Nutrición Hospitalaria

Nutr Hosp. 2015;32(6):2701-2709
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Original/*Síndrome metabólico*

Suitability of visceral adiposity index as a marker for cardiometabolic risks in Jordanian adults

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Abstract

Introduction: **visceral adiposity index (VAI) has recently been proposed as a predictor of cardiometabolic risk, but its usefulness has not been confirmed.**

Objectives: **to evaluate the association between VAI and conventional adiposity and cardiometabolic risk indices and examine VAI risk predictive ability and compare it with other adiposity indices.**

Methods: **a total of 1622 Jordanian adults, 686 men and 936 women, aged 20-80 years were included this study. VAI, body mass index (BMI), waist circumference (WC), waist-hip ratio (WHR), waist-height ratio (WHtR) were examined and high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), fasting serum glucose (FSG), systolic (SBP), and diastolic (DBP) blood pressure were determined. Associations and age-and gender-specific distribution and differences were evaluated. Receiver operating characteristic (ROC) curve and area under curve (AUC) were used for risk predictive ability comparison.**

Results: **VAI of women (6.82±6.43) was higher than of men (4.15±4.62). VAI severity increased with age in a dose-response trend (p<0.001) in both genders. Women had higher prevalence than men of high risks of VAI and all adiposity and cardiometabolic indices. VAI markedly associated with TG, HDL-C, FSG, SBP and DBP or WHR, WC, WHtR and BMI in respective order of correlation potency for cardiometabolic or adiposity risk indices. In men and women respectively, the largest AUC was for VAI (0.79 *vs.* 0.77), followed by WHR (0.73 *vs.* 0.75), WC (0.69 *vs.* 0.74), WHtR (0.65 *vs.* 0.71) and BMI (0.53 *vs.* 0.51).**

IDONEIDAD DEL ÍNDICE DE ADIPOSIDAD VISCERAL COMO MARCADOR DE RIESGO CARDIOMETABÓLICO EN ADULTOS JORDANOS

Resumen

Introducción: **el índice de adiposidad visceral (VAI) ha sido propuesto recientemente como predictor de riesgo cardiometabólico, pero su utilidad no ha sido confirmada.**

Objetivos: **evaluar la asociación entre VAI y los índices de adiposidad y riesgo cardiometabólico convencionales y examinar la capacidad predictiva del riesgo VAI en comparación con otros índices de adiposidad.**

Métodos: **en este estudio se incluyeron un total de 1.622 adultos de Jordania, 686 hombres y 936 mujeres, de edad entre 20 y 80 años. Fueron examinados el VAI, el índice de masa corporal (BMI), la circunferencia de la cintura (WC), la relación cintura-cadera (WHR) y la relación cintura-estatura (WHtR) y se determinaron el colesterol de lipoproteínas de alta densidad (HDL-C), los triglicéridos (TG), la glucosa sérica en ayunas (FSG), y la presión arterial sistólica (SBP) y diastólica (DBP). Se evaluaron las asociaciones, la distribución por edad y género y las diferencias. El receptor de funcionamiento característico (ROC) y el área bajo la curva (AUC) se utilizaron para comparar la capacidad de predicción del riesgo.**

Resultados: **el VAI de las mujeres (6,82 ± 6,43) fue mayor que el de los hombres (4,15 ± 4,62). El VAI severidad aumenta con la edad en una tendencia dosis-respuesta (p < 0,001) en ambos sexos. Las mujeres tuvieron mayor prevalencia que los hombres de alto riesgo de VAI y todos los índices de adiposidad y cardiometabólicos. VAI marcadamente asociado con TG, HDL-C, FSG, SBP y DBP o WHR, WC, WHtR y el BMI en orden respectivo de la potencia de correlación para los índices de riesgo cardiometabólico o adiposidad. En hombres y mujeres, respectivamente, el AUC era más grande para VAI (0,79 *vs.* 0,77), seguido por WHR (0,73 *vs.* 0,75), aseo (0,69 *vs.* 0,74), WHtR (0,65 *vs.* 0,71) y el BMI (0,53 *vs.* 0,51).**

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Recibido: 27-VI-2015.
Aceptado: 26-VIII-2015.

Conclusions: **the findings suggest that VAI potentially associates with cardiometabolic risks and proves to be superior to other adiposity indices in predicting such risk.**

(*Nutr Hosp*. 2015;32:2701-2709)

DOI:10.3305/nh.2015.32.6.9543

Key words: *Cardiometabolic risk. Visceral adiposity index. Body mass index. Waist-hip ratio. Waist-height ratio. Waist circumference.*

Conclusiones: **los hallazgos sugieren que el VAI potencialmente se asocia con riesgos cardiometabólicos y demuestra que es superior a otros índices de adiposidad en la predicción de tales riesgos.**

(*Nutr Hosp*. 2015;32:2701-2709)

DOI:10.3305/nh.2015.32.6.9543

Palabras clave: *Riesgo cardiometabólico. Índice de adiposidad visceral. Índice de masa corporal. Relación cintura-cadera. Relación cintura-estatura. Circunferencia de la cintura.*

Abbreviations

VAI: visceral adiposity index.
WC: waist circumference.
HP: hip circumference.
WHR: waist-hip ratio.
WHtR: waist-height ratio.
BMI: body mass index.
TG: triglycerides.
HDL-C: high-density lipoprotein cholesterol.
FSG: fasting serum glucose.
SBP: systolic blood pressure.
DBP: diastolic blood pressure.

Introduction

Nowadays, obesity poses one of the greatest public health challenges worldwide[1]. Visceral adiposity and its associated disorders including dyslipidemia, hypertension, insulin resistance and diabetes are the key elements characterizing the cardiometabolic risk[2,3]. Computerized tomography and magnetic resonance imaging are the methods of choice for measuring visceral fatness, though their use is extremely limited owing to the cost, complexity and time[4]. Body mass index (BMI), the classical index to define and classify obesity, does not measure visceral adiposity[5]. Waist circumference (WC) is the anthropometrical measure most commonly used to identify visceral adiposity[4,6]. However, it has been shown that WC is a poor indicator in differentiating between visceral and subcutaneous fat[4,5].

Visceral adiposity index (VAI) is a recently developed gender- specific mathematical model that uses both biochemical and anthropometric indices including high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), BMI and WC.[7] This index has been shown to conform well to visceral adiposity measured by imaging techniques and has been considered a simple surrogate marker of adipose tissue dysfunction and an indirect predictor of cardiometabolic risk, although the prospective of this notion is not yet elucidated[8]. The AVI has also shown strong links with cardiovascular events[7] and has proved to be a good predictor for metabolic risk components particularly dyslipidemia, WC and BMI[9,10]. Nevertheless, some studies failed to support this[11,12].

The application of VAI in the Arab communities of the Middle East has not been reported. These communities are characterized by high prevalence of cardiometabolic risks including obesity, diabetes, dyslipidemia and hypertension[13-15]. Therefore, the primary objectives of this cross-sectional study in Jordanian men and women were to evaluate the association between VAI and conventional anthropometric adiposity, metabolic and clinical risk indices including BMI, WC, waist-hip ratio (WHR), waist-height ratio (WHtR), fasting serum glucose (FSG), TG, HDL-C and blood pressure, and examine the risk predictive ability of VAI and compare it with the other adiposity indices.

Materials and Methods

Study subjects

A total of 1,622 Jordanian subjects, 686 men and 936 women between 20 and 80 years old, were included in this cross-sectional study. Subjects were with and without cardiometabolic conditions and were recruited from the visitors and their companions of the internal medicine clinics at the King Hussein Medical Center and from those attending several family health clinics or centers in Amman, Jordan. Subjects with normal weight, overweight, obese and with diabetes type 2 not taking medication were included in the study. Pregnant and lactating women or those with polycystic ovary syndrome or subjects with known existing or history of major medical illness such as diabetes type 1, cancer, thyroid dysfunction and mental or physical disability were excluded. The study was approved by the Institutional Ethics Committee. Consent was obtained from each subject at the start of the study.

Data collection

Each subject answered a questionnaire that included personal, social, health, nutritional and lifestyle information. Body weight, height and circumferences of the waist and hip were measured following standard methods of anthropometry[16]. The weight was

measured with light clothing and without shoes to the nearest 0.1kg using a measuring scale and height was recorded to the nearest 0.5cm using a stadiometer. WC was measured standing to the nearest 5mm at a level midway between the lower rib margin and the iliac crest during normal end-expiratory phase. Hip circumference (HC) was measured at the level of the greater trochanters. BMI was calculated as body weight (kg) divided by height (m^2). WHR was calculated as the WC divided by HC, and WHtR was obtained by dividing the WC to height. The VAI was calculated using the following equations developed by Amato et al.[7]:

wc39.68+(1.88 xBMI) x TG1.03x1.31HDL-C
wc36.58+(1.89 xBMI) x TG0.81x1.52HDL-C

Systolic (SBP) and diastolic (DBP) blood pressure were measured twice using a standardized mercury sphygmomanometer after seating the subject for at least 15 minutes, and then the average blood pressure was recorded[16].

Blood samples were collected in the morning after 10-12 hours overnight fasting by senior laboratory technicians. Blood samples were taken in a sitting position according to the standard protocol, centrifuged and sera were stored frozen until biochemical analysis.

Cardiometabolic diagnosis

Harmonized definition was adopted to diagnose subjects with cardiometabolic conditions[2]. Subjects were considered to have cardiometabolic condition if they have three or more of any of the following five risk factors: WC ≥94 cm for men or ≥80 cm for women; TG ≥150 mg/dl; HDL-C <40 mg/dl for men, and <50 mg/dl for women; SBP ≥130 mmHg and/or DBP or ≥85 mmHg; FSG ≥100 mg/dl. For the purpose of the current study, documented cut-off points for WHtR and VAI were also used. A cut-off point ≥0.5 for WHtR has been proposed as an index of adiposity[17]. Age-stratified cut-off points for VAI have recently been proposed as an indicator of the adipose tissue dysfunction and as an indirect expression of the cardiometabolic risk[8].

Biochemical analysis

Concentrations of FSG, TG and HDL-C were determined by using commercial biochemical kits and according to the manufacturer's instructions (Abbott Laboratories, Japan). Analysis was performed at the Laboratories of King Hussein Medical Center, Amman, Jordan, using a pre-calibrated Roche/Hitachi automated clinical chemistry analyzer (Roche/Hitachi Diagnostics, Japan).

Statistical analysis

Data analysis was performed using statistical analysis software (SPSS Inc., version 15, Chicago, USA). Results were expressed as means ± standard deviation (SD) or percentages where appropriate. Significance was set at $p < 0.05$. Partial correlations were used to test the relationship between each of the anthropometric and cardiometabolic risk indices after controlling for age. The *t*-test was performed for differences between men and women and between age groups regarding the studied variables. The trend was assessed by regression. Receiver operating characteristic (ROC) curve was applied and the area under the curve (AUC) was calculated to compare the predictive effect between the various anthropometric indices for cardiometabolic risk.

Results

Selected clinical and anthropometrical characteristics of 686 men and 936 women enrolled in this study are presented in table I. Marked differences ($p<0.001$) between men and women regarding all studied variables were observed. Women were older (48.4 ± 14.8 years) than men (38.1 ± 16.4 years) with an overall age range of 20-80 years. Women were also heavier and shorter and had markedly higher BMI, WC, HC, WHR, WHtR, TG, FSG, HDL-C, SBP and DBP than men. Further, women had significantly higher ($p<0.001$) VAI (6.82 ± 6.43) than men (4.15 ± 4.62).

Numbers and percentages in men and women of the desired and risk levels of the studied indices as well as of the components of cardiometabolic syndrome are given in table II. There was no consistent direction for the distribution of men or women over the desired and risk levels of the anthropometric adiposity and cardiometabolic indices. With the exception of WC, WHR and HDL-C, in contrast to other indices, more men or women were at risk than at desired levels for VAI, BMI and WHtR. Approximately 57%, 66% and 71% of men and 87%, 72% and 89% of women were respectively at mild-severe, overweight-obese or WHtR risk. In general, for all indices, more women than men were at high risk, particularly VAI (43.1% vs. 74.0%), WC (42.5% vs. 100.0%), WHR (29.4% vs. 66.6%), WHtR (70.8% vs. 89.2%) and HDL-C (31.0% vs. 65.0%) respectively. The percentages of women with one or two cardiometabolic risk components were higher ($p<0.001$) than those of men. The prevalence of cardiometabolic syndrome was also significantly higher ($p<0.001$) in women (46.8%) than in men (31.0%) with an overall prevalence of (40.1%).

Means and percentages of different VAI categories in relation to age in the study subjects are given in table III. In the age groups 20-29, 30-39 and 40-49 years, most men and women were either at desired or severe VAI categories, whereas in the age groups 50-59 and ≥60 years, men and women fell mainly in the moder-

Table I
Selected clinical and anthropometrical characteristics of the study group.

Character[#]	*Total (n=1622)*	*Men (n=686)*	*Women (n=936)*	*P value*[*]
Age (years)	44.0 ± 16.2	38.2 ± 16.2	48.3 ± 14.7	<0.001
Weight (kg)	77.4 ± 15.9	75.3 ± 15.9	79.0 ± 15.8	<0.001
Height (cm)	162.9 ± 9.2	163.9 ± 8.3	162.2 ± 9.7	<0.001
WC (cm)	95.0 ± 14.3	91.2 ±14.7	97.8 ± 13.3	<0.001
HC (cm)	110.2 ± 11.4	108.0 ± 11.2	111.8 ± 11.2	<0.001
BMI	29.20 ± 5.70	28.04 ± 5.58	30.04 ± 5.65	<0.001
WHR	0.862 ± 0.092	0.843 ± 0.097	0.875 ± 0.085	<0.001
WHtR	0.584 ± 0.090	0.557 ± 0.090	0.604 ± 0.084	<0.001
FSG (mg/dl)	108.4 ± 48.1	101.3 ± 43.9	113.6 ± 50.3	<0.001
TG (mg/dl)	133.8 ± 97.1	124.7 ± 97.7	140.4 ± 96.2	<0.001
HDL-C (mg/dl)	46.1 ± 10.1	45.4 ± 10.7	46.7 ± 9.5	<0.01
SBP	125.8 ± 19.9	120.9 ± 20.9	129.3 ± 18.4	<0.001
DPB	81.1 ± 11.4	78.5 ± 12.1	83.0 ± 10.4	<0.001
VAI	5.69 ± 5.88	4.15 ± 4.62	6.82 ± 6.43	<0.001

Data are presented as mean ± standard deviation.
[#]WC: waist circumference; HC: hip circumference; BMI; body mass index; WHR: waist-hip ratio; WHtR: waist-height ratio; FSG: fasting serum glucose; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; SBP: systolic blood pressure; DBP: diastolic blood pressure; VAI: visceral adiposity index.
[*]Statistical differences between men and women.

ate and severe VAI categories. By increasing age, the number of men and women with severe VAI progressively increased and that with desired VAI decreased. There was a marked dose-response relationship (trend, $p<0.001$) between age and the number of men and women in the desired and severe VAI categories. Increasing age (20-59 years) caused a significant increase ($p<0.02$) in VAI of men and women. This variable started to drop after the age of 60 years in both genders.

There were significant associations ($p<0.01$) between VAI and each of other adiposity indices with similar order of potency in men and women as follows: WHR (0.433 vs. 0.399), WC (0.383 vs. 0.303), WHtR (0.334 vs. 0.213) and BMI (0.207 vs. 0.100). The VAI also correlated ($p<0.001$) with age of men ($r= 0.279$), women ($r= 0.148$) and overall sample ($r= 0.245$). In men and women, age was correlated ($p<0.01$) with WHR ($r= 0.643$ vs. $r= 0.510$), WHtR ($r= 0.591$ vs. $r= 0.479$), WC ($r= 0.574$ vs. $r= 0.425$), BMI ($r= 0.300$ vs. $r= 0.192$), HDL-C ($r= -0.150$ vs. $r= -0.114$), TG ($r= 0.313$ vs. $r= 0.164$), FSG ($r= 0.463$ vs. $r= 0.263$), SBP ($r= 0.678$ vs. $r= 0.494$) and DBP ($r= 0.553$ vs. $r= 0.285$). In the whole sample, these correlations ($p<0.01$) were ($r= 0.591$), ($r= 0.568$), ($r= 0.530$), ($r= 0.278$), ($r= -0.105$), ($r= 0.244$), ($r= 0.365$), ($r= 0.605$) and ($r= 0.448$) respectively. Among these indices, WHR, WHtR, DBP and SBP had the strongest, whereas BMI and HDL-C had the weakest correlations with age.

Table IV presents age-controlled correlations between adiposity and cardiometabolic risk indices in the study subjects. Significant correlations ($p<0.001$) between VAI and each of the cardiometabolic risk indices was observed in men, women and overall sample with the following order of correlation potency: TG, HDL-C, FSG, SBP and DBP. Among the five adiposity indices, VAI exhibited the strongest correlations with TG and HDL-C and ranked as second with FSG and the weakest with blood pressure. Among the four conventional adiposity indices, WHR showed the strongest correlations with all cardiometabolic risk indices, followed by WC, WHtR and BMI ($p<0.001$).

The results of the ROC analysis and AUC with its corresponding 95% confidence intervals for the various adiposity indices in men and women considering three or more cardiometabolic risks are given in table V. In men and women respectively, the largest AUC was observed for VAI (0.79 vs. 0.77), followed by WHR (0.73 vs. 0.75), WC (0.69 vs. 0.74), WHtR (0.65 vs. 0.71) and BMI (0.53 vs. 0.51).

Discussion

Cardiometabolic risk has frequently been used to describe the aggregate risk of developing cardiovascular diseases[18]. Although there is a general agreement upon such a risk, differences in the diagnosis of cen-

Table II
Desired and risk levels of studied indices and components of cardiometabolic syndrome: numbers and percentages in men and women.

Index[#]	*Desired and risk levels*[$]	*Total (n=1622) n (%)*	*Men*[*] *(n=686) n (%)*	*Women*[*] *(n=936) n (%)*
VAI	Desired	418 (25.8)	296 (43.1)	122 (13.0)
	Mild-moderate risk	215 (13.3)	94 (13.7)	121 (12.9)
	Severe risk	989 (61.0)	296 (43.1)	693 (74.0)
BMI	Desired (<25)	386 (23.8)	217 (31.6)	169 (18.1)
	Overweight (25-30)	547 (33.7)	222 (32.4)	325 (34.7)
	Obese (≥30)	689 (42.5)	247 (36.0)	442 (47.2)
WC	Desired (<94, men; <85, women)	396 (24.4)	396 (57.7)	0 (0)
	Risk (≥94, men; ≥85, women)	1226 (75.6)	290 (42.3)	936 (100)
WHR	Desired (<0.90, men; <0.85, women)	853 (52.6)	484 (70.6)	369 (39.4)
	Risk (≥0.90, men; ≥0.85, women)	769 (47.4)	202 (29.4)	567(60.6)
WHtR	Desired (<0.50)	301 (18.6)	200 (29.2)	101 (10.8)
	Risk (≥0.50)	1321 (81.4)	486 (70.8)	835 (89.2)
TG	Desired (<150 mg/dl)	1136 (70.0)	513 (74.9)	623 (66.6)
	Risk (≥150 mg/dl)	486 (30.0)	173 (25.2)	313 (33.4)
FSG	Desired (<100 mg/dl)	1045 (64.4)	502 (73.2)	543 (58.0)
	Risk (≥100 mg/dl)	577 (35.6)	184 (26.8)	393 (42.8)
HDL-C	Desired (≥40, men; ≥50, women mg/dl)	801 (49.4)	473 (69.0)	328 (35.0)
	Risk (<40, men; <50, women mg/dl)	821 (50.6)	213 (31.0)	608 (65.0)
SBP	Desired (<130 mmHg)	968 (59.7)	471 (68.6)	497 (53.1)
	Risk (≥130 mmHg)	654 (40.3)	215 (31.4)	439 (46.1)
DPB	Desired (<85 mmHg)	1127 (69.5)	514 (74.9)	613 (65.5)
	Risk (≥85 mmHg)	495 (30.5)	172 (25.1)	323 (34.5)
Number of cardiometabolic risk component				
1 criterion present		1226 (75.6)	290 (42.3)	936 (100)
2 criteria present		823 (50.7)	215 (31.3)	608 (65.0)
≥ 3 criteria present		651 (40.1)	213 (31.0)	438 (46.8)

Data are presented as number of men and women, and percentages in parenthesis.
[#]VAI: visceral adiposity index; BMI; body mass index; WC: waist circumference; WHR: waist-hip ratio; WHtR: waist-height ratio; FSG: fasting serum glucose; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; SBP: systolic blood pressure; DBP: diastolic blood pressure.
[$]Based on documented desired and risk levels [2,3,8,17].
[*]Differences between men and women are statistically significant ($P<0.05$) for all values.

tral obesity still exist[2-5]. In this research, in addition to conventional indices of central obesity, we used the recently introduced VAI and its age-stratified cut-off points[8]. The high prevalence of cardiometabolic syndrome and its risk indices in Jordanians was confirmed. Women were also found to be at a higher risk than men. In total, 40.1% of the study population had cardiometabolic syndrome, being higher in women (46.8%) than in men (31.0%). Among adiposity indices, WHtR showed the highest prevalence followed by WC, VAI, WHR and BMI. In men, high VAI ranked as the second risk index, whereas in women it ranked as the third.

This study is perhaps the first to address the prevalence of high VAI and its rank among other risk indices in Arab population. The prevalence of high VAI has recently been reported in Asians[9] and Western adults[7,8] corroborating our results. A high prevalence of cardiometabolic syndrome has also been documented in Jordanians[13,14] and other Arabs[15], Asians[9], Africans[19]

Table III
Categories of visceral adiposity index in relation to age: means and percentages in the study group[#]

Age (years)			*Visceral adiposity index[$]*				
			Desired	*Mild*	*Moderate*	*Severe*	*Overall[*]*
	n (%)	*Mean ± SD*	*n (%)*	*n (%)*	*n (%)*	*n (%)*	*Mean ± SD*
Total 1622 (100)							
20-29	400 (24.7)	23.5 ± 3.1	263 (65.8)	9 (2.3)	13 (3.3)	115 (28.8)	2.99 ± 3.78[e]
30-39	266 (16.4)	34.1± 2.6	74 (27.8)	14 (5.3)	48 (18.0)	130 (48.9)	4.49 ± 4.18[d]
40-49	300 (18.5)	44.3± 2.7	46 (15.3)	19 (6.3)	5 (1.7)	230 (76.7)	7.47 ± 7.03[ab]
50-59	311 (19.2)	53.6± 2.7	17 (5.5)	14 (4.5)	43 (13.8)	237 (76.2)	7.87 ± 7.29[a]
≥ 60	345 (21.3)	66.5± 5.6	18 (5.2)	11 (3.2)	39 (11.3)	277 (80.3)	6.24 ± 5.00[c]
P/ trend			<0.001	NS	NS	<0.001	
Men 686 (42.3)							
20-29	280 (40.8)	23.4 ± 2.3	206 (73.6)	3 (1.1)	9 (3.2)	62 (22.1)	2.65 ± 3.50[e]
30-39	134 (19.5)	33.5± 2.2	54 (40.3)	4 (3.0)	28 (20.9)	48 (35.8)	3.59 ± 3.00[d]
40-49	85 (12.4)	44.3 ± 2.7	22 (25.9)	6 (7.1)	1 (1.2)	56 (65.9)	6.53 ± 5.73[ab]
50-59	81 (11.8)	53.9 ± 2.8	6 (7.4)	7 (8.6)	9 (11.1)	59 (72.8)	6.88 ± 7.38[a]
≥ 60	106 (15.5)	66.5 ± 5.4	8 (7.5)	4 (3.8)	23 (21.7)	71 (67.0)	4.86 ± 3.18[c]
P/ trend			<0.001	NS	NS	<0.001	
Women 936 (57.7)							
20-29	120 (12.8)	23.8 ± 2.8	57 (47.5)	6 (5.0)	4 (3.3)	53 (44.2)	3.78 ± 4.27[d]
30-39	132 (14.1)	34.7 ± 3.0	20 (15.2)	10 (7.6)	20 (15.2)	82 (62.1)	5.40 ± 4.96[c]
40-49	215 (23.0)	44.3 ± 2.7	24 (11.2)	13 (6.0)	4 (1.9)	174 (80.9)	7.84 ± 7.47[ab]
50-59	230 (24.6)	53.4 ± 2.7	11 (4.8)	7 (3.0)	34 (14.8)	178 (77.4)	8.23 ± 7.24[a]
≥ 60	239 (25.5)	67.0 ± 5.7	10 (4.2)	7 (2.9)	16 (6.7)	206 (86.2)	6.86 ± 5.53[b]
P/ trend			<0.001	NS	NS	<0.001	

[#]Data are presented as number of men and women, and percentages in parenthesis or mean ± standard deviation (SD). NS: not significant.
[$]Based on documented age-stratified desired, mild, moderate and severe cut-off points [8].
[*]Values in the column with different superscripts within men, women or total are significantly different (p <0.02).

and Western communities[20]. However, the use of different definitions for diagnosis of the syndrome often limits comparison among various populations. Consistent with present results, a higher prevalence of cardiometabolic syndrome and its risk indices in women than men has been described[14,21]. Female gender aged 25 years and above has also been associated with increased odds of BMI- and WC-defined obesity[22].

In men and women, we observed marked associations between age and various indices of adiposity and

Table IV
Age-controlled correlations between indices of anthropometrical adiposity and cardiometabolic risks of the study group

Index[#*]		*HDL-C*	*TG*	*FSG*	*SBP*	*DBP*
Total (n=1622)	BMI	-0.095	0.206	0.129	0.263	0.282
	WHR	-0.360	0.385	0.415	0.505	0.411
	WHtR	-0.181	0.311	0.307	0.444	0.394
	WC	-0.271	0.301	0.319	0.462	0.437
	VAI	-0.553	0.936	0.379	0.230	0.167
Men (n=686)	BMI	-0.180	0.242	0.138	0.300	0.297
	WHR	0.380	0.420	0.455	0.580	0.502
	WHtR	-0.260	0.363	0.336	0.507	0.443
	WC	-0.320	0.394	0.354	0.534	0.495
	VAI	-0.560	0.964	0.347	0.245	0.166
Women (n=936)	BMI	-0.051[$]	0.162	0.093	0.184	0.224
	WHR	0.379	0.344	0.370	0.398	0.283
	WHtR	0.157	0.253	0.255	0.330	0.288
	WC	-0.269	0.301	0.265	0.343	0.330
	VAI	-0.621	0.956	0.372	0.168	0.113

[#]BMI; body mass index; WC: waist circumference; WHR: waist-hip ratio; WHtR: waist-height ratio; VAI: visceral adiposity index; HDL-C: high density lipoprotein cholesterol; TG: triglycerides; FSG: fasting serum glucose; SBP: systolic blood pressure; DBP: diastolic blood pressure.
[*]All correlations in men, women or whole sample are significant (P<0.001), except that marked with the dollar symbol.

Table V
Area under receiver operating characteristic curves and 95% confidence intervals of the various adiposity indices in the study group

Index[#$]	*Area under receiver operating characteristic curve*				
	VAI	*BMI*	*WC*	*WHR*	*WHtR*
Men (n=686) ≥ 3 risks	0.79 (0.73-0.84)	0.53 (0.49-0.57)	0.69 (0.61-0.77)	0.73 (0.65-0.81)	0.65 (0.58-0.71)
Women (n=936) ≥ 3 risks	0.77 (0.69-0.84)	0.51 (0.46-0.56)	0.74 (0.68-0.79)	0.75 (0.70-0.80)	0.71 (0.64-0.78)

[#]Data represent area under receiver operating characteristic curves and 95% confidence intervals in parenthesis.
[$]VAI: visceral adiposity index; BMI: body mass index; WC: waist circumference; WHR: waist-hip ratio; WHtR: waist-height ratio.

cardiometabolic risks. We also observed a progressive increase in VAI with increasing age. The prevalence of high VAI was found to increase with age in a dose-response manner. The link between VAI and age has been addressed by other studies and age-stratified cut-off points for VAI have been reported[7,8]. The coincidence rate of abdominal obesity determined by visceral fat area has been shown to increase with age in obese Chinese women[23]. It is also well documented that the prevalence of cardiometabolic syndrome and its risk indices increases with age[13,14,19] which accord with the present results.

The current study shows marked correlations between VAI and all cardiometabolic risk indices, and those with TG, HDL-C and FSG were the strongest in both men and women. Likewise, the correlations between such risk indices and each of WHR, WC and WHtR were strong and those with BMI were fairly weak. Almost similar results have been obtained in a study with Peruvian men and women showing significant correlations between adiposity indices namely VAI, WHR, WC, WHtR and BMI and all cardiometabolic risk indices, but with different order of correlations potency compared to present results[12]. Consistently, VAI has been shown to correlate with FSG, HDL-C and TG in Brazilian adults of both genders[24]. The outcomes of cardiovascular diseases have been reported to correlate with BMI, WC, and VAI, and VAI has independently associated with these diseases, while WC and BMI have not shown any significant

correlation[7]. These differences may be attributed to different study populations.

According to the AUC of the ROC analysis, VAI presented the largest AUC (0.79 in men; 0.77 in women), followed by WHR, WC, WHtR and BMI. However, the AUCs for WHR, WC and WHtR ranged between 0.69 and 0.75 indicating good but relatively lower predictive discriminatory powers of these indices especially in women. BMI presented the smallest AUC, thus had the weakest predictive power in men and women. Further, as discussed earlier, VAI exhibited the strongest correlations with three of four cardiometabolic risk indices, whereas WHR, WC and WHtR showed similar correlations but relatively lesser strength, and BMI showed the weakest correlations. These results suggest that VAI may be better than other adiposity indices in identifying cardiometabolic risk. The high predictive power of VAI has been reported by several studies and contradicted by others. VAI has recently been proposed as a valuable indicator of visceral adipose function and its increase is strongly associated with cardiometabolic risk in Caucasian Sicilian population[7,8]. Similar results have been obtained in a study with Chinese adults showing that VAI is a better and convenience surrogate marker for visceral adiposity and in identifying diabetes risk[9]. In a cross-sectional survey with Brazilian cohort, VAI has proven to be a good predictor for cardiometabolic syndrome components[24]. However, the ability of VAI in identifying cardiometabolic and diabetes risk has not been found to be better than WHtR in Iranian population[11]. In a study with Peruvian adults, no single adiposity measure has been identified as best predictor for cardiometabolic syndrome[12]. Indeed, heterogeneity of study populations may explain the discrepancy in the results of these studies. Thus, the applicability and usefulness of VAI in predicting cardiometabolic risk necessitate further investigations especially in different populations with different ethnicities.

The principal limitation of this study was the use of cross-sectional data to compare the ability of anthropometric indices to predict cardiometabolic risk factors, thus causality cannot be clearly explained. Nevertheless, we confirmed the high prevalence of cardiometabolic syndrome and its risk indices in Jordanians. We also proved that VAI is reliable, suitable and better than other adiposity indices in identifying cardiometabolic risk.

Conflict of interest statement

The authors report no conflict of interest.

Acknowledgment

The authors would like to thank the Deanship of Scientific Research at The University of Jordan for their financial support.

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