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# Visceral adiposity index is a better predictor of type 2 diabetes than body mass index in Qatari population

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## Abstract

The prevalence of type 2 diabetes (T2D) has increased recently in Qatar. Body mass index (BMI) is a predictor of T2D in many populations. However, BMI is based on height and weight measurements and not on body adiposity. Therefore, the utility of BMI for predicting the risk of T2D has been questioned. Visceral adiposity appears to be a better predictor of T2D.

This study aimed to assess the relative effectiveness of visceral adiposity index (VAI) and body adiposity index (BAI), in comparison with BMI, for T2D among Qatari adults.

A random sample of 1103 adult Qatari nationals and long term residents over 20 years old were included in this study. This data were obtained from the Qatar Biobank (QBB). We performed a multivariate logistic regression to examine the association between VAI, BAI, BMI, and T2D, and computed z-scores for VAI, BAI and BMI.

VAI z-scores showed the strongest association with the risk of T2D (OR, 1.44; 95% CI: 1.24–1.68) compared with the z-scores for BAI (OR, 1.15; 95% CI: 0.93–1.43) and BMI (OR, 1.33; 95% CI: 1.11–1.59). ROC curve analysis showed that VAI was a stronger predictor than BAI and BMI ( $P < .0001$ ). Subgroup analysis indicated that the association was stronger between VAI and T2D in Qatari women than in men.

VAI was a stronger and an independent predictor of T2D compared to BAI and BMI among the Qatari adult population. Therefore, VAI could be a useful tool for predicting the risk of T2D among Qatari adults.

**Abbreviations:** BAI = body adiposity index, BF = body fat, BMI = body mass index, DM = diabetes mellitus, FPG = fasting plasma glucose, HDL-C = high-density lipoprotein cholesterol, LDL-C = low-density lipoprotein cholesterol, OR = odds ratio, T2D = type 2 diabetes, TG = triglycerides, VAI = visceral adiposity index, WC = waist circumference.

**Keywords:** body adiposity index, body mass index, Qatar Biobank, type 2 diabetes, visceral adiposity index

## 1. Introduction

Diabetes mellitus (DM) is the ninth leading cause of death worldwide. Globally, one in 11 adults is diagnosed with DM and approximately 90% of cases are type 2 diabetes mellitus (T2D).<sup>[1]</sup> In Qatar, it is estimated that by 2050 one in every four Qataris

would have DM.<sup>[2]</sup> Evidence shows that higher body fat is associated with increased risk for several metabolic disorders such as cardiometabolic diseases, inflammatory diseases, and DM.<sup>[3–7]</sup>

For decades, body mass index (BMI) has been used as a surrogate marker for underweight, overweight, and obesity.

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All data and materials are owned by Qatar Biobank (QBB) and any request for data must be obtained according to QBB policy.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki. All study protocols were approved by the Institutional Review Board of Qatar Biobank prior to survey study.

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Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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Many studies have questioned the use of BMI in weight classification as it cannot differentiate between lean mass and fat mass.<sup>[8]</sup> For instance, Lam et al showed that waist circumference (WC) is a better indicator of abdominal or visceral adiposity than BMI.<sup>[9]</sup> A cohort study by Yang et al showed that WC is a better diagnostic marker for obesity-related diabetes risk. The gold standard for the measurement of adiposity is magnetic resonance imaging and computed tomography. However, the cost and availability of these two methods preclude the possibility of using them in routine out-patient settings.<sup>[10]</sup>

Body adiposity index (BAI) was first introduced in 2011. This measurement is based on body fat (BF) and body fat percentage (BF%).<sup>[11]</sup> The mathematical formula for BAI [BAI=hip circumference (cm)/height (m)<sup>1.5</sup>–18] has been noted for its ease of administration.<sup>[12]</sup> This method offers an alternative tool for assessing obesity and for predicting cardiometabolic disorders.<sup>[9]</sup>

On the other hand, visceral adiposity index (VAI) seems to be a better predictor for metabolic disorders associated with insulin resistance than a single anthropometric index.<sup>[13]</sup> VAI is a mathematical formula that consists of BMI and WC, as well as clinical measurements such as triglycerides (TG) and high-density lipoprotein cholesterol (HDL-C) concentrations.<sup>[14]</sup> In contrast, the calculation of BAI includes only anthropometric measurements such as hip circumference and standing height. Although both VAI and BAI can predict the risk of cardiometabolic diseases such as T2D, it is not known which one of these is a better predictor of T2D in Qatari adults. Therefore, the aim of this study was to investigate the effectiveness of VAI and BAI in predicting the risk of T2D in the Qatari adult population.

## 2. Materials and methods

### 2.1. Study design and population

In this study, we used the data from the Qatar Biobank (QBB). A random sample of 1103 adults over 20 years old and those who had lived in Qatar for more than 15 years were included in the study. Sociodemographic data, lifestyle factors, and dietary habits were collected by a self-administrated questionnaire. Data regarding health condition, family history of disease, and medication use were collected by a registered nurse through face-to-face interviews. Blood samples (60 mL) were collected from each participant. All the study protocols were approved by the Qatar Biobank Institutional Review Board.

### 2.2. Outcome variables

DM was defined as having fasting plasma glucose (FPG)  $\geq 7.0$  mmol/L, glycated haemoglobin (HbA1c)  $\geq 6.5\%$ , previous diagnosis of DM, or reported use of antidiabetic medications. Based on these criteria, 187 (17%) participants out of the 1103 subjects had DM.

### 2.3. Independent variables

BMI was calculated as weight in kg divided by standing height in m<sup>2</sup>.

VAI scores for men and women were calculated with the following formulas:

Men : VAI

$$= \frac{WC(cm)}{39.68 + (1.88 \times BMI)} \times \left( \frac{TG(mmol/L)}{1.03} \right) \times \left( \frac{1.31}{HDL - C(mmol/L)} \right)$$

Women : VAI

$$= \frac{WC(cm)}{36.58 + (1.89 \times BMI)} \times \left( \frac{TG(mmol/L)}{0.81} \right) \times \left( \frac{1.52}{HDL - C(mmol/L)} \right)$$

BAI scores were calculated using the following equation:

$$BAI = \frac{Hip\ circumference\ (cm)}{Standing\ height\ (m)^{1.5}} - 18$$

## 2.4. Anthropometric measurements

Participants were asked to remove their shoes and to stand on an electronic weighing scale. Height was measured with participants standing straight without shoes against a wall. WC was measured with an inelastic tape to the nearest 0.1 cm at the central point between the bottom of the rib cage and the uppermost border of the iliac crests, at the end of exhalation in standing position. BF and visceral fat were measured by iDXA scan (GE Healthcare, Madison, WI, USA)

## 2.5. Biochemical measurements

Blood samples were collected after at least 8 hours of overnight fasting. Blood samples were then centrifuged and stored at  $-87^{\circ}C$  for analysis later. FPG and HbA1c measurements were taken immediately before samples were frozen. The glucose oxidase phenol 4-aminoantipyrine peroxidase method was used to measure the plasma glucose. The whole blood HbA1c was measured with high-performance liquid chromatography. A biochemical auto-analyser was used to measure total cholesterol, TG, low-density lipoprotein cholesterol (LDL-C), and HDL-C.

## 2.6. Statistical analysis

The chi-square test was used to compare differences between genders for categorical variables, and the t-test for continuous variables. We used scatter plots to present the association between VAI and BAI, and total fat and visceral fat. Multivariable logistic regression was used to assess the association between different measures of obesity (i.e. z-scores of VAI, BAI, and BMI) and DM. Three multivariable logistic regression models were constructed. Model 1 was adjusted for age and gender, model 2 was further adjusted for education, and model 3 was further adjusted for physical activity. We tested multiplicative interactions between gender, age (below or above 40 years), education (low, medium, and high), and obesity measures (z-scores of VAI, BAI, and BMI) by including a cross-product term in the main multivariable model (model 3). The interactions were visually presented by employing a user-written syntax, “ipdover”. All the analyses were performed using STATA 16 (Stata Corporation,

**Table 1****Sample characteristics by diabetes.**

	<b>Total N = 1103</b>	<b>No N = 916</b>	<b>Yes N = 187</b>	<b>P value</b>
Sex				.14
Male	567 (51.4%)	480 (52.4%)	87 (46.5%)	
Female	536 (48.6%)	436 (47.6%)	100 (53.5%)	
Age (yr)	39.7 (11.2)	37.6 (10.4)	50.2 (9.1)	<.001
Education				<.001
Low	125 (11.3%)	68 (7.4%)	57 (30.5%)	
Medium	338 (30.7%)	287 (31.4%)	51 (27.3%)	
High	639 (58.0%)	560 (61.2%)	79 (42.2%)	
Body mass index (kg/m <sup>2</sup> )	29.3 (5.8)	28.8 (5.6)	31.8 (5.8)	<.001
Body mass index categories				<.001
Normal	243 (22.0%)	226 (24.7%)	17 (9.1%)	
Overweight	399 (36.2%)	340 (37.1%)	59 (31.6%)	
Obese	461 (41.8%)	350 (38.2%)	111 (59.4%)	
Waist circumference (cm)	89.7 (13.8)	88.0 (13.5)	97.9 (12.7)	<.001
Body adiposity index	32.7 (6.9)	32.3 (6.6)	34.6 (7.6)	<.001
Visceral adiposity index	1.7 (1.6)	1.6 (1.5)	2.5 (1.8)	<.001
Body weight (kg)	79.9 (16.7)	79.1 (16.9)	83.5 (15.7)	.002
Total fat (kg)	31.4 (10.8)	30.8 (10.7)	34.0 (10.9)	<.001
Trunk fat (kg)	16.6 (6.6)	16.0 (6.3)	19.5 (7.1)	<.001
Total vat	1.1 (0.8)	1.0 (0.7)	1.6 (0.8)	<.001
Leisure time physical activity (MET h/wk)	17.4 (36.9)	18.6 (38.4)	11.4 (28.0)	.015

Data are presented as mean (SD) for continuous measures, and n (%) for categorical measures. Participants fasted  $\geq 8$  h.

College Station, TX, USA). Statistical significance was considered when  $P < .05$  (two-sided).

### 3. Results

Table 1 shows the characteristics of the study sample by DM status. More than 50% of participants with DM were women, while non-diabetic participants were mostly men. The mean ages of subjects with DM and without DM were 50.2 years and 37.6 years, respectively. About 58% of the participants had a high education level. The prevalence of obesity was 41.8% (59.4% in persons with DM and 38.2% in persons without DM). Persons with DM had a higher mean BMI, WC, and total fat than participants without DM. Mean VAI and BAI were higher in DM subjects, compared with subjects without DM.

Table 2 shows the association between VAI and BAI, and DM among Qatari adults using different adjusted logistic regression models. After adjusting for age and gender, the VAI z-score was directly associated with the prevalence of DM (OR, 1.44; 95% CI: 1.24–1.68), while BMI z-scores showed lesser association with DM. With a further adjustment for education and physical activity, the VAI z-score was more strongly associated with the prevalence of DM (OR, 1.38; 95% CI: 1.18–1.61) compared to the BMI z-score (OR, 1.27; 95% CI: 1.06–1.53). There was no

relationship between BAI z-score and the prevalence of DM in the multivariable-adjusted model. ROC analysis showed that the VAI has the highest area under the curve (AUC) as compared to other indices (Fig. 1). We compared the ROC curve and found the AUCs are statistically different ( $P < .0001$ ). VAI has the highest AUC.

Subgroup analyses suggested that there was a significant interaction between VAI and DM with gender and age (Fig. 2). The association between VAI z-score and DM was stronger in women than in men. Among young participants ( $<40$  years old), VAI z-score was not associated with DM. The association between BAI z-score and DM was not significant when stratified by gender, age, education and BMI (Fig. 3). Furthermore, subgroup analyses suggested that there was a significant interaction between BMI and DM with gender, age and education (Fig. 4). The association between BMI z-score and DM was stronger in women than in men. Among young participants ( $<40$  years), BMI z-score was not associated with DM.

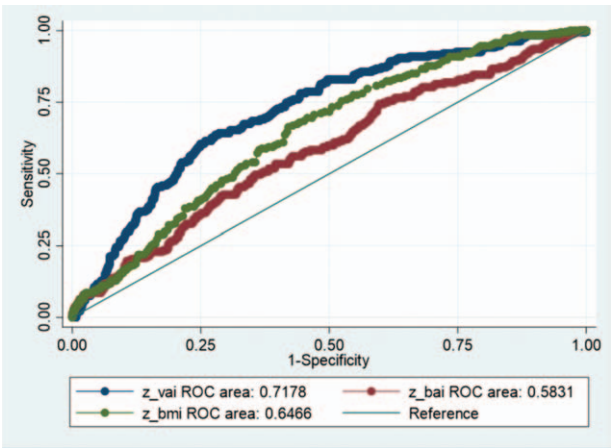
### 4. Discussion

To the best of our knowledge, this is the first study to determine the effectiveness of VAI in predicting DM in the Qatari

**Table 2****Association of visceral adiposity index, body adiposity index and body mass index with diabetes among Qatari adults.**

	Visceral adiposity index z-score		Body adiposity index z-score		Body mass index z-score	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Model 1	1.44 (1.24–1.68)	<.001	1.15 (0.93–1.43)	.203	1.33 (1.11–1.59)	.002
Model 2	1.39 (1.19–1.63)	<.001	1.09 (0.87–1.36)	.445	1.28 (1.07–1.54)	.008
Model 3	1.38 (1.18–1.61)	<.001	1.08 (0.86–1.35)	.502	1.27 (1.06–1.53)	.011

Model 1 adjusted for age and gender. Model 2 further adjusted for age, gender, and education. Model 3 further adjusted for age, gender, education, and physical activity.



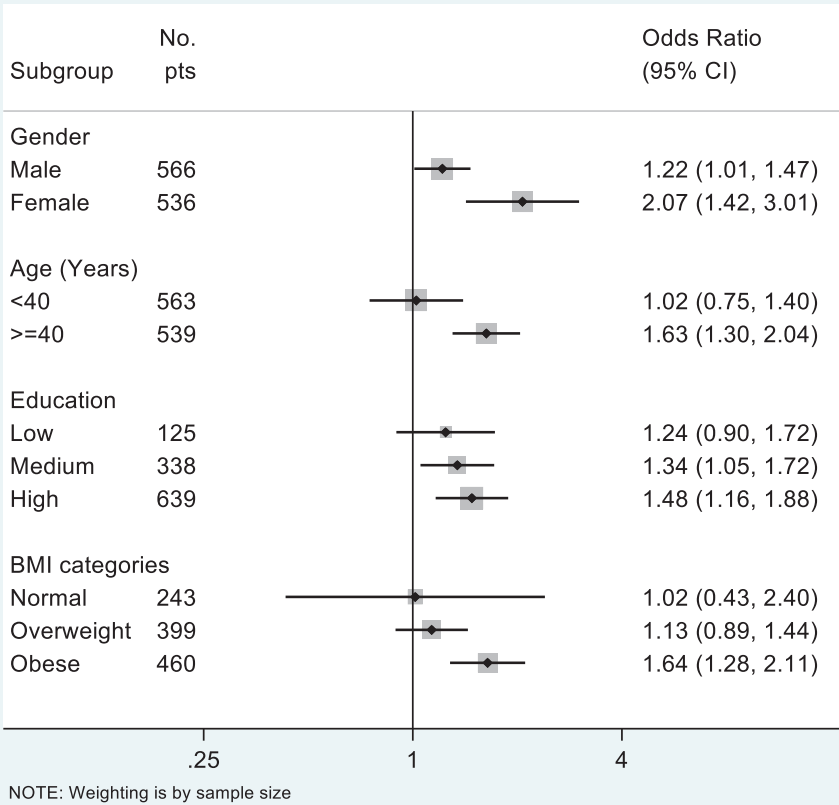
**Figure 1.** ROC curves for visceral adiposity index; body adiposity index and body mass index as predictors for diabetes ( $P < .0001$ ).

population. The study has shown that VAI has a strong association with DM, and also showed that VAI is superior to BAI and BMI in predicting DM after adjustment for age, gender, education and physical activity.

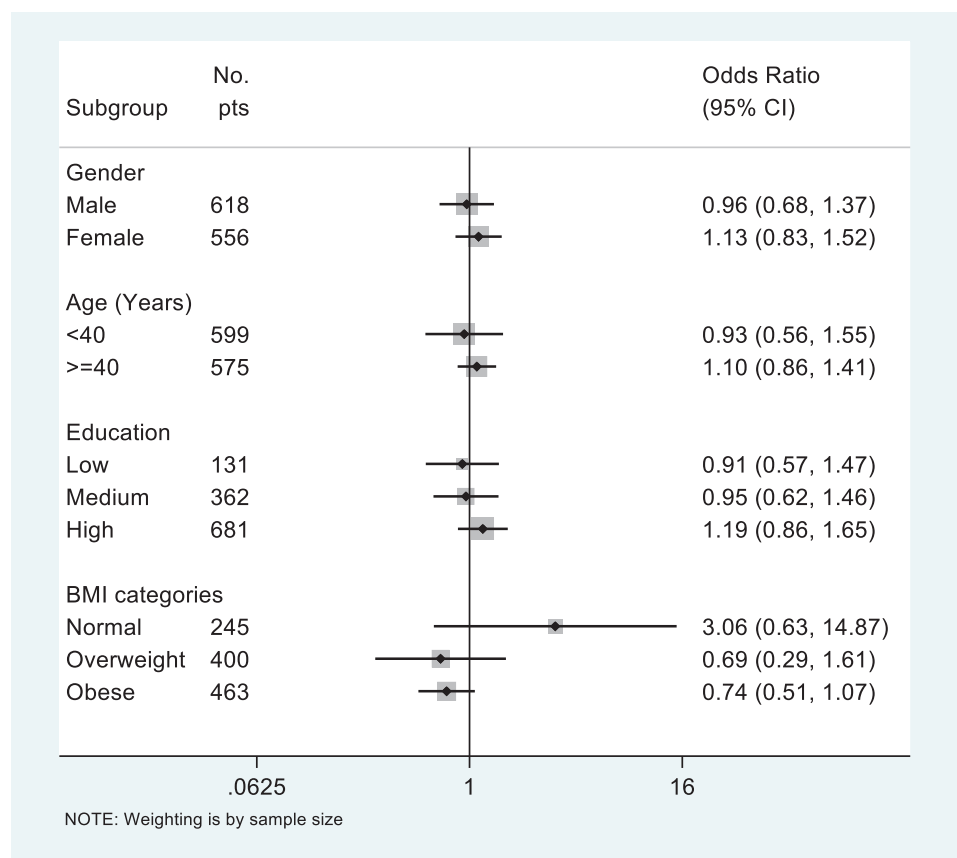
Findings from this study are in agreement with the findings by Liu et al, who reported that there was a significant direct

relationship between VAI and dysglycaemia in both genders.<sup>[15]</sup> Another study was conducted to investigate the ability of VAI to identify the risk of developing DM. A positive association was found between VAI scores and risk of DM for both genders.<sup>[16]</sup> Consistently with the previous studies, Wei et al proved that Chinese VAI (CVAI) has a superior diagnostic ability for DM compared with BMI, WC, and body shape index in Chinese people.<sup>[17]</sup> Several studies support our findings in which VAI can be considered as a strong indicator for predicting DM in both men and women. However, a cohort study found that VAI is also a good indicator for DM but, when compared with other simple anthropometric measurements, its prediction ability is no more effective than Waist to hip ratio.<sup>[13]</sup> A 15-year prospective cohort study that was conducted on 687 individuals concluded that VAI can be independently used to predict DM in Chinese people; however, its discriminatory power is no stronger than other simple measures like BMI and WC.<sup>[18]</sup>

This study also examined the predictive power of BAI for the risk of DM compared with BMI. BAI did not show any significant predictive ability for the risk of DM among the Qatari population. In contrast, a study compared the efficiency of BMI, WC, and BAI in the risk assessment for T2D in two populations in Brazil (general and Amerindian). Results showed that BAI is a better risk predictor of T2D than BMI and WC in the Amerindian population and specifically in men from the general population, whereas WC is superior to BAI and BMI for women



**Figure 2.** Subgroup analysis of the association between VAI z-score and diabetes. Values adjusted for age, gender, education, and physical activity. Stratification variables were not adjusted in the corresponding analyses. There was a significant interaction between VAI z-score and diabetes with gender, age and education.



**Figure 3.** Subgroup analysis of the association between BAI z-score and diabetes. Values adjusted for age, gender, education, and physical activity. Stratification variables were not adjusted in the corresponding analyses. The association between BAI z-score and diabetes was not significant when stratified by gender, age, education and BMI.

from the general population. The study suggested that BAI is a useful assessment tool for T2D.<sup>[19]</sup>

Our findings could be explained in that VAI includes both physical and metabolic biomarkers such as BMI, TG, HDL-C, and WC. Several studies have also investigated the strong association of visceral adiposity with the increased production of adipocytokine, with pro-inflammatory activity and with a drop in insulin sensitivity with abnormal glucose regulation.<sup>[20–23]</sup> This showed that VAI is associated with poor glucose control, increased insulin resistance and impaired  $\beta$ -cell function.<sup>[24–26]</sup> VAI is associated not only with DM but also with increased cardiometabolic risk.<sup>[23]</sup> The multiple components of VAI (BMI, WC, TG, and HDL-C) have a stronger association with induced inflammation and adipocytokine production, which may explain the higher predictive power of VAI for DM, compared with BMI alone.<sup>[20–22]</sup>

Remarkably, this study showed that the association between VAI and DM is stronger in women than in men, from which our findings corroborate with those of Wei et al. This may be related to the physiological differences between both genders in terms of visceral fat deposition and distribution, and reproductive hormones.<sup>[17]</sup> In addition, this study found that VAI is not associated with DM among young participants (<40 years). This could be explained by the changes with age in the concentrations

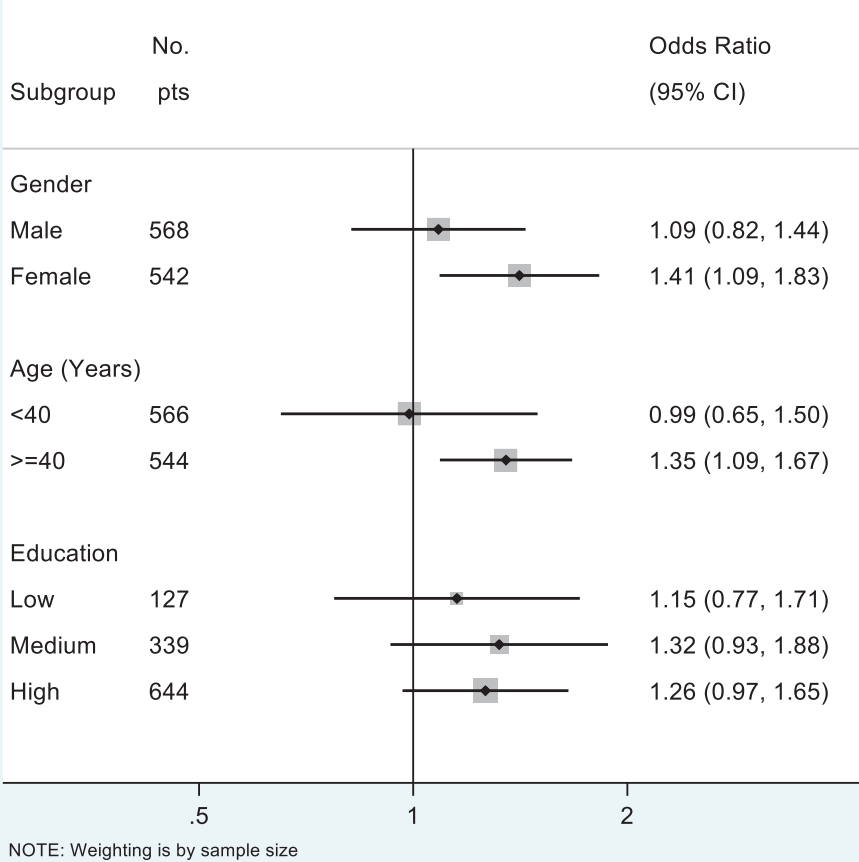
of inflammatory markers that are related significantly to the increased visceral adiposity distribution in older adults.<sup>[27]</sup>

The strength of this study is that it included direct assessment of participants, as each participant was measured on site, which gives more accurate results than self-reported assessment. Moreover, fat distribution was calculated using DEXA, which provides more accurate results than Tanita or other measurement tools. Because of the richness of the Qatar Biobank data, we were able to adjust the analysis for several confounding variables. However, because the data is cross-sectional in nature, the results should not be viewed in terms of a cause-and-effect relationship between VAI and DM. In conclusion, VAI is a strong and independent predictor of T2D among the Qatari population. The predictive ability of VAI is superior to that of BMI and BAI. Therefore, VAI could be a useful tool for the prediction of the risk of T2D among Qataris. Nevertheless, if VAI were not available, BMI is still known to be non-invasive and the most applicable compared with other measurements (Supplementary Figure, <http://links.lww.com/MD/E583>).

#### Author contributions

**HB:** conceptualization of the research, supervising students, writing manuscript.





**Figure 4.** Subgroup analysis of the association between BMI z-score and diabetes. Values adjusted for age, gender, education, and physical activity. Stratification variables were not adjusted in the corresponding analyses. There was a significant interaction between BMI z-score and diabetes with gender, age and education.

**AA:** results interpretation, drafting the manuscript.  
**FA:** results interpretation, drafting the manuscript.  
**RQ:** results interpretation, drafting the manuscript.  
**ZS:** statistical analysis; drafting the manuscript.  
**VG:** results interpretation, drafting the manuscript.  
**RS:** drafting the manuscript.

References

[1] Zheng Y, Ley SH, Hu FB. Global aetiology and epidemiology of type 2 diabetes mellitus and its complications. *Nat Rev Endocrinol* 2018;14:88.  
[2] Awad SF, O’Flaherty M, Critchley J, et al. Forecasting the burden of type 2 diabetes mellitus in Qatar to 2050: a novel modeling approach. *Diabetes Res Clin Pract* 2018;137:100–8.  
[3] Barazzoni R, Cappellari GG, Ragni M, et al. Insulin resistance in obesity: an overview of fundamental alterations. *Eat Weight Disord* 2018;23:149–57.  
[4] Serrano NC, Suarez DP, Silva AR, et al. Association between body fat mass and cardiometabolic risk in children and adolescents in Bucaramanga, Colombia. *Int J Pediatr Adolesc Med* 2019;6:135–41.  
[5] Darroudi S, Fereydouni N, Tayefi M, et al. Oxidative stress and inflammation, two features associated with a high percentage body fat, and that may lead to diabetes mellitus and metabolic syndrome. *BioFactors* 2019;45:35–42.  
[6] Ding C, Chan Z, Chooi YC, et al. Visceral adipose tissue tracks more closely with metabolic dysfunction than intrahepatic triglyceride in lean Asians without diabetes. *J Appl Physiol* 2018;125:909–15.

[7] Han TS, Al-Gindan YY, Govan L, et al. Associations of BMI, waist circumference, body fat, and skeletal muscle with type 2 diabetes in adults. *Acta Diabetol* 2019;1–8.  
[8] Javed A, Jumean M, Murad MH, et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity in children and adolescents: a systematic review and meta-analysis. *Pediatr Obes* 2015;10:234–44.  
[9] Lam BCC, Koh GCH, Chen C, et al. Comparison of body mass index (BMI), body adiposity index (BAI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) as predictors of cardiovascular disease risk factors in an adult population in Singapore. *PLoS One* 2015;10:e0122985.  
[10] Yang X, Zhang M, Luo X, et al. Body mass index, waist circumference and waist-to-height ratio associated with the incidence of type 2 diabetes mellitus: a cohort study. *Zhonghua yu fang yi xue za zhi [Chin J Prevent Med]* 2016;50:328–33.  
[11] Bergman RN, Stefanovski D, Buchanan TA, et al. A better index of body adiposity. *Obesity (Silver Spring)* 2011;19:1083–9. doi: 10.1038/oby.2011.38 [published Online First: Epub Date].  
[12] Chang H, Simonsick EM, Ferrucci L, et al. Validation study of the body adiposity index as a predictor of percent body fat in older individuals: Findings from the BLSA. *J Gerontol Ser A* 2013;69:1069–75.  
[13] Bozorgmanesh M, Hadaegh F, Azizi F. Predictive performance of the visceral adiposity index for a visceral adiposity-related risk: type 2 diabetes. *Lipids Health Dis* 2011;10:88.  
[14] Oh JY, Sung YA, Lee HJ. The visceral adiposity index as a predictor of insulin resistance in young women with polycystic ovary syndrome. *Obesity* 2013;21:1690–4.

- [15] Liu PJ, Ma F, Lou HP, et al. Visceral adiposity index is associated with pre-diabetes and type 2 diabetes mellitus in Chinese adults aged 20-50. *Ann Nutr Metab* 2016;68:235–43.
- [16] Du T, Sun X, Huo R, et al. Visceral adiposity index, hypertriglyceridemic waist and risk of diabetes: the China Health and Nutrition Survey 2009. *Int J Obes* 2014;38:840.
- [17] Wei J, Liu X, Xue H, et al. Comparisons of visceral adiposity index, body shape index, body mass index and waist circumference and their associations with diabetes mellitus in adults. *Nutrients* 2019;11:1580.
- [18] Wang Y, He S, He J, et al. Predictive value of visceral adiposity index for type 2 diabetes mellitus. *Herz* 2015;40:277–81.
- [19] de Oliveira Alvim R, Mourao-Junior CA, de Oliveira CM, et al. Body mass index, waist circumference, body adiposity index, and risk for type 2 diabetes in two populations in Brazil: general and Amerindian. *PLoS One* 2014;9:e100223.
- [20] Amato MC, Giordano C, Galia M, et al. Visceral adiposity index: a reliable indicator of visceral fat function associated with cardiometabolic risk. *Diabetes Care* 2010;33:920–2.
- [21] Yang Y, Feng Y, Ma X, et al. Visceral adiposity index and insulin secretion and action in first-degree relatives of subjects with type 2 diabetes. *Diabetes Metab Res Rev* 2015;31:315–21.
- [22] Amato MC, Pizzolanti G, Torregrossa V, et al. Visceral adiposity index (VAI) is predictive of an altered adipokine profile in patients with type 2 diabetes. *PLoS One* 2014;9:e91969.
- [23] Amato MC, Giordano C, Galia M, et al. Visceral adiposity index: a reliable indicator of visceral fat function associated with cardiometabolic risk. *Diabetes Care* 2010;33:920–2. doi: 10.2337/dc09-1825 [published Online First: Epub Date].
- [24] Ciresi A, Radellini S, Guarnotta V, et al. The visceral adiposity index is associated with insulin sensitivity and IGF-I levels in adults with growth hormone deficiency. *Endocrine* 2017;56:579–88. doi: 10.1007/s12020-016-1076-5 [published Online First: Epub Date].
- [25] Du T, Sun X, Huo R, et al. Visceral adiposity index, hypertriglyceridemic waist and risk of diabetes: the China Health and Nutrition Survey 2009. *Int J Obes* 20052014;38:840–7. doi: 10.1038/ijo.2013.181 [published Online First: Epub Date].
- [26] Gu D, Ding Y, Zhao Y, et al. Visceral adiposity index was a useful predictor of prediabetes. *Exp Clin Endocrinol Diabetes* 2018;126:596–603. doi: 10.1055/s-0043-120440 [published Online First: Epub Date].
- [27] Cartier A, Côté M, Lemieux I, et al. Age-related differences in inflammatory markers in men: contribution of visceral adiposity. *Metabolism* 2009;58:1452–8.