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Serum vitamin D concentration and anthropometric indicators of adiposity in adults without or with low dose statin users: a cross-sectional study

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Abstract

Background This study sought to determine the accuracy of several anthropometric parameters in association with serum Vit. D concentrations and to compare the novel indices with the conventional ones.

Methods A total of 947 individuals referred to the cardiology clinic who have not used statin or take low-dose statin were evaluated through a cross-sectional study. Data on demographic information, anthropometric indices, and biochemical measurements were gathered using a checklist. Both the multivariable regression modeling and the area under the receiver-operating characteristic (ROC) were employed for the analysis.

Results Considering novel indices, BRI (Body Roundness Index) showed the most powerful correlation with serum Vit. D levels among both genders. Among conventional ancient indices, WC (Waist Circumference) had the strongest association in both men and women groups. Based on the confounding factors-adjusted model, the highest odds ratio (OR) for the presence of Vit. D deficiency belonged to WHtR (Waist to Height Ratio) in women (OR, 0.347 (0.171–0.704), $P=0.003$). None of the indices predicted Vit. D deficiency significantly among men. A Vit. D concentration of 4.55 ng/ml was found as a cutoff based on the metabolic syndrome status.

Conclusion The most powerful association with serum Vit. D levels were detected for BRI in both genders among newly developed indices. In addition, WHtR predicted Vit. D deficiency independent of confounding factors among women.

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Key message

• Body Roundness Index is the most powerful correlated novel parameter with serum Vit. D levels among both genders.
• Among conventional indices, Waist Circumference had the strongest association in both men and women groups.
• Waist to Height Ratio predicted Vit. D deficiency independent of age, triglyceride level, Fasting blood sugar, Systolic blood pressure, and supplement intake among women.
• A Vit. D concentration of 4.55 ng/ml was found as a cutoff based on the presence of metabolic syndrome.

Keywords 25-hydroxyvitamin D3, Obesity, Anthropometry, Body mass index, Metabolic syndrome

Introduction

It has been estimated that about one billion people have vitamin D (Vit. D) deficiency around the world [1] ranging from 10 to 70% across different countries including Iran [2–6]. Based on the second National Integrated Micronutrient Survey (NIMS) the prevalence of vitamin D deficiency was 23.3% in infants aged 15–23 months, 76% in adolescents, 59.1% in adults, and 85.3% in pregnant women [6]. It is well-known that Vit. D deficiency can cause osteomalacia in adults and rickets in children [7]. However, considering the importance of this micronutrient with significant roles in cardiovascular function, the control of cell growth, and the immune system, 25(OH) Vit. D deficiency has recently been introduced as one of the risks of cardiovascular and cancer-related deaths [8]. Other approved conditions associated with low Vit. D serum levels are metabolic syndrome and obesity, autoimmune disorders, insulin resistance and diabetes, dementia, and sepsis [9–12]. Interestingly, Vit. D deficiency is feasible to detect and easy to replace.

Obesity is a preventable disease that needs more attention among health issues because of its significant social, economic, and psychological effects [13]. In addition to genetic predisposition, this condition is still believed to result from a sedentary lifestyle with inappropriate nutritional programs [14]. Lending to various abnormalities, such as increased blood pressure, high blood sugar, excess waist fat, and abnormal lipid profile, associated with more complications including diabetes, cardiovascular disease, and premature mortality [15]. Centers for Disease Control and Prevention (CDC) has declared an obesity prevalence of 42.4% among U.S. adults in 2017–2018 being most prevalent among the middle-aged population [16]. According to a meta-analysis of 2023 in Iran, the overall prevalence rates of overweight and obesity was close to 35.09% [17] which varied across different age groups. The rates of overweight and obese among the total population were 20.1% and 13.44%, respectively with higher proportion among those aged 18 years and above (35.26% for overweight and 21.38% for obesity) while lower among children below 18 years (11.71% for overweight and 8.08% for obesity).

To estimate the magnitude of obesity/overweight we may use the conventional anthropometric indices which include measurements like Body Mass Index (BMI) and waist circumference, or the novel indices which incorporate additional factors such as body fat distribution, body composition, and metabolic health markers to provide a more comprehensive assessment of obesity For obese people who are at higher risk of metabolic syndrome, body mass index (BMI) has been used extensively recently among other indices though some recent studies have found low to moderate sensitivity for obesity detection [18, 19]. Half of adults with excess body fat were defined as non-obese using BMI [19]. Therefore, the use of more tools was sensible which could allow us to distinguish the lean mass from the fat mass. Visceral fat can be evaluated with techniques, such as bioelectrical impedance analysis, MRI (magnetic resonance imaging), and computerized tomography (CT) scans [20–22], though they are expensive and are with some radiation hazards. The use of the new body shape index like body Shape Index (BSI) based on WC and adjusted for height and weight is superior in predicting mortality hazard independently than body mass index [23]. Lipid Accumulation Product (LAP) is also a new index for assessing the body fat mass using WC and TG concentration, and the last one is Visceral Adiposity Tissue (VAI) as a sex-specific factor to predict metabolic syndrome [24].

A systematic review and meta-analysis of 23 observational studies showed that the prevalence of Vit. D deficiency was 35% higher in obese adults than a normal-weighted group independent of their age, Vit. Levels/level cut-offs, and the study location [9]. A study by Abiaka on the Omani population showed an association between serum Vit. D levels and BMI, but they found the weight-to-hip ratio (WHR) as the predictor of Vit. D deficiency [25]. In a study in New Zealand, low serum vitamin D3 was inversely related to weight and BMI, but not to the fat mass [26]. Bardini et al. suggested inverse associations between 25(OH) Vit. D levels and BMI, WC, and LAP with good predicting capacity among both Type 2 diabetic females and males [27]. Sousa-Santos et al. found that 25(OH)D levels were correlated with not only BMI and WC but also BRI and BSI in the older

adult Portuguese population [28]. In the same breath, the Chinese study also documented an association between 25(OH)D levels and obesity indices exclusively among participants aged 45–64 years, regardless of their sex. In addition to this, the study found that mean values of BMI, WC, WHtR, and BRI increased with 25(OH)D insufficiency [29]. In contrast, one study evaluating women among childbearing age reported negative association between 25(OH)D level and WC and WHtR [30].

Given the conflicting results documented earlier and limited studies on newly developed, we aimed to gather a wide range of anthropometric indices and examined the nature of obesity and Vit. D level dependency on ethnicity and geographical place, contextually to clarify interrelations between serum Vit. D levels and anthropometric indices.

Materials and methods

Study design and participants

Tehran, the capital city of the Islamic Republic of Iran, is located at the center of Iran with geographic coordinates of 35.6892° N and 51.3890° E, with an average annual temperature of 23.19 °C (range: 8.3–36.8 °C). The longest average daylight is perceived in June (14.5 h) and December is the month with the shortest days (9.8 h). This cross-sectional study was conducted at Sina Hospital, affiliated with Tehran University of Medical Sciences, from January 2018 to April 2019. Patients who were referred to the cardiology clinic of the hospital were enrolled with consecutive sampling. Of the 947 referred subjects, 864 of them had complete sets of data.

Data collection and procedure

Experienced nurses were trained for 3 days and standardized their data collection methods on anthropometric measurements and completion of forms to decrease inter-rater bias. All participants were aware of the research goals and signed informed consent forms at the beginning of participation. This study was approved by the Ethics research committee of the Tehran University of Medical Sciences (code: IR.TUMS.VCR.REC.1397.061). Study design and implementation were based on the Declaration of Helsinki and good practice (GCP) guidelines. All patients referred to the center on low-dose Statins (Lovastatin 20 mg daily or Simvastatin: 10 mg daily) were included regardless of the season due to their minimal effect on TG levels while those on high-dose Statins were excluded. In addition, all pregnant and those with acute conditions such as decompensated heart failure, stroke, infection, patients with chronic diseases like rheumatologic disorders and took supplements were also excluded.

The tool used had several components like demographic information, lifestyle, past medical history, and medication or supplementation use; anthropometric measurements and lab investigations such as fasting blood sugar level, serum vitamin D and lipid panel test.

Anthropometric measurements

Body weight and height were measured with accuracies of 0.1 kg and 0.1 cm using the Seca 755 Dial Column Medical Scale and a standard stadiometer while patients were standing, wearing light clothes without shoes, respectively. Weight divided by height squared (kg/m2), was used for BMI calculation. The midpoint between the top of the hip bone and the bottom of the ribs was measured as WC, maximal protuberance of gluteal measured as hip circumference using a single tape. A body composition analyzer, BC-418 MA (TANITA, Tokyo, Japan), was used for the evaluation of anthropometric indices including total fat percentage, total fat mass, and total free fat mass [31].

VAI and LAP, as sex-specific indices, were calculated using the equation mentioned below (TG and HDL are expressed in mmol/l). For males: VAI = (WC/39.68+(1.88×BMI)) × (TG/1.03) × (1.31/HDL), for females: VAI = (WC/36.58+(1.89×BMI))×(TG/0.81)×(1.52/HDL) [32], and LAP = (WC-65) × TG for men and (WC-58) × TG for women [33].

BSI was calculated using the formula, BSI = WC / ($BMI^{2/3}$x $height^{1/2}$) [23], where WC and height are in meters. BRI was calculated using the Eq. $364.2-365.5\sqrt{1-((\mathrm{WC\,[m]}/2\pi)2(0.5\mathrm{height\,[m]}))}$ [34]. BAI was calculated using the equation (hip circumference (cm)/height $(m)^{1.5}$) − 18) [35]. WHtR of patients is defined as WC divided by height, with the same units as both measures. WHR is defined as their WC divided by hip circumference, both measured with the same units [36].

FMI and FFMI were measured by calculating the total fat mass and free fat mass by a body composition analyzer and then using the formulas: FMI = fat mass/height squared (m^2) and FFMI = fat-free mass/height squared (m^2) [31].

Biochemistry evaluations

Levels of fasting blood sugar (FBS), triglyceride (TG), cholesterol (CHOL), low-density lipoprotein (LDL), and high-density lipoprotein (HDL) were evaluated after fasting for 12 h. The enzymatic colorimetric technique was implemented for fasting plasma glucose (FPG). Serum lipids were determined using an Erba Mannheim auto analyzer XL-640 (Erba Diagnostics Mannheim, Germany) with a Pars Azmoon reagent kit (Tehran, Iran). Then, the low-density lipoprotein-cholesterol (LDL-cholesterol) level was calculated based on Fried Ewald's formula [37]. In cases with serum triglyceride levels of more than 400 mg/dl, LDL cholesterol was directly measured

Table 1 Clinical anthropometric measures, indices and measure indicators adjusted for gender and VitD status

Gender	Males (499, 57.8%)				Females (365, 42.2%)			
characteristic	Normal (vit D ≥ 30)	Insufficient (30 > vit D > 15)	Deficient (vit D ≤ 15)	*P* value	Normal (vit D ≥ 30)	Insufficient (30 > vit D > 15)	Deficient (vit D ≤ 15)	*P* value
Age (years)	62.62 ± 10.88	57.91 ± 11.92	57.90 ± 11.917	0.008* #	57.73 ± 11.97	54.09 ± 12.60	50.41 ± 14.33	0.001*#
Anthropometric measures								
BMI (kg/m^2)	27.22 ± 6.48	28.25 ± 5.78	28.05 ± 7.50	0.361	32.72 ± 7.96	34.45 ± 8.42	37.13 ± 10.68	0.015*#
WC (cm)	99.65 ± 17.75	101.67 ± 15.74	110.76 ± 22.75	0.192	108.25 ± 13.43	112.06 ± 14.22	122.28 ± 16.33	<0.001*
HC (cm)	143.50 ± 21.92	142.15 ± 16.16	140.15 ± 11.91	0.898	140.13 ± 27.17	136.81 ± 9.59	139.44 ± 11.88	0.552
WHtR	0.59 ± 0.09	0.60 ± 0.08	0.64 ± 0.12	0.002 *#	0.69 ± 0.08	0.71 ± 0.08	0.76 ± 0.10	< 0.001 *#
WHR	1.01 ± 0.10	0.98 ± 0.04	1.03 ± 0.06	0.161	0.87 ± 0.11	0.89 ± 0.06	0.91 ± 0.09	0.167
Past history								
Hypertension (%)	9.8%	44.5%	45.6%	0.703	23.5%	36.6%	39.9%	0.127
Smoking (%)	52.2%	67%	71.2%	0.139	2.8%	3%	12.5%	0.137
Supplement intake (%)	4.2%	1.9%	0.4%	< 0.001*#	16.7%	1.6%	1.9%	< 0.001*#
Biochemistry measures								
FBS (mg/dl)	110.40 ± 35.11	110.30 ± 34.48	119.55 ± 43.27	0.391	116.76 ± 52.22	107.96 ± 33.64	133.07 ± 61.13	0.453
HbA1c	5.79 ± 0.39	5.57 ± 0.46	5.76 ± 0.53	0.066	5.70 ± 0.28	5.66 ± 0.42	5.86 ± 0.71	0.872
hsCRP	0.47 ± 1.40	0.39 ± 0.63	0.54 ± 0.83	0.831	0.32 ± 0.31	0.26 ± 0.32	0.34 ± 0.22	0.548
Fasting insulin (IU/L)	13.34 ± 17.88	13.00 ± 11.62	14.70 ± 13.73	0.733	15.02 ± 8.01	12.98 ± 10.04	15.97 ± 9.73	0.325
Serum Cr (mg/dl)	0.99 ± 0.25	0.91 ± 0.18	0.95 ± 0.20	0.240	0.78 ± 0.22	0.79 ± 0.21	0.70 ± 0.22	0.624
TG (mg/dl)	135.48 ± 66.72	143.27 ± 77.34	152.10 ± 77.32	0.243	133.37 ± 56.27	153.48 ± 69.63	161.66 ± 77.45	0.013*
Tch (mg/dl)	165.76 ± 47.26	175.80 ± 46.50	181.54 ± 46.03	0.235	193.45 ± 44.54	195.53 ± 41.85	197.05 ± 46.10	0.693
LDL (mg/dl)	97.59 ± 35.15	105.34 ± 37.23	104.61 ± 37.32	0.185	114.97 ± 39.47	121.97 ± 36.55	118.17 ± 41.24	0.381
HDL (mg/dl)	39.41 ± 8.25	40.19 ± 12.66	38.32 ± 10.24	0.878	46.02 ± 12.50	45.77 ± 13.46	41.62 ± 8.28	0.100
Hb (mg/dl)	14.72 ± 2.00	15.24 ± 1.42	15.35 ± 1.35	0.219	13.69 ± 1.35	13.62 ± 1.36	13.37 ± 1.15	0640
Anthropometric indices								
LAP	56.57 ± 40.29	63.70 ± 59.04	84.76 ± 70.90	0.128	80.70 ± 41.14	95.46 ± 55.95	118.10 ± 67.81	0.009*
BAI	43.36 ± 7.90	43.29 ± 5.85	42.08 ± 6.37	0.911	54.27 ± 14.18	50.08 ± 4.66	50.81 ± 6.14	0.056
VAI	1.97 ± 0.93	2.35 ± 1.42	2.54 ± 2.06	0.060	2.91 ± 1.90	3.19 ± 1.78	3.16 ± 1.71	0.382
BRI	5.40 ± 2.29	5.57 ± 2.11	6.82 ± 3.27	0.237	7.98 ± 2.36	8.39 ± 2.14	9.97 ± 3.12	0.004*
BSI	0.08 ± 0.00	0.08 ± 0.00	0.08 ± 0.00	0.151	0.08 ± 0.00	0.08 ± 0.02	0.07 ± 0.00	0.784

*significant for comparison of deficient versus normal groups, #significant for comparison of insufficient versus normal groups, $ significant for comparison of deficient versus insufficient groups

by the enzymatic method using commercial kits (Pars Azmoon, Karaj, Iran).

The concentration of 25(OH) Vit. D was measured by the direct competitive immunoassay chemiluminescence method using LIASON® 25 OH Vitamin D assay TOTAL (DiaSorin, Inc.), with a coefficient of variation of 9.8%.

Table 2 The area under the curve, cut off, sensitivity and specificity of each anthropometric measures for the presence of vitamin D deficiency in both genders

Predictors	Female					Male				
	PCC	Cut off	sens	spec	AUC(95%CI)	PCC	Cut off	sens	Spec	AUC(95%CI)
WC	-0.277*	107.32	0.68	0.57	0.37(0.52–0.76)	-0.188*	113.86	0.61	0.74	0.47(0.34–0.67)
HC	-0.079	116.55	0.67	0.44	0.41(0.45–0.70)	0.105	115.69	0.65	0.51	0.59(0.47–0.72)
WHR	-0.102	0.92	0.51	0.63	0.44(0.47–0.71)	-0.175	0.94	0.72	0.62	0.28(0.19–0.54)
WHtR	-0.247*	0.74	0.72	0.60	0.41(0.55–0.79)	-0.171*	0.93	0.70	0.45	0.48(0.35–0.73)
LAP	-0.185*	67.43	0.60	0.52	0.44(0.57–0.78)	-0.165*	90.27	0.53	0.65	0.39(0.29–0.61)
VAI	-0.012	2.05	0.77	0.48	0.52(0.53–0.75)	-0.114	2.26	0.58	0.53	0.37(0.23–0.51)
BSI	0.050	0.08	0.35	0.67	0.56(0.52–0.76)	-0.085	0.08	0.50	0.61	0.63(0.47–0.88)
BRI	-0.246*	7.73	0.63	0.69	0.41(0.55–0.79)	-0.169*	6.51	0.68	0.65	0.48(0.33–0.81)
BAI	0.007	41.89	0.61	0.58	0.48(0.50–0.74)	0.058	38.66	0.51	0.70	0.59(0.41–0.76)

Abbreviations: PCC (Pearson Correlation Coefficient), WC (waist circumstance), HC (hip circumstance), BMI (body mass index), WHR (Waist to hip ratio), WHtR (waist-to-height ratio), BSI (body shape index), BRI (body roundness index), BAI (body adiposity inde). (*) means statistically significant (P < 0.05)

Definitions

Metabolic syndrome refers to three or more out of five criteria based on the Adult Treatment Panel III (ATPIII) Guideline. Vit. D deficiency is defined as a serum 25(OH) Vit. D concentration < 20 ng/mL (50 nmol/L). Vit. D insufficiency is defined as a 25(OH) Vit. D concentration < 30 ng/mL [38]. A level of 30 > BMI ≥ 25 was determined as overweight and obesity was defined as BMI ≥ 30.

Statistical analysis

Quantitative and qualitative variables are reported as mean ± standard deviation (SD) and as percentages. To detect significant differences, an independent t-test and chi-square test were employed for quantitative and categorical variables, respectively. Pearson's correlation test was used to examine the associations between anthropometric indices and serum Vit. D levels. The receiver operating characteristic (ROC) curve and the area under the curve (AUC) with 95% confidence intervals (CIs) were used to assess the power of each anthropometric measure. ROC curves are interpreted as the probability that the modeled phenotype(s) can correctly discriminate subjects developing endpoints from those without end points, where 0.5 is chance discrimination and 1.0 is perfect discrimination. To determine the optimal thresholds, the point on the ROC curve with maximum Youden index [sensitivity- (1-specificity)]), and the point with shortest distance value from the point (0,1) [(1 - sensitivity)^2 + (1 - specificity)^2] were calculated [39]. Due to the gender-specific nature of some indices [40], data were analyzed in two subgroups for men and women. The odds ratios (ORs) and their 95% CIs for the presence of Vit. D deficiency was estimated by binary logistic regression analysis (dependent variable: Vit. D deficiency, independent variables: anthropometric indices). Variables were adjusted for age, triglyceride, FBS, SBP, and supplement intake. All statistical analyses were performed using IBM SPSS Statistics 20.0 (SPSS Inc., Chicago, IL, USA). *P*-values < 0.05 were considered statistically significant.

Results

In the final analysis, 864 out of 947 participants, with a complete set of data, were included in this study. The proportion of males and females was 57.8% and 42.2%, respectively.

Table 1 shows baseline anthropometric and biochemical parameters of individuals based on serum levels of 25(OH) Vit. D. The deficient group had the highest percentage (44.7%), while insufficient and normal levels of 25(OH) Vit. D levels were recorded in 38.8% and 13.7% of participants, respectively. Moreover, 29.3% of participants had a BMI < 25, 48.1% were overweight, and 22.6% were obese.

Table 3 Odds ratio (95% CI) of the presence of vitamin D deficiency for each anthropometric measure

Predictors	Females		Males	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
BMI	0.492(0.075–3.154)	0.864	0.069(-0.006-3.050)	0.955
WC	0.505(0.090–2.835)	0.125	0.687(0.337-1.400)	0.556
HC	0.453(0.013–0.763)	0.427	0.260(-0.086-5.029)	0.648
WHR	0.862(0.430–1.728)	0.437	0.074(-0.259-8.119)	0.301
WHtR	0.347(0.171–0.704)	**0.003**	0.715(0.205–2.487)	0.597
LAP	0.882(0.473–1.647)	0.372	0.701(0.320–1.530)	0.693
VAI	0.341(0.031–2.108)	0.715	0.322(0.112–1.673)	0.565
BSI	0.122 (0.006–1.024)	0.882	0.200(0.013–2.009)	0.701
BRI	0.564(0.223–1.429)	0.227	0.496(0.182–1.370)	0.176
BAI	0.365(0.036–1.872)	0.886	0.017(0.004–0.998)	0.762
MetS	0.766(0.486–1.208)	0.225	0.802(0.364–1.765)	0.586

Abbreviations: WC (waist circumstance), HC (hip circumstance), BMI (body mass index), WHR (Waist to hip ratio), WHtR (waist-to-height ratio),BSI (body shape index), BRI (body roundness index), BAI (body adiposity index), LAP (lipid accumulation product), VAI (visceral adiposity index); Model: Adjusted for Age, Triglyceride, Fasting blood sugar, Systolic blood pressure and supplement intake

Out of newly developed indices, mean differences of LAP (p-value = 0.009) and BRI (p value = 0.004) were significant among females according to the serum level of 25(OH) Vit. D, but no significant differences were detected among males. BMI, WC, and WHtR (p-value = 0.015, < 0.001 and 0.001, respectively) showed significant mean differences in the female group, while only WHtR (p-value = 0.002) showed the mentioned effect among males.

After adjustment for sex, Pearson correlation of 25(OH) Vit. D with anthropometric indices showed inverse significant associations with WC (r = -0.188, p = 0.005), WHtR (r = -0.171, p = 0.017), LAP (r = -0.169, p = 0.014), and BRI (r = -0.165, p = 0.015) in the male group. Almost the same pattern was observed in the female group, where 25(OH) Vit. D levels were inversely correlated with WC (r = -0.277, p < 0.0001), LAP (r = -0.185, p = 0.004), and BRI (r = -0.246, p < 0.0001) in the female group. The correlation between 25(OH) Vit. D and BMI were inversely significant only in women (r = 0.165, p = 0.002) and was not seen in the male group (r = -0.034, p = 0.456). Scatter plots are shown in Fig. 1.

Regarding the area under the curve analysis, BSI represented the best AUC [AUC (95% CI) = 0.56(0.52–0.76)] not only among women but also among men [AUC (95% CI) = 0.63(0.47–0.88)], although it showed only a sufficient power in discriminating Vit. D-deficient from normal persons (Table 2).

After structuring a model to predict Vit. D deficiency considering age, triglyceride, FBS, SBP, and supplement intake as confounding factors (factors selected according to clinical concepts and for being a component of metabolic syndrome), only WHtR predicted Vit. D deficiency independent of the mentioned variables with OR = 0.347(0.171–0.704) and P value = 0.003 in the

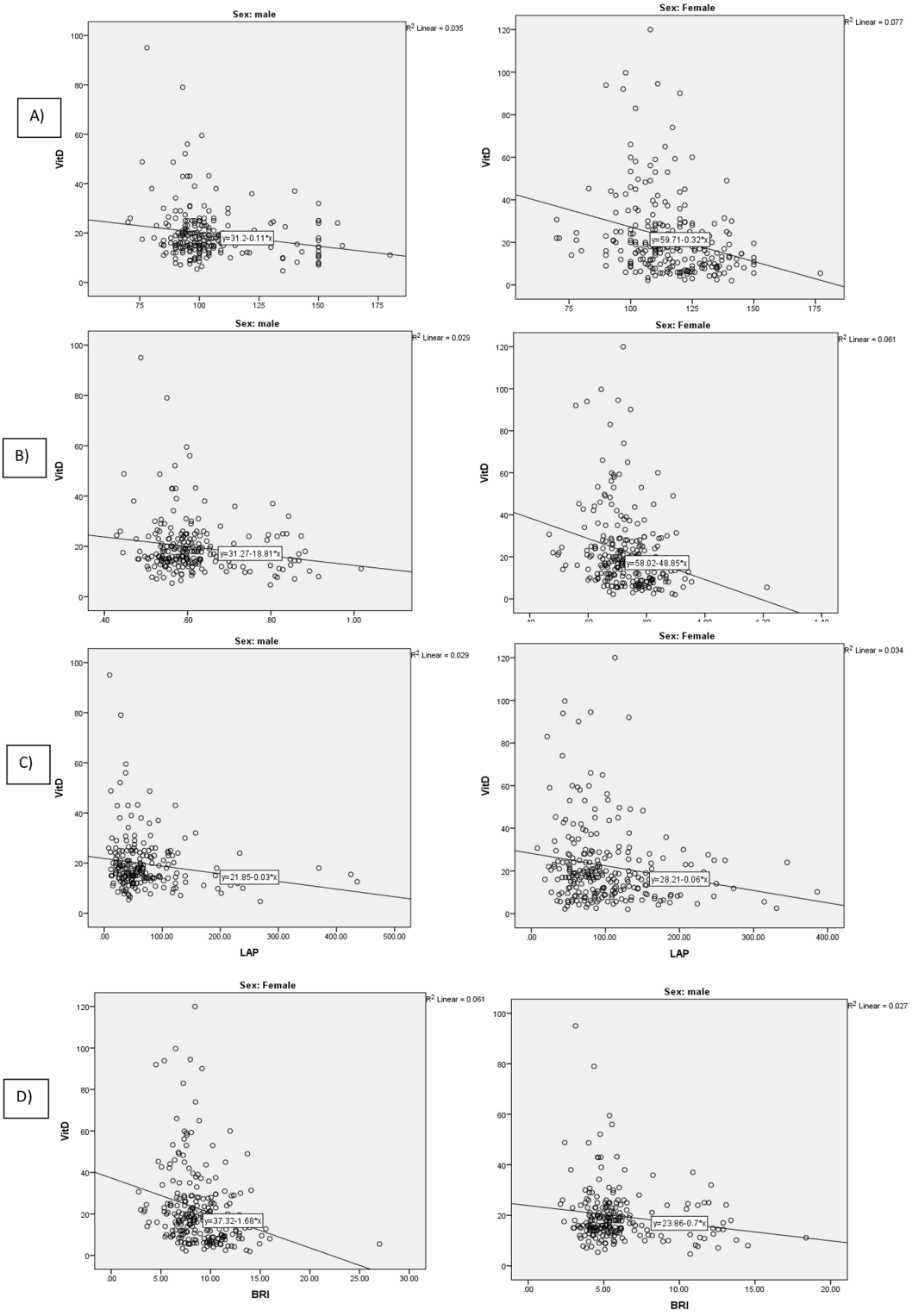

Fig. 1 Scatter plot of serum VitD level and (**A**) WC, (**B**) WHtR, (**C**) LAP, (**D**) BRI association in both genders

women group but not in the men group (Table 3). Finally, the optimal cut point of Vit. D levels was calculated to differentiate patients with metabolic syndrome from those without Metabolic syndrome [Fig. 2].

Discussion

The association between serum Vit. D levels and obesity indices detected through this cross-sectional study. BRI is introduced as the most powerful correlated index with Vit. D concentrations among men and WC among women. After adjusting for age, triglyceride, FBS, SBP, and supplement intake, WHtR predicted a significant Vit. D deficiency in the female group.

There are three mechanisms to explain how Vit. D concentrations could inversely be related to obesity. First, impairing insulin resistance by altering metabolic processes in adipose tissue in Vit. D deficiency [41, 42]. Second, sequestration of Vit. D is a fat-soluble agent in a large number of adipose tissues [43]. Third, less skin surface area among the obese population with limitations in Vit. D anabolism [44]. Another psychological point of view emphasizes less tendency of obese people to be in the community leading to limited sun exposure, however, this hypothesis has not been yet studied [45].

Although the aforementioned correlation was reported in some previous studies [9, 46, 47],the findings regarding ethnicity differences and their effect on anthropometric indices are controversial. Sousa-Santos et al. showed BRI as the most relevant obesity index with the greatest odds ratio in the prediction of Vit. D level [28]. In other study on the Omani population, Abiaka et al. suggested WHR as the best predictor of Vit. D levels evaluating anthropometric indices [25]. Zhu et al. studied Chinese people and concluded that BRI among women and BSI and BRI among men in the line of BMI, WHtR, and WC could predict Vit. D concentrations regardless of adjustments [29]. Considering the first and second mechanisms mentioned above, WC is an indicator of central obesity and the third mechanism reinforces surface importance, BRI, and WHtR as indices constructed from WC and height, which are reasonable choices for the best-associated candidates with Vit. D concentrations. Although BRI and BSI showed some capacity to be used as obesity indices to identify adults at risk of Vit. D deficiency, conventional indices are still more powerful in this regard. Additionally, serum Vit. D level cut-off was reported here for the first time to discriminate patients with and without metabolic syndrome.

A recent systematic review examined the relationship between serum vitamin D levels and various measures of body fat and body size across different age groups. The review found an inverse association between vitamin D

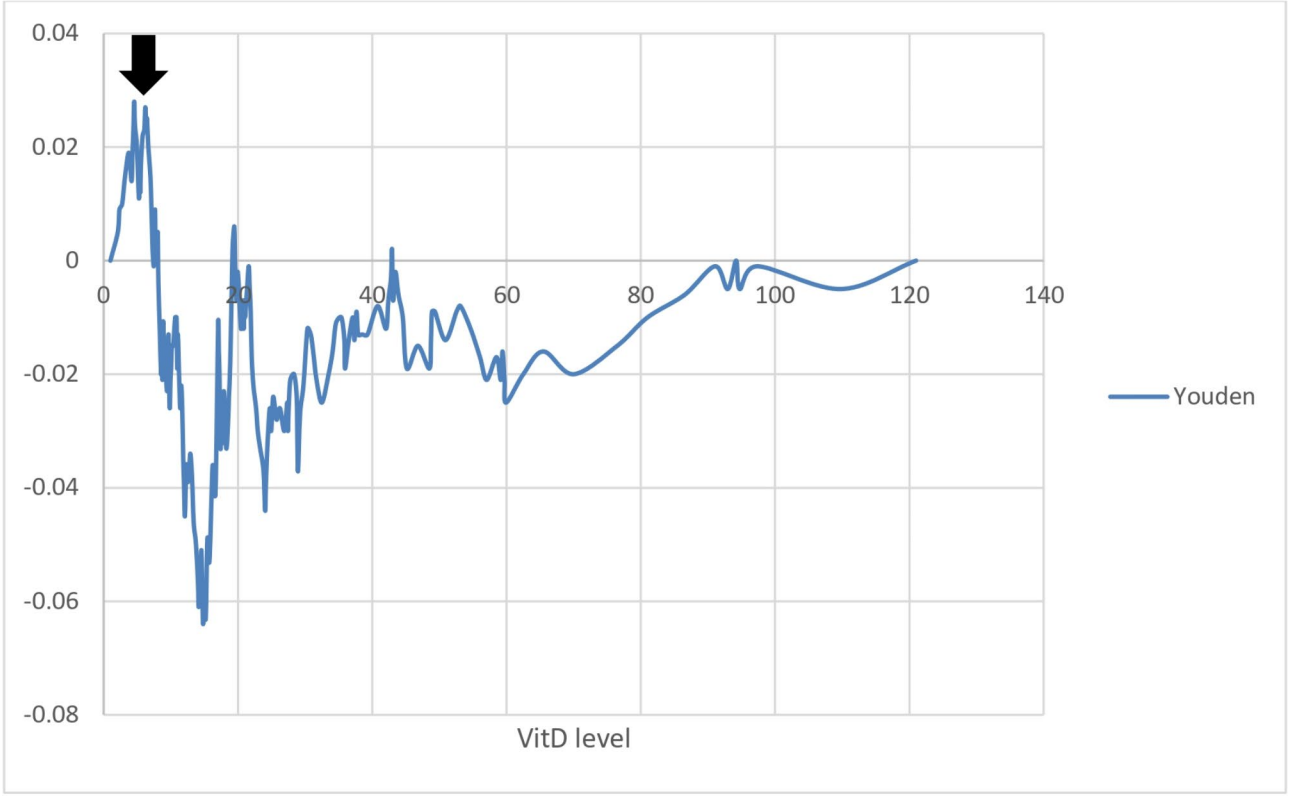

Fig. 2 The optimal cut of point of Vit D level for differentiating patients with metabolic syndrome from patients without MetS (arrow shows cutoff = 4.55)

levels and adiposity indicators, particularly in females among both pediatric and adult populations, highlighting that the relationship between vitamin D and adiposity is consistent across different age groups. The review also noted the importance of considering confounding factors that might influence the relationship between vitamin D and adiposity, such as dietary habits, physical activity, and exposure to sunlight [48].

Limitations

The strength of this study is that we used efficient sample size and evaluation of a wide range of anthropometric indices contextually in addition to clarifying some of the conflicting results documented elsewhere. Nonetheless, it had some limitations due to the nature of the study design employed in which we are unable to confirm causality relationships. In addition, although variables in multivariate regression analysis were adjusted as far as possible to find confounding factors, it might have been possible to miss some factors. We also did not assess the patient's amounts of physical activity, as well as sun exposure, or fat mass percentage. Since our study included a population who were referred to the cardiovascular unit, we excluded those with high Statin users and enrolled those with low dose Statin users or none, therefore the findings need to be interpreted cautiously in terms of generalizability.

Conclusion

In summary, the most powerful association with serum Vit. D level was detected for BRI in both genders among newly developed indices. In addition, WHtR predicted Vit. D deficiency among women independent of confounding factors. Other indices were not significant in the prediction after adjustments.

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Author contributions

All authors contributed to data gathering, data analysis, drafting, or revising the manuscript. They approved the final version of the manuscript to be published and agreed to be responsible for all aspects of the work.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

All participants were aware of the research goals and signed informed consent forms at the beginning of participation. This study was approved by the Ethics research committee of the Tehran University of Medical Sciences (code: IR.TUMS.VCR.REC.1397.061). Study design and implementation were based on the Declaration of Helsinki and good practice (GCP) guidelines.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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