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Superiority of the body roundness index over BMI in linking central adiposity with vitamin D3: A cross-sectional study in Iraqi adults

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ABSTRACT

Background: Body mass index is a poor measure of central adiposity. The Body Roundness Index may be a better measure, although data for Middle Eastern adults are limited.

Objectives: To investigate the association of animal-fat consumption with adiposity indices as well as vitamin D3, and compare BRI with BMI as a marker of body fat in Iraqi adults.

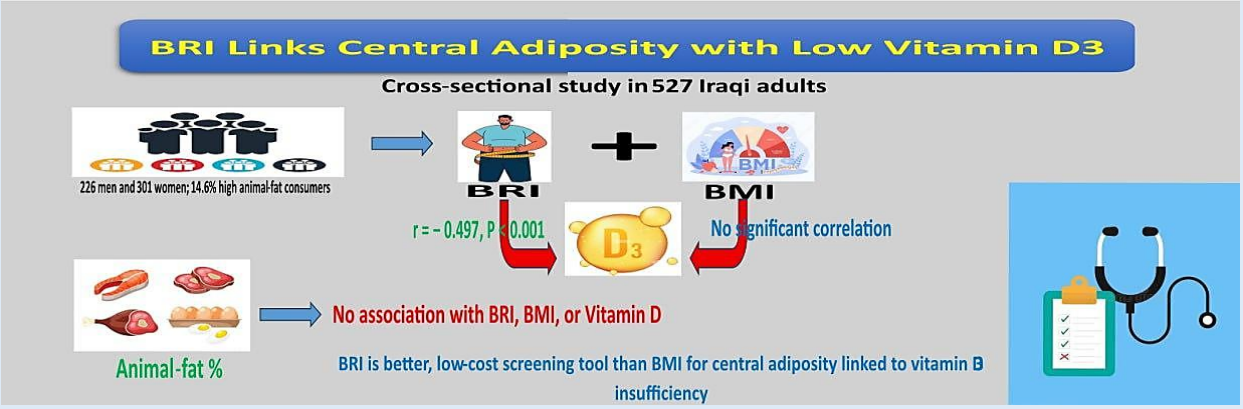
Methods: We used dietary questionnaires, anthropometry, and bioelectrical impedance to estimate visceral fat area and serum vitamin D3 in a cross-sectional study of 527 adults. Correlation and regression analyses were performed.

Results: There was no association between animal-fat intake and the adiposity indices or vitamin D3. In contrast with BMI, BRI presented a quite strong inverse correlation with vitamin D3 ($r = –0.497$, $p < 0.001$). Visceral fat area was not predicted by any of the indices.

Novelty explicit: In this adult sample from Iraq, BRI is more helpful than BMI for detecting central adiposity, which is associated with vitamin D3 insufficiency; as a result, BRI may be a better screening tool in a clinical and epidemiological context.

Conclusion: BRI was a better indicator of metabolic risk associated with adiposity than BMI. In both clinical and epidemiological settings, it might be a beneficial screening tool for central adiposity and Vitamin D deficiency.

Keywords: Body Roundness Index; Vitamin D3; Visceral fat; Body Mass Index; Adiposity.



Graphical Abstract: Superiority of the body roundness index over BMI in linking central adiposity with vitamin D3: a cross-sectional study in Iraqi adults

INTRODUCTION

Obesity remains one of the most critical public health challenges of the 21st century, with its prevalence increasing worldwide despite decades of intervention efforts. The World Health Organization reported that in 2022, more than 1.9 billion adults were overweight and more than 650 million were obese [1]. It is worth noting that obesity per se is not a homogeneous condition, as adipose tissue distribution is critical in defining health. Visceral or abdominal obesity, of which visceral fat is the major contributor, has a higher correlation with insulin resistance, type 2 diabetes (DM), hypertension, non-alcoholic fatty liver disease (NAFLD), and cardiovascular (CV) diseases morbidity and mortality than general obesity [2].

Classical anthropometric indices, such as Body Mass Index (BMI), continue to be used for the classification of overweight and obesity, despite known deficiencies in their ability to differentiate between lean and fat mass or to account for adipose tissue distribution [3]. Waist circumference (WC) and waist-to-hip ratio (WHR) are better indicators of abdominal adiposity; however, they also lack precision in reflecting 3-dimensional body shape. To fill this gap, the Body Roundness Index (BRI) was proposed as a geometrical index based on WC and height. BRI was found to represent Visceral Adipose Tissue (VAT) better and to predict CV risk in several population studies [4–6], compared with BMI and WHR. Recent findings underscore the BRI as a reliable marker for CV risk stratification. Most cross-sectional studies have shown that serum vitamin D levels are inversely associated with adiposity indicators and that an elevated BRI is linked to a higher risk of CV diseases in patients with cardiometabolic syndrome[7–9].

Dietary habits are central to the occurrence and progression of obesity. Nutrition transitions involving the adoption of energy-dense, high-fat diets have driven escalating rates of metabolic disease worldwide in recent decades [10]. Some types of dietary fats are especially problematic, such as saturated fats from animal sources.

Epidemiological evidence associates high consumption of animal fat with insulin resistance, systemic inflammation, and increased visceral and hepatic fat accumulation [11-12]. In contrast, replacing animal fat with unsaturated plant-derived fats has been linked to reduced ectopic fat accumulation and lower cardiometabolic mortality [13-14]. However, other studies do not report such consistent associations, whereas genetic predisposition, sex-specific differences, and the overall dietary context may influence these effects [15]. Therefore, additional studies are needed to elucidate the impact of animal-fat consumption on body composition and fat distribution.

Another point closely associated with obesity and metabolic health is vitamin D3 (cholecalciferol). Beyond its classical role in calcium and phosphate metabolism, vitamin D3 exerts numerous effects on immune function, glucose metabolism, and inflammation [16-17]. Despite abundant sunlight in many parts of the world, an estimated 1 billion people suffer from vitamin D3 deficiency [18]. Obesity is also consistently linked to reduced blood vitamin D levels, which may result from volumetric dilution, sequestration of the fat-soluble vitamin within adipocytes, and various abnormalities in signaling by vitamin D3 receptors [19-20]. On this note, previous studies have reported that vitamin D3 status is significantly associated with central adiposity indices such as BRI, WC, and WHR, rather than BMI [8,21]. Obese participants also exhibit a diminished induction of biomarkers in response to vitamin D3 supplementation, supporting the clinical significance of this relationship [22].

There have been few investigations of the combined effects of dietary animal-fat intake, BRI, visceral adiposity, and vitamin D3 status in an adult population, despite the progress of nutrition epidemiology, among adult populations in areas with recent marked changes in the traditional diet. As is the case for many countries in the Middle East, Iraq has undergone a rapid increase in overweight, obese, and non-communicable diseases in recent years, partly because of the proliferation of westernized dietary patterns high in animal fats [23]. The way these dietary exposures interact with new measures of adiposity and micronutrient status must be elucidated to improve risk assessment and focused interventions. The need for food fortification arises because of the close relationship between humans, health, and food [24]

Improvement in vitamin D3 status through dietary interventions is becoming an increasingly important topic in functional-food research. Experimental and epidemiological evidence suggests that functional formulations and food fortification (such as lipid carriers, bioactive matrices, and probiotic combinations) can raise serum 25(OH)D levels [25]. Finding food-based strategies to boost vitamin D3 levels in people with larger bodies is essential for public-health fortification initiatives and for tailored functional food development, as adiposity alters vitamin D3 distribution and bioavailability [26].

Accordingly, we examined the interrelationships between dietary animal-fat intake, body roundness index (BRI), visceral adiposity, and serum vitamin D3 concentrations in adults. Using anthropometric, dietary, and biochemical variables, we aimed to examine the superiority of BRI as a predictor of metabolic risk over traditional indices and to elucidate the contribution of dietary fat quality and vitamin D status in the relationship between obesity and metabolic risk.

The primary objective of this study is to evaluate the association between BRI and serum vitamin D3 levels in adults. Secondary objectives involved the comparison of adiposity indices (BRI, BMI, body fat %, visceral fat area) across categories of animal-fat intake, the examination of whether dietary animal-fat intake modifies the association between BRI and vitamin D3, and the assessment of the moderating role of family history of obesity or DM in the relationships among animal-fat intake, BRI, and visceral adiposity. The exploratory

objective is to determine whether BRI provides superior predictive ability compared with classical anthropometric measures (BMI, WHR) for vitamin D3 status and adiposity-related risk.

Regarding the research hypotheses and in light of prior research, we predicted that a direct association exists between consumption of animal fat and central adiposity, serum level of vitamin D3 would be inversely related to the BRI, and relative to BMI or any other classic indexes, BRI would dictate favorable relations with vitamin D3 status and adiposity indices.

METHODOLOGY

Study design: A cross-sectional observational study conducted from July 2021 to October 2024 in private specialty referral clinics in Baghdad, Iraq. The study aimed to assess the associations between dietary animal-fat intake and adiposity-related parameters (including BRI and VAI) and other obesity-related parameters. Detailed anthropometric, dietary, and biochemical data were collected and analyzed.

Study Population: This study included 527 adults (226 males and 301 females) with complete anthropometric measurements, body composition, food intake data, serum vitamin D3 concentrations, and family history of obesity or diabetes. Exclusion criteria included incomplete dietary/anthropometric data or implausible energy intakes (±3 standard deviation (SD) from the mean).

Data collection

Anthropometric Measures: Standard procedures were applied to measure height, waist, and hip circumferences. BMI was calculated as weight (kg) divided by height (m). BRI was calculated using a validated formula [27]. The bioelectrical impedance analysis (BIA) was used to measure visceral fat area (VFA, cm^2) and body fat percentage (BFP, %).

Dietary Assessment: A semi-structured questionnaire (Appendix A) was filled in to get the necessary information regarding sociodemographic, lifestyle factors, and animal-fat intake. Feasibility was confirmed in pilot testing in 20 subjects. Intake of animal fat (kcal/d) and total energy (kcal/d) were calculated, and the percentage of daily energy from animal fat was determined. Consistent with European Food Safety Authority 2010 (EFSA 2010) guidelines, participants with consumption above or below 25% of total energy from animal fat were assigned to high (≥25%) or low/moderate (<25%) consumers.

Biochemical Measures: Serum vitamin D3 was measured and classified as sufficient (≥ 30 ng/mL), insufficient (20–29 ng/mL), or deficient (< 20 ng/mL). Family history of obesity or diabetes was self-reported (positive/negative).

Variables: Dietary intake of animal fat and family history were some of the independent variables considered. BRI, BMI, body fat percentage, and VFA were dependent on variables. Cutoffs used: For obesity and central obesity: BMI ≥30 kg/m^2, WC ≥102 cm (men) / ≥88 cm (women); For body fat: >25% (men) / >32% (women), and VFA: >100 cm^2 for elevated risk.

Covariates: Adjusted regression models for waist and hip circumferences, serum vitamin D3, family history, and total energy intake to minimize confounding.

Ethical considerations: The research followed all the guidelines established by the 1964 Declaration of Helsinki and subsequent revisions, as well as other relevant ethical guidelines. In this case, the College of Medicine at Ibn Sina University for Medical and Pharmaceutical Sciences' Scientific Committee granted

its administrative blessing. Everyone who needed to provide consent did so. Instead of names, identification codes were used. Confidential information is stored on a laptop that requires a password and is used only for study.

Statistical Analysis: Using IBM SPSS version 28, the data were statistically analyzed. Descriptive statistics were reported as mean ± SD or frequency (%). Normality was checked using the Shapiro–Wilk. Welch's t-test or Mann–Whitney U tests were used as appropriate, with Cohen's effect sizes. Chi-square tests categorical variables. Pearson's/Spearman's correlations assessed relationships among animal-fat intake, BRI, VFA, and vitamin D3. Multivariable linear regression examined the association between animal-fat intake (% energy) and BRI, with interaction terms for family history and vitamin D3. Statistical significance was set at $P < 0.05$ (two-sided $\alpha = 0.05$).

Conceptual framework diagram of the proposed model of the correlation between the consumption of animal fat in the diet (independent variable) and BRI, visceral adiposity (dependent variables), and metabolic risk. Potential moderating factors, including vitamin D3 status and family history, are adjusted for (Figure 1).

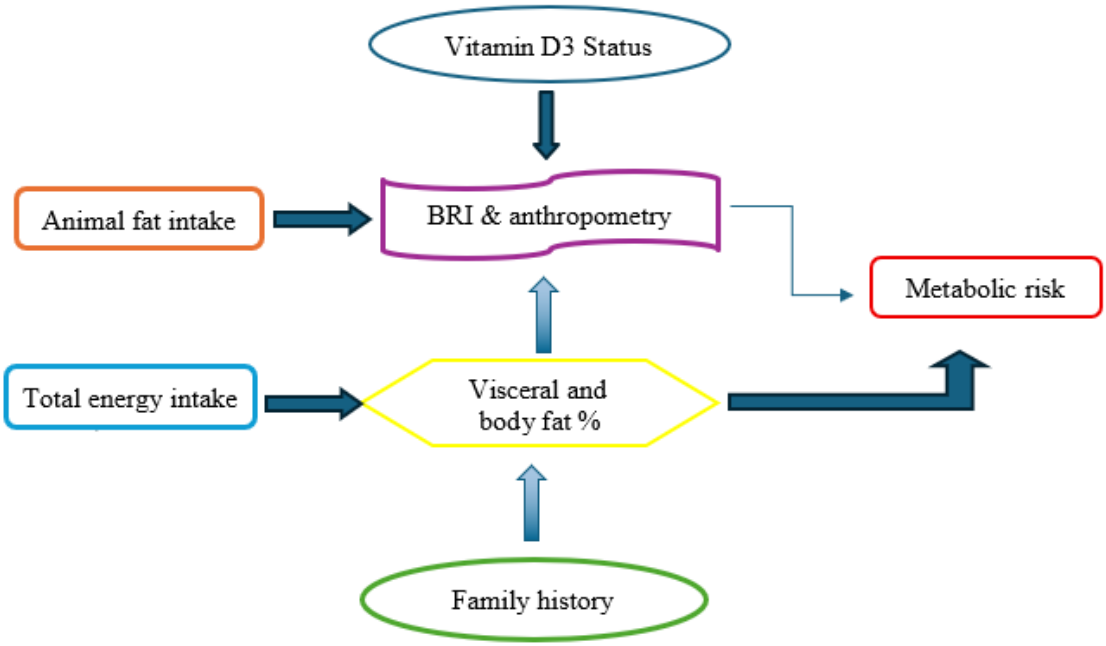


Figure 1: Conceptual framework of the study

RESULTS

Participant characteristics: As shown in Table 1, a total of 527 subjects were included in the analysis: 77 (14.6%) were habitually high secondary animal-fat consumers (≥ 25% of daily energy intake from animal fat) and 450 (85.4%) low/moderate consumers. Baseline participant characteristics are summarized by intake of animal fat. Except for BRI, no significant difference was noted between groups.

Group comparisons: Table 2 shows Between-group comparisons (Welch's t, Mann–Whitney U, and Cohen's d). BRI was also significantly increased in the high animal-fat group (small effect size; $p = 0.008$). There was also a slight difference in body fat %, which was significant in the non-parametric test ($p = 0.042$). There was no significant group difference in BMI, VFA, and vitamin D3.

Table 1: Descriptive statistics for health outcomes by group.

Variable	Group	n	Mean	SD	Median (IQR)
BRI	High	77	4.78	1.61	4.53 (1.78)
BRI	Low	450	4.24	1.60	4.14 (1.98)
BMI	High	77	27.48	4.02	27.40 (5.20)
BMI	Low	450	27.02	3.90	26.90 (5.18)
Body fat (%)	High	77	31.13	5.18	31.20 (7.90)
Body fat (%)	Low	450	29.96	4.83	29.95 (6.52)
VFA (cm^2)	High	77	12.54	2.88	12.40 (3.20)
VFA (cm^2)	Low	450	12.96	3.01	12.90 (3.90)
Vitamin D3	High	77	29.60	6.02	29.67 (7.90)
Vitamin D3	Low	450	30.01	7.03	30.18 (9.87)
Waist (cm)	High	77	94.58	11.34	92.90 (15.70)
Waist (cm)	Low	450	90.28	11.69	90.30 (15.08)
Hip (cm)	High	77	99.95	10.53	100.70 (13.4)
Hip (cm)	Low	450	100.70	10.11	100.35 (13.65)
Animal Fat (%)	High	77	25.36	0.20	25.39 (0.36)
Animal Fat (%)	Low	450	20.50	3.38	21.21 (5.67)
Animal Fat (kcal)	High	77	855.09	24.28	858.16 (44.16)
Animal Fat (kcal)	Low	450	501.11	181.49	500.01 (320.86)
Total Energy (kcal)	High	77	3371.70	69.39	3380.46 (126.16)
Total Energy (kcal)	Low	450	2360.31	518.54	2357.18 (916.75)

Table 2. Group Comparisons (High vs Low/Moderate)

Variable	Mean High	Mean Low	Welch's t (p)	Mann–Whitney U (p)	Cohen's d	Significant?
BRI	4.78	4.24	2.70 (P=0.008)	20778.0 (P=0.005)	0.33	Yes
BMI	27.48	27.02	0.94 (P=0.351)	18694.5 (P=0.268)	0.12	No
Body Fat %	31.13	29.96	1.85 (P=0.068)	19832.5 (P=0.042)	0.23	Yes
VFA (cm^2)	12.54	12.96	-1.18 (P=0.241)	16020.0 (P=0.291)	-0.14	No
Vitamin D3	29.6	30.01	-0.54 (P=0.592)	16625.0 (P=0.571)	-0.06	No

Notes: BRI [4–5]; BMI cutoffs [1]; Body Fat Percentage (BF%) thresholds [2]; Visceral fat >100 cm^2 = high risk [2]; / D3 categories; WC/Hip Circumference (HC) cutoffs [1]; Animal Fat % cutoffs [30]; Total energy risk >3000 kcal [10].

Correlation analyses: As shown in Table 3, there were significant Pearson correlations between animal fat % intake, BRI, BMI, visceral fat area, body fat %, and Vitamin D3. The consumption of animal fat was not associated with adiposity indices or with vitamin D3. BRI had a weak positive correlation with BMI ($r = 0.097$, $P = 0.026$) and a significant inverse correlation with vitamin D3 ($r = -0.497$, $P < 0.001$).

Regression analyses: As presented in Table 4, a regression model, inverse associations were found between vitamin D3 and BRI ($p < 0.001$), and a positive association for total energy ($p = 0.031$). Percent animal fat had a small negative effect ($p = 0.029$), but family history and interactions were non-significant. The model accounted for ~25% of the variance in BRI.

Table 3: Pearson Correlations (r), p-values, and n

Variable Pair	r	p-value	n
Animal Fat % vs BRI	-0.008	0.854	527
Animal Fat% vs BMI	0.037	0.392	527
Animal Fat% vs VFA	-0.033	0.446	527
Animal Fat% vs Body Fat%	0.007	0.878	527
Animal Fat% vs Vitamin D3	0.032	0.463	527
BRI vs BMI	0.097	0.026	527
BRI vs VFA	-0.042	0.335	527
BRI vs Body Fat%	-0.001	0.984	527
BRI vs Vitamin D3	-0.497	0.000	527
BMI vs VFA	0.025	0.560	527
BMI vs Body Fat%	0.011	0.795	527
BMI vs Vitamin D3	0.030	0.496	527
VFA vs Body Fat%	-0.040	0.364	527
VFA vs Vitamin D3	0.048	0.267	527
Body Fat% vs Vitamin D3	-0.004	0.927	527

*** n= number**

Table 4: Multiple Linear Regression Predicting BRI

Term	Coef	SE	95% CI	p-value	Model Fit
Intercept	4.4378	0.1662	(4.1112, 4.7643)	0.0000	R^2=0.255; adj R^2=0.247; AIC=1856.0; n=527
Animal Fat%	-0.2042	0.0932	(-0.3872, -0.0211)	0.0289	
FH (Family Medicine)	-0.1317	0.1787	(-0.4828, 0.2193)	0.4613	
Animal Fat%: FH	0.0434	0.0519	(-0.0585, 0.1453)	0.4035	
Vitamin D3	-0.1159	0.0089	(-0.1333, -0.0984)	0.0000	
Animal Fat %: Vitamin D3	0.0005	0.0026	(-0.0046, 0.0055)	0.8518	
Total Energy	0.0010	0.0005	(0.0001, 0.0020)	0.0311	

* AIC: Akaike Information Criterion, CI: Confidence Interval, and SE: Standard Error.

For VFA in table 5, only family history was significantly positively associated (p = 0.035) with VFA, whereas intake of animal fat, vitamin D3, BRI, and total energy were not significant predictors. The model accounted for only 2.6% of the variance in visceral fat and was shown to be ill-fitting.

The multiple regression analyses for the prediction of VFA-inclusive BMI, only family history significantly predicted VFA (P=0.035).

BMI, animal fat, vitamin D3, and total energy were not significant, and the model accounted for only 2.6% of the variance in VFA (Table 6).

Table 5: Multiple Linear Regression Predicting Visceral Fat Area (with BRI)

Term	Coef.	SE	95% CI	p-value	Model Fit
Intercept	12.3357	0.5439	(11.2672, 13.4043)	0.0000	R^2=0.026; adj R^2=0.013; AIC=2651.5; n=527
Animal Fat %	0.0851	0.1989	(-0.3057, 0.4759)	0.6689	
FH (any)	0.8036	0.3800	(0.0571, 1.5500)	0.0349	
Animal Fat%: FH (any)	0.2089	0.1103	(-0.0078, 0.4257)	0.0588	
Vitamin D3	0.0171	0.0217	(-0.0255, 0.0598)	0.4305	
Animal Fat%: Vitamin D3	0.0000	0.0055	(-0.0107, 0.0107)	0.9983	
Total Energy	-0.0018	0.0010	(-0.0038, 0.0002)	0.0782	
BRI	-0.0285	0.0932	(-0.2116, 0.1546)	0.7599	

Table 6. Multiple Linear Regression Model for Visceral Fat Area (including BMI)

Term	Coef.	SE	95% CI	p-value	Model Fit
Intercept	11.7236	0.9573	(9.8429, 13.6042)	0.0000	R^2=0.026; adj R^2=0.013; AIC=2651.3; n=527
Animal Fat%	0.0942	0.1981	(-0.2949, 0.4833)	0.6345	
FH (any)	0.8022	0.3798	(0.0560, 1.5483)	0.0352	
Animal Fat %: FH (any)	0.2064	0.1103	(-0.0102, 0.4230)	0.0618	
Vitamin D3	0.0201	0.0189	(-0.0169, 0.0572)	0.2864	
Animal Fat%: Vitamin D3	-0.0001	0.0055	(-0.0108, 0.0106)	0.9885	
Total Energy	-0.0018	0.0010	(-0.0038, 0.0001)	0.0696	
BMI	0.0181	0.0331	(-0.0470, 0.0832)	0.5854	

As indicated in Table 7, models with BRI (or BMI) accounted for only ~2.6% of the variation in visceral fat, and their fit indices were almost similar (AIC ≈ 2651). Accordingly, either anthropometric index was of no significant predictive value even for VFA.

Table 7. Comparison of rejection of the fit model (BRI vs. BMI) for predicting VAT area

Model	R^2	Adj R^2	AIC	n
Visceral Fat + BRI	0.0257	0.0126	2651.5	527
Visceral Fat + BMI	0.0261	0.0130	2651.3	527

To visualize the associations between animal fat intake and adiposity indices, scatterplots were investigated. As can be seen in Figure 2, no relationship was found between dietary animal fat and BRI.

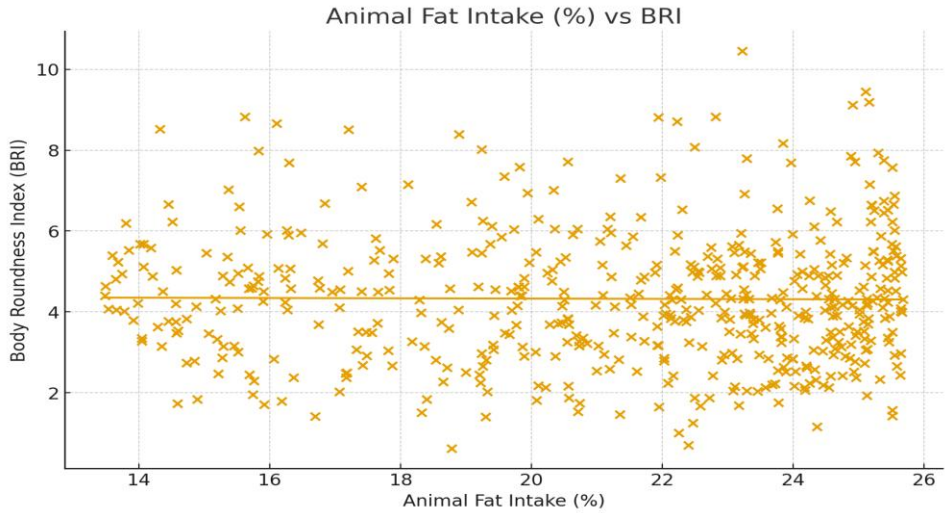


Figure 2: Scatterplot of animal fat consumption (%) and with BRI

Figure 3 presents the scatterplot of animal fat intake (%) and the visceral fat area. In line with the correlation analysis (r = –0.033) a total lack of sex specificity could be found due to no significant association, as well as the fitted line showing no pattern over the intake levels.

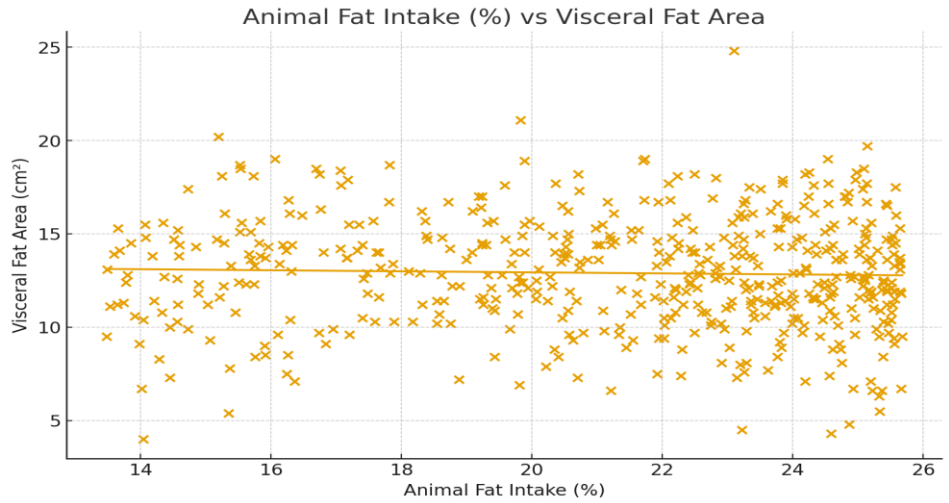


Figure 3: Plot of animal fat intake (%) versus visceral fat area

As shown in figure 4, each point signifies one participant (n = 527). A significant negative correlation was found (r = –0.497, p < 0.001), and the higher the BRI, the less Vitamin D3 level.

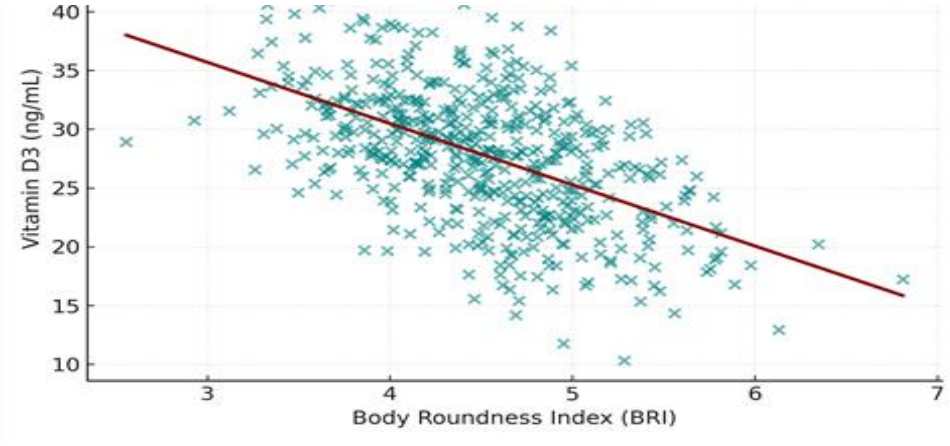


Figure 4: Scatterplot of BRI versus serum Vitamin D3 (ng/mL)

DISCUSSION

Principal's findings: In this cross-sectional study of adults with diverse intakes of dietary fat, we observed no consistent linear relationship between the proportion of animal-based fat and adiposity markers (BRI, BM, % BF, or VAT). The BRI had a rather strong and inverse correlation with vitamin D3 levels (r ≈ −0.497, p < 0.001). These relationships underscore the potential for BRI to catch central adiposity in paths linked to micronutrient status, as opposed to the dietary intake of animal fats alone, that was not a predictor of adiposity or vitamin D3 status.

Regression models also revealed that neither BRI nor BMI was a significant predictor of visceral fat area; together, these two models accounted for only ~2.6% of variance (Tables 5–7). This finding may indicate that BRI is more useful as an indicator of metabolic disturbance (vitamin D3 status) rather than directly for visceral fat volume.

BRI, a surrogate measure of central adiposity: BRI has shown a strong correlation with visceral fat and cardiometabolic risk factors better than BMI. Our results are consistent with previous large-scale studies that reported an association of BRI with metabolic syndrome, diabetes risk, and CV events in different populations [10]. More importantly, unlike BMI, a waist-based index such as BRI measures abdominal roundness and fat distribution, which are more closely related to metabolic and nutritional status.

Indeed, the lack of association between BRI and BIA-based VFA in our sample may reflect a limitation of bioelectrical impedance in underestimating VAT compared with CT/MRI [27]. More recent imaging-calibrated prediction models remain superior for accurate VAT measurement [28].

Dietary animal fat and adiposity: Although animal-fat % was not related to BRI or to BMI or VFA in our sample, in large MRI-based analyses, higher intake of saturated fat and animal fat is related to ectopic fat deposition and an increased risk of cardiometabolic diseases, particularly in women [11,13]. Dietary replacement studies also suggest that substituting animal fat with polyunsaturated plant oils lowers VAT and improves insulin sensitivity [12,14].

Our null results could be due to confounding by total energy intake, measurement error in dietary pattern assessment, or sex-specific differences. This emphasizes the use of isocaloric substitution models to unravel the effects of fat quality versus total fat intake [29].

Vitamin D and adiposity interactions: The inverse, strong relationship between BRI and serum vitamin D3 status is consistent with previous data suggesting that central adiposity dilutes circulating vitamin D [30-31]. Mechanisms include vitamin D storage in adipose tissue, decreased bioavailability, and changes in signaling of the vitamin D3 receptor [19].

Recent cross-sectional studies demonstrate that BRI and WHR have better diagnostic values of vitamin D3 deficiency than BMI [21]. Furthermore, intervention studies, including the VITAL trial, show that adults with more adiposity have a muted biomarker response to supplementation [20-22]. Taken together, these findings indicate that adiposity affects vitamin D3 metabolism and should be considered when planning vitamin D3 supplementation.

The differences in the increment are pictorially supported by the scatterplots (Figures 2–4). They depict a relationship between animal fat intake and a strong negative slope for BRI vs. vitamin D3.

Clinical implications: Our findings support the use of BRI as an affordable, easy-to-administer screening test for identifying patients at risk of central adiposity and vitamin D3 deficiency, particularly in clinical settings where imaging is not readily available. Please note that, due to the cross-sectional nature of the study, causality cannot be assessed—whether lower vitamin D3 levels promote fatness or cause it, or whether reduced vitamin D3 absorption could be further clarified.

The quality of dietary fat is of greater clinical importance than the total percentage of animal fat. The transition towards unsaturated plant-based fats aligns with global dietary recommendations for lowering cardiometabolic burden [11-12,14,29].

In this population, BRI is more useful than BMI for screening for vitamin D3 deficiency because it better reflects central adiposity, which is associated with lower vitamin D3 levels.

According to our findings that connect higher BRI to lower serum vitamin D3, population subgroups with higher central adiposity may benefit significantly from tailored functional-food initiatives. Some examples of practical uses for vitamin D3 include adding it to staple foods people often eat, creating food items with high bioavailability (such as emulsified lipid matrices), and considering adding co-nutrients or probiotics to boost absorption.

Strengths and limitations: The strengths of this study included standardized anthropometry, concurrent measurement of vitamin D3, and stratification by dietary fat intake. The cross-sectional design, dietary recall bias, and use of BIA to estimate visceral fat were limitations. Other potential confounding factors (such as sunlight exposure, outdoor activity, and seasonal variation) are also likely to influence vitamin D3 status.

Future directions: We recommend:

- Longitudinal studies examine the temporal relationship of BRI with adiposity and vitamin D3.
- Isocaloric replacement analyses to shed light on the contribution of animal vs. plant fat to visceral adiposity.
- Sex and ethnicity-specific cutoff of BRI, validated by imaging-based VAT.
- Personalized vitamin D3 dosing trials by BRI or WC, to cater for adiposity-related dilution effects.

CONCLUSION

This cross-sectional study involving Iraqi adults found that the association between BRI and serum vitamin D3 was strong and inverse, whereas animal fat intake, a traditional source of vitamin D3, did not significantly associate with body adiposity indices or vitamin D3 status. Regressions also showed that neither BRI nor BMI predicted visceral fat area, implying that BRI may relate more directly to metabolic risk through its association with vitamin D3 than other bioelectrical measurements of visceral fat. To the best of our knowledge, our findings are among the first to be reported for the Iraqi adult population on these relationships and add regional data to the growing body of research on adiposity and micronutrient status.

In a clinical setting, BRI may act as an easy, cheap alternative for patients at high risk for central adiposity and vitamin D3 deficiency, especially in low-resource settings where there is no imaging available. The use of a structured questionnaire improved the analysis by considering dietary and lifestyle confounders, but the cross-sectional study design restricted causality. Prospective interventional studies are needed to disentangle causation and test approaches such as personalized supplementation with vitamin D3 or dietary fat substitution to prevent metabolic risk.

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