetS: Metabolic Syndrome; AUC: Area Under the Curve; WC: Waist Circumference; BMI: Body Mass Index; WHpR: Waist-to-Hip Ratio; WHtR: Waist to Height Ratio; Systolic BP: Systolic Blood Pressure; Diastolic BP: Diastolic Blood Pressure; FBG: Fasting Blood Glucose; HDL-C: High Density Lipoprotein Cholesterol; TG: Triglycerides; HOMA: Homeostasis Model Assessment

(0.850), WHpR (0.842) and BMI (0.830). In women, AUC was highest for WHtR (0.872), followed by WHpR (0.871), WC (0.866) and BMI (0.831).These data show similar results to those obtained from partial correlation coefficients of anthropometric indices with individual components of MetS, in that WC and WHtR have the highest predictive power for MetS and its components. Lower values of AUC from WC ROC curves were obtained by Al-Odat et al[39] study; 0.64 in men and 0.74 in women for identifying MetS using IDF criteria. In a Lebanese study, AUC from WC ROC curves, for identifying MetS using ATP III criteria, was 0.92 in men and 0.99 in women[40]. The results from these studies demonstrate a high predictive power of WC for the prediction of MetS.

The optimal cut-off points of WC were 98.5 cm for men and 86.7 cm for women, compared to 102 cm for men and 88 cm for women in the ATP III criteria and 94 cm for Caucasian men and 80 cm for Caucasian women in the IDF criteria (Table IV). The IDF also declared that ethnic-specific WC cut-offs should be considered[27,37]. The WC cut-offs obtained from the current study lie between those of the ATP III and the IDF which allows the detection of a higher number of subjects at risk of MetS than using ATP III criteria and at the same time to overcome the over estimation of MetS risk if IDF criteria are used. In their study involving 1918 Caucasian men and women, Lean et al[41] proposed WC as a simple measure of central obesity, using cut-off points of 102 cm for men and 88 cm for women, to indicate high health risks and they advised that men with WC≥94 cm and women with WC≥80 cm should gain no further weight, and these latter cut-off "action" levels were subsequently used to indicate central obesity in IDF definition of MetS[27]. Dobbelsteyn et al[13] conducted a study involving a total of 9913 Canadian men and women aged 18-74 and showed that WC cut-off points of≥90cm in men and≥80cm in women may be most appropriate for prediction of individual and multiple risk factors in Caucasian populations.

In Al-Odat et al study from Jordan[39], WC cut-off points for identifying MetS (IDF criteria), was 97.8 cm for men and 95.6 cm for women, compared to 98.5 cm for men and 86.7 cm for women in the current study. The differing values in women may be explained by the difference in sampling method used in each study. Khader and his colleagues[23] carried out a large scale study involving 4590 Jordanian adult subjects and found that WC cut-off values, for predicting individual MetS components, varied from 88.5 to 91.8 cm in men and from 84.5 to 88.5 cm in women. However, the researchers did not calculate the cut-off values for identifying MetS. Different WC cut-off points were

Table IV
Comparisons of the optimal cut-off points for metabolic syndrome risk factors between the current study and international organizations cut-off points

MetS Risk Factors	*Gender*	*Current Study*	*WHO, 1999*	*ATP III, 2001*	*IDF, 2005*
WC (cm)	Men	98.5	-	102	94
	Women	86.7	-	88	80
BMI (Kg/m^2)	Men	28.97	30	30	30
	Women	30.14	30	30	30
WHpR	Men	0.94	0.9	-	-
	Women	0.86	0.85	-	-
Systolic BP (mmHg)	Men	135	140	130	130
	Women	125	140	130	130
Diastolic BP (mmHg)	Men	82.5	90	85	85
	Women	82.5	90	85	85
FBG (mg/dl)	Men	102.5	110	110	100
	Women	100.5	110	110	100
HDL-C (mg/dl)	Men	51.5	35	40	40
	Women	49.5	40	50	50
TG (mg/dl)	Men	181	150	150	150
	Women	143	150	150	150

MetS: Metabolic Syndrome; WHO: World Health Organization; ATP III: Adult Treatment Panel III; IDF: International Diabetes Federation; WC: Waist Circumference; BMI: Body Mass Index; WHpR: Waist-to-Hip Ratio; Systolic BP: Systolic Blood Pressure; Diastolic BP: Diastolic Blood Pressure; FBG: Fasting Blood Glucose; HDL-C: High Density Lipoprotein Cholesterol; TG: Triglycerides; HOMA: Homeostasis Model Assessment.

obtained in various parts from the Arab world; 80 cm for men and 84.5 cm for women for identifying CVD in Omani subjects[42], 85 cm for both Tunisian men and women, for identifying T2DM and CVD[43], and 99.5 cm for men and 91 cm for women in Lebanese subjects, for identifying MetS using ATP III criteria[40]. In Iraqi subjects, WC cut-off points of 90 cm for men and 91 cm for women were obtained for identifying T2DM; and 95 cm for both men and women for identifying hypertension[25].

In the present study, AUC from BMI ROC curves, for identifying MetS using IDF criteria, was 0.83 in men and 0.831 in women. Although it had a good predictive value, BMI had the weakest predictive power in both genders compared to other anthropometric indices. Similar conclusions were reached by Lee et al[11] and Al-Odat et al[39] who had AUC from BMI ROC curves of 0.59 in men and 0.67 in women. However, Chedid et al[40] obtained AUC value of 0.95 for both genders for identifying MetS using ATP III criteria.The optimal cut-off points for BMI were 28.97 kg/m^2 in men and 30.14 kg/m^2 in women, for identifying MetS (IDF criteria), in the current study. These results are close to the corresponding value (30.0 kg/m^2 for both men and women) used in the various MetS definition criteria (Table IV). Similar results were obtained in other studies from Jordan. The BMI cut-off values in Al-Odat et al[39] study, for identifying MetS (IDF criteria), were 28.4 kg/m^2 for men and 30.3 kg/m^2 for women. Khader et al[23] found that BMI cut-off values, for predicting individual MetS components rather than MetS itself, ranged from 26.2 to 27.2 kg/m^2 in men and from 27.2 to 30.0 kg/m^2 in women. Other studies from the Arab world obtained different cut-off points for BMI: 23.3 kg/m^2 for men and 26.2 kg/m^2 for women, for identifying CVD, in Al-Lawati and Jousilahti[42] Omani study, 24 kg/m^2 for men and 27 kg/m^2 for women, for identifying T2DM and CVD, in Bouguerra et al[43] study from Tunisia, and 27.5 kg/m^2 for both men and women, for identifying MetS (ATP III criteria), in Chedid et al[40] study from Lebanon. Mansour and Al-Jazairi[25] from Iraq obtained cut-off points of 25.4 kg/m^2 for men and 24.9 kg/m^2 for women, for identifying T2DM; and 26.1 kg/m^2 for men and 26.5 kg/m^2 for women, for identifying hypertension.

In the present study, AUC from WHpR ROC curves, for identifying MetS using IDF criteria, was 0.842 in men and 0.871 in women. WHpR also had high predictive value in Al-Odat et al[39] study, with AUC of 0.71 in men and 0.76 in women. The optimal cut-off points for WHpR, for identifying MetS using IDF criteria, were 0.94 for men and 0.86 for women. These results are close to the corresponding values (0.90 for men and 0.85 for women) used in the WHO definition criteria for MetS (Table IV) and to results obtained by Al-Odat et al[39] of 0.89 for men and 0.84 for women for identifying MetS (IDF criteria). Khader et al[23] found that WHpR cut-off values, for predicting individual MetS components rather than MetS itself, ranged from 0.88 to 0.90 in men and from 0.80 to 0.83 in women. Other studies from the Arab world obtained different cut-off points for WHpR; 0.91 for both men and women for identifying CVD in Al-Lawati and Jousilahti[42] study; 0.92 for men and 0.91 for women for identifying T2DM and 0.92 for men and 0.91 for women for identifying hypertension in Mansour and Al-Jazairi [25] study.

In the present study, AUC from WHtR ROC curves, for identifying MetS using IDF criteria, was 0.85 in men and 0.872 in women. AUC in Al-Odat et al[39] study was 0.67 in men and 0.75 in women. In the meta-analysis published by Lee et al[11] WHtR was found to be the best predictor for hypertension, diabetes, and dyslipidemia in both genders with AUC ranging from 0.67 to 0.73 in men and from 0.68 to 0.76 in women. The higher values for AUC from the current study show that WHtR had a better overall predictive power for identifying subjects with MetS than other anthropometric indices with WC having closely similar results. The optimal cut-off points of WHtR in the current study, for identifying MetS using IDF criteria, were 0.56 for men and 0.52 for women. These values are close to the cut-off points proposed by various studies; 0.5 for both men and women for identifying obesity in Ashwell and Hsieh[7] study; 0.48 for both men and women for identifying obesity in Ho et al[18]; 0.52 for men and 0.56 for women for identifying T2DM and 0.55 for men and 0.59 for women for identifying hypertension in Mansour and Al-Jazairi[25] study. In addition, Khader et al[23] found WHtR cut-off values, for predicting individual MetS components rather than MetS itself, ranging from 0.50 to 0.51 in men and women. A higher cut-off value of 0.61 for both men and women was obtained in Al-Odat et al[39] study for identifying MetS using IDF criteria.The cut-off value of 0.5 for WHtR is claimed to be independent of age, sex, and ethnicity[7,9,11,19,22]. However, WHtR $\geq$ 0.5 is probably the most effective anthropometric index for screening patients at high risk of MetS in populations of low average heights, especially Asians[22].

The varying cut-off points for anthropometric indices obtained in different studies (including the current study) may be explained by different sample size, ethnic variations in different study populations regarding body composition and fat distribution, dietary patterns, cultural factors, socioeconomic status, levels of physical activity, and lifestyle. Moreover, studies investigating anthropometric indices cut-off points also have differences in the dependent variable studied (for example, CVD, T2DM, hypertension and various MS definitions).

Conclusions

Both WHtR and WC showed highly significant correlations with the individual components of MetS in men and women. They also exhibited the strongest predictive power for identifying subjects with MetS compared to other anthropometric indices. Waist-to-hip ratio seemed to have a good predictive power for identifying subjects with MetS, but it came next to WHtR and WC. Body mass index exhibited the weakest predictive power among anthropometric indices in both genders. The optimal cut-off points obtained in the current study for anthropometric, clinical and biochemical indices were comparable to those of international cut-offs. WHtR seemed to be a good measure for central obesity, and can replace WC for this purpose. A single WHtR cut-off point may be applicable to all races and both genders and has the advantage of direct comparisons with other populations.

It is recommended for the Arab populations to have their own anthropometric cut-off points to illustrate their ethnic variations, a matter that requires further studies using representative large sample size.

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Conflict of interests

The authors declare that they have no conflict of interests.

References

1. Gallagher E, LeRoith D, Karnieli E. The metabolic syndrome: from insulin resistance to obesity and diabetes. *Endocrinol Metab Clin North Am* 2008; 37: 559-579.
2. Sui X, Church T, Meriwether R, Lobelo F, Blair S. Uric acid and the development of metabolic syndrome in women and men. *Metabolism* 2008; 57: 845-852.
3. Alberti K, Eckel R, Grundy S, Zimmet P, Cleeman J, Donato K, Fruchart J-C, James W, Loria C, Smith S. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation task force on epidemiology and prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation* 2009; 120: 1640-1645.
4. Zimmet P, Alberti K, Rios M. A new International Diabetes Federation worldwide definition of the metabolic syndrome: the rationale and the results. *Rev Esp Cardiol* 2005; 58: 1371-1376.
5. Petrucelli OM. The metabolic syndrome. *Northeast Florida Medicine* 2008; 59(3): 18-21.
6. Asao K, Kao W, Baptisite-Roberts K. Short stature and the risk of adiposity, insulin resistance, and type 2 diabetes in middle age. *Diabetes Care* 2006; 29: 1632-1637.
7. Ashwell M, Hsieh S. Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. *Int J Food Sci Nutr* 2005; 56: 303-307.
8. Kahn H, Imperatore G, Cheng Y. A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. *J Pediatr* 2005; 146: 482-488.
9. Hsieh S, Muto T. Metabolic syndrome in Japanese men and women with special reference to the anthropometric criteria for the assessment of obesity: Proposal to use the waist-to-height ratio. *Prev Med* 2006; 42: 135-139.
10. Romao I, Roth J. Genetic and environmental interactions in obesity and type 2 diabetes. *J Am Diet Assoc* 2008; 108: S24-S28.
11. Lee K, Song Y, Sung J. Which obesity indicators are better predictors of metabolic risk? Healthy twin study. *Obesity* 2008; 16: 834-840.
12. Liu A, Abbasi F, Reaven G. Adiposity indices in the prediction of metabolic abnormalities associated with cardiovascular disease in non-diabetic adults. *Nutr Metab Cardiovasc Dis* 2011; 21(8): 553-560.
13. Dobbelsteyn C, Joffres M, MacLean D, Flowerdew G, The Canadian Heart Health Surveys Research Group. A comparative evaluation of waist circumference, waist-to-hip ratio and body mass index as indicators of cardiovascular risk factors. The Canadian Heart Health Surveys. *Int J Obesity* 2001; 25: 652-661.
14. Bagry H, Raghavendran S, Carli F. Metabolic syndrome and insulin resistance. *Anesthesiology* 2008; 108: 506-523.
15. Duvnjak L, Duvnjak M. The metabolic syndrome - an ongoing story. *J Physiol Pharmacol* 2009; 60: S19-S24.
16. Smith G, Greenwood R, Gunnell D, Sweetnam P, Yarnell J, Elwood P. Leg length, insulin resistance, and coronary heart disease risk: the Caerphilly study. *J Epidemiol Community Health* 2001; 55: 867-872.
17. López-Alvarenga JC, Montesinos-Cabrera R, Velázquez-Alva C, González-Barranco J. Short stature is related to high body fat composition despite body mass index in a Mexican population. *Arch Med Res* 2003; 34: 137-140.
18. Ho S, Lam T, Janus E, Hong Kong Cardiovascular Risk Factor Prevalence Study Steering Committee. Waist to stature ratio is more strongly associated with cardiovascular risk factors than other simple anthropometric indices. *Ann Epidemiol* 2003; 13: 683-691.
19. Hsieh S, Yoshinaga H, Muto T. Waist-to-height ratio, a simple and practical index for assessing central fat distribution and metabolic risk in Japanese men and women. *Int J Obes Relat Metab Disord* 2003; 27: 610-616.
20. Hsieh S, Muto T, Yoshinaga H, Tsuji H, Arimoto S, Miyagawa M, Hoshihara Y, Hara Sh. Waist-to-height ratio, a simple and effective predictor for metabolic risk in Japanese men and women. *Int Congr Ser* 2006; 1294: 186-189.
21. Parikh R, Joshi S, Menon P, Shah N. Index of central obesity - a novel parameter. *Med Hypotheses* 2007; 68: 1272-1275.
22. Mombelli G, Zanaboni A, Gaito S, Sirtori C. Waist-to-Height ratio is a highly sensitive index for the metabolic syndrome in a Mediterranean population. *Metab Syndr Relat Disord* 2009; 7: 477-484.
23. Khader Y, Batieha A, Jaddou H, Batieha Z, El-Khateeb M, Ajlouni K. Anthropometric cutoff values for detecting metabolic abnormalities in Jordanian adults. *Diabetes Metab Syndr Obes Target Ther* 2010; 3: 395-402.
24. Rodea-Montero E, Evia-Viscarra M, Apolinar-Jiménez E. Waist-to-Height ratio is a better anthropometric index than waist circumference and BMI in predicting metabolic syndrome among obese Mexican adolescents. *Int J Endocrinol* 2014; Article ID 195407: 9 pages.
25. Mansour A, Al-Jazairi M. Cut-off values for anthropometric variables confer increased risk of type 2 diabetes mellitus and hypertension in Iraq. *Arch Med Res* 2007; 38: 253-258.
26. Esmaillzadeh A, Mirmiran P, Azizi F. Waist-to-hip ratio is a better screening measure for cardiovascular risk factors than other anthropometric indicators in Tehranian adult men. *Int J Obes Relat Metab Disord* 2004; 28: 1325-1332.
27. IDF. The IDF consensus worldwide definition of the metabolic syndrome (booklet online). 2005. Available from: http://www.idf.org/webdata/docs/IDF_Meta_def_final.pdf. Accessed 15 Sept 2013.
28. CDC. *NHANES anthropometry and physical activity monitor procedures manual*. 2005. Available from: http://www.cdc.gov/nchs/data/nhanes/ nhanes_05_06/BM.pdf. Accessed 15 Sept 2013.

29. Lee R, Nieman D. Nutritional assessment. 5th ed. USA: McGraw-Hill Press; 2010. p. 160-213.
30. WHO. Definition, Diagnosis and Classification of Diabetes Mellitus and its Complications. Report of a WHO Consultation. Part 1: Diagnosis and Classification of Diabetes Mellitus. Department of Noncommunicable Disease Surveillance. Geneva: Switzerland; 1999.
31. Chen H, Sullivan G, Quon M. Assessing the predictive accuracy of QUICKI as a Surrogate Index for insulin sensitivity using calibration model. *Diabetes* 2005; 54: 1914-1925.
32. Wahrenberg H, Hertel K, Leijonhufvud B-M, Persson L-G, Toft E, Arner P. Use of waist circumference to predict insulin resistance: retrospective study. *Brit Med J* 2005; 330: 1363-1364.
33. Akobeng AK. Understanding diagnostic tests-3: Receiver operating characteristic curves. *Acta Paediatrica* 2007; 96(5): 644-647.
34. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Executive summary of the third report of the National Cholesterol Education Program (NCEP). *JAMA* 2001; 285: 2486-2497.
35. Grundy S, Brewer H, Cleeman J, Smith S, Lenfant C. Definition of metabolic syndrome. Report of the National Heart, Lung, and Blood Institute/American Heart Association Conference on scientific issues related to definition. *Circulation* 2004; 109: 433-438.
36. Lemieux I, Pascot A, Couillard C, Lamarche B, Tchernof A, Alme´ras N, Bergeron J, Gaudet D, Tremblay G, Prud'homme D, Nadeau A, Despre´s J-P. Hypertriglyceridemic waist a marker of the atherogenic metabolic triad (Hyperinsulinemia; Hyperapolipoprotein B; Small, Dense LDL-C) in men. *Circulation* 2000; 102: 179-184.
37. Alberti K, Zimmet P, Shaw J. IDF Epidemiology Task Force Consensus Group. The metabolic syndrome: a new worldwide definition. *Lancet* 2005; 366: 1059-1062.
38. Han T, Van Leer E, Seidell J, Lean M. Waist circumference action levels in the identification of cardiovascular risk factors: prevalence study in a random sample. *Brit Med J* 1995; 311: 1401-1405.
39. Al-Odat AZ, Ahmad MN, Haddad FH. References of anthropometric indices of central obesity and metabolic syndrome in Jordanian men and women. *Diabetes Metab Syndr* 2012; 6(1): 15-21.
40. Chedid R, Gannagé-Yared M, Khalifé S, Halaby G, Zoghbi F. Impact of different metabolic syndrome classifications on the metabolic syndrome prevalence in a young Middle Eastern population. *Metabolism* 2009; 58(6): 746-752.
41. Lean M, Han T, Morrison C. Waist circumference indicates the need for weight management. *Brit Med J* 1995; 311(6998): 158-161.
42. Al-Lawati JA. Jousilahti P. Body mass index, waist circumference and waist-to-hip ratio cut-off points for categorization of obesity among Omani Arabs. *Public Health Nutr* 2008; 11: 102-108.
43. Bouguerra R, Alberti H, Smida H, Salem L, Rayana C, El Atti J, Achour A, Gaigi S, Slama C, Zouari B, Alberti K. Waist circumference cut-off points for identification of abdominal obesity among the Tunisian adult population. *Diabetes Obes Metab* 2007; 9: 859-868.