Original Article

Association of visceral adiposity index with insulin resistance in adults with diabetes mellitus

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Abstract

Background and objectives: Visceral adiposity is linked to excess morbidity and mortality and positively correlates with the risk of insulin resistance, type-2 diabetes mellitus, cardiovascular disease and premature death. The study was conducted to find out the relationship between visceral adiposity index (VAI) and homeostatic model assessment insulin resistance (HOMA-IR) in diabetes mellitus (DM).

Materials and methods: This cross sectional study was carried out on adult population with and without DM. Waist circumference (WC) and body mass index (BMI) were measured. BMI of 25-29.9 kg/m^2 and ≥30 kg/m^2 was defined as overweight and obese respectively. HOMA-IR method was used to calculate insulin resistance (IR). Standard formula using BMI, WC, triglyceride (TG) and high density lipoprotein cholesterol (HDL-c) was used to calculate VAI. Blood was analyzed for fasting blood glucose (FBS), TG, HDL-c and insulin level.

Results: A total of 439 individuals were included in the study of which 269 had DM and 170 were healthy volunteers and the mean age was 41.47±6.82 and 36.16±7.44 years respectively. Compared to healthy controls, a greater number of diabetics had high VAI (86.5% vs. 98.9%) and high IR (43.5% vs. 85.1%). We found the highest sensitivity and specificity at a cut-off of 2.23 of VAI while at 3.65 had the highest specificity. Insulin resistance was observed significantly higher in those with diabetes compared to control, both in case of normal and high VAI at all cut-offs of VAI. Among anthropometric parameters (WC, BMI and VAI), VAI had positive ($r=0.21$, $p<0.001$) correlation with HOMA-IR than WC ($r=0.10$, $p=0.043$). Visceral fat was linearly related with insulin resistance (ß=0.18, $p<0.001$). Area under the curve (AUC) (0.66) showed that VAI can discriminate HOMA-IR.

Conclusion: There was a high rate of raised VAI in cases with DM. VAI had positive association with HOMA-IR in diabetes mellitus. Although weak, there was an acceptable discrimination between them.

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Introduction

Visceral adiposity has become a major concern in public health due to its significant role in obesity associated diseases. Abnormally increased deposition of visceral adipose tissue surrounding intra-abdominal organs is known as visceral obesity [1]. Previous studies have reported that individuals with high visceral adiposity are at increased risk of

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insulin resistance and metabolic disorders, and are more likely to develop diabetes [2-4]. Major metabolic abnormality behind type-2 diabetes mellitus is insulin resistance and the compensatory hyperinsulinemia [5].

Adipose tissue is a main source of reactive oxygen species, which may contribute to obesity-associated insulin resistance and cause type-2 diabetes mellitus as a consequence [6]. It secretes adipocytokines that impair insulin sensitivity in tissues such as liver and muscle. Release of inflammatory cytokines by macrophages in visceral adipose tissue also impairs insulin sensitivity [7].

The classical parameters for measuring obesity namely waist circumference (WC) and body mass index (BMI) alone cannot help to distinguish between subcutaneous and visceral fat [8]. Magnetic resonance imaging (MRI) and computed tomography (CT) are considered as the gold standards for measuring the body fat distribution [9]. However, they are expensive and not suitable for daily clinical practice. Moreover, adipocytokines assessment for evaluating visceral adipose dysfunction is not feasible due to the complex function of the 'adipose endocrine organ' [10] and high costs [11]. A novel and feasible sex-specific index called visceral adiposity index (VAI) based on WC, BMI, triglyceride (TG) and high density lipoprotein cholesterol (HDL-c) has been introduced by Amato et al [12]. As VAI includes both physical and clinical parameters, it provides an estimation of both fat distribution and function. Moreover, it reflects altered production of adipocytokines, increased lipolysis and plasma free fatty acids [12].

Bangladesh has the second highest prevalence of diabetes in South-East Asian region in 2017 (prevalence of diabetes 10%) [13,14]. VAI could be a simple clinical marker to identify adipose tissue dysfunction or indirectly the risk of insulin resistance. Therefore, our study was conducted to determine VAI and insulin resistance in adult people with diabetes mellitus and to assess the association between them.

Methodology

This cross sectional study was conducted on adult participants with and without DM. DM cases were selected from outpatient department of BIRDEM General Hospital over a period of 2 years. DM was diagnosed according to WHO criteria, 2006 [15]. Diabetes mellitus with cardiovascular complications, pregnant women, women taking oral contraceptive pill and patients taking lipid lowering agents were excluded from the study. Healthy adult volunteers without DM served as control group. The study was approved by the ethical committee of BADAS and written informed consent was taken from each participant.

Study procedure

Participants were asked to fill up a questionnaire focusing on socio-demographic attributes and background characteristics of diabetes including duration, mode of treatment and presence of any complications.

A digital scale was used to measure body weight (BW). Height was measured using a commercial stadiometer. Body mass index (BMI) was calculated as body weight in kg divided by square of the height in meter (m^2). Waist circumference (WC) was measured in the standing position at the midpoint between lower rib margin and the iliac crest [16]. Based on the International Obesity Task Force, an individual with BMI of 25-29.9 kg/m^2 and ≥30 kg/m^2 were defined as overweight and obese respectively [17]. To determine the extent of central adiposity, waist circumference cut off points of ≥90 cm in men and ≥80 cm in women were taken [18].

Venous blood samples were drawn for biochemical tests following a 12-hour overnight fast. Collected blood was allowed to clot, centrifuged, appropriately labeled and stored at -20^{0}C. Serum TG was measured by glycerol phosphate dehydrogenase-peroxidase (GPO-POD) method and HDL-c was by precipitating method using the total cholesterol enzymatic reagent [19]. Blood glucose was measured by glucose oxidase method. Serum insulin was measured by ELISA.

Operational definition

HOMA-IR: Homeostatic model assessment for insulin resistance (HOMA-IR) is a method to calculate insulin resistance based on the degree

of fasting hyperglycemia which is determined by the combination of ß-cell deficiency and insulin resistance.

The formula to calculate HOMA-IR is

HOMA-IR = fasting insulin [mIU/L] x fasting glucose [mmol/L] / 22.5 [20].

HOMA-IR cut-off of 2.6 has been found to indicate presence of insulin resistance in Bangladeshi population [21].

VAI: VAI is a simple sex-specific index based on physical and biochemical measures to reflect regional fat. BMI, WC, TG (mmol/L) and HDL-c (mmol/L) levels are used in the formula [12].

Male: VAI = {WC/39.68 + (1.88×BMI)} × (TG/1.03) × (1.31/HDL)

Female: VAI = {WC/36.58 + (1.89×BMI)} × (TG/0.81) × (1.52/HDL)

VAI of 1 is considered normal, i.e., normal adipose tissue distribution and normal TG and HDL cholesterol levels [12].

Statistical analysis

Data were expressed as mean±SD or frequency with percentage; independent student's t test and Chi square test were used to compare VAI between groups with and without insulin resistance. Control and diabetic populations were classified into normal and high VAI after considering cut-off at 1.0, 2.23 and 3.65 for VAI. Pearson's correlation analysis was done to determine the correlation between VAI and HOMA-IR. Linear regression analysis was done using HOMA-IR as dependent variable and BMI, WC and VAI as independent variables. A receiver operating characteristic (ROC) curve analysis was performed for VAI to observe its ability to discriminate HOMA-IR. Area under the curve was used to determine highest cut-off of VAI for our population.

Results

A total of 439 individuals were included in the study of which 269 had DM and 170 were healthy volunteers. The mean age of patients with DM and without DM (control group) was 41.47±6.82 and

Table-1: *Clinical and biochemical characteristics of study population (n=439)*

Variable	Control (n=170) Mean±SD	DM (n=269) Mean±SD	Total (n=439) Mean±SD	p value
Age (years)	36.16±7.44	41.47±6.82	39.41±7.52	0.001
WC (cm)	87.66±10.53	88.28±10.34	88.04±10.41	0.543
BMI (kg/m^2)	25.09±4.27	25.79±3.54	25.52±3.85	0.063
TG (mg/dl)	128.98±78.34	168.98±76.43	153.49±79.52	0.001
HDL-c (mg/dl)	42.76±15.88	34.62±10.54	37.77±13.46	0.001
FBS (mmol/L)	4.34±0.84	9.35±4.19	7.41±4.13	0.001
S. insulin level (µIU/ml)	14.8±12.07	21.0±15.11	18.6±14.32	0.001
VAI	2.83±2.40	3.69±2.12	3.32±2.30	0.001
HOMA-IR	2.73±2.44	8.57±7.46	6.35±6.64	0.001

Note: p value calculated by independent student's t test.

Table-2: *Frequency of clinical and biochemical characteristics of study population (n=439)*

Variable	Control (n=170)	DM (n=269)	p value
Central obesity	103 (60.6%)	158 (58.7%)	0.696
Overweight	78 (45.9%)	161 (59.9%)	0.004
Hypertriglyceridemia	42 (24.7%)	133 (49.4%)	0.001
Low HDL-c	104 (61.2%)	223 (82.9%)	0.001
High VAI	147 (86.5%)	266 (98.9%)	0.001
High IR	74 (43.5%)	229 (85.1%)	0.001

Note: p value calculated by Z test.

36.16±7.44 years respectively. The clinical and biochemical profiles of the study population are shown in Table-1. Except WC and BMI, the average values of TG, FBS, insulin resistance and VAI were significantly higher in DM than that of control cases (Table-1). More participants from control group had central obesity (60.6% vs 58.7%). A greater number of participants with DM had high VAI (86.5% vs 98.9%) and high IR (43.5% vs 85.1%; Table-2). Out of 439 cases, 136 had normal HOMA-IR and 303 cases had raised HOMA-IR. VAI was found significantly higher in individuals with raised HOMA-IR compared to those with normal levels (2.7±2.21 vs. 3.6±2.28, p<0.001) (Table-3).

Table-3: *VAI in total population with normal and high HOMA-IR (n=439)*

Variable	Normal HOMA-IR (n=136) Mean±SD	High HOMA-IR (n=303) Mean±SD	p value
VAI	2.7±2.21	3.6±2.28	0.001

Note: p value by independent student's t-test.

Table-4a: *Association between HOMA-IR and VAI in the study population (n=439) using VAI cut-off of 1*

Variable		HOMA-IR (Mean±SD)	p value
DM (n=269)	Normal VAI (n=58)	6.96±7.06	<0.001
	High VAI (n=211)	9.01±7.53	
Control (n=170)	Normal VAI (n=108)	2.89±2.61	
	High VAI (n=62)	2.72±2.0	

Note: One-way ANOVA test was done. Significant difference was seen between Group 1 vs 2 p=0.044, 1 vs 3 p=0.001, 1 vs 4 p=0.003, 2 vs 3 p<0.001, 2 vs 4 p<0.001. Group 1=DM with normal VAI, 2= DM with high VAI, 3=Control with normal VAI, and 4=Control with high VAI.

Three cut-off points of VAI (1, 2.23 and 3.65) were used to show association with HOMA-IR in Table-4a, 4b and 4c. VAI 1 was considered normal [12]. We used cut-off of 2.23 to classify individuals with high VAI, as this level had both the highest sensitivity and specificity. Cut-off of 3.65 had the highest specificity. Total population was divided into four groups (group 1=DM with normal VAI, 2=DM with high VAI, 3=control with normal VAI and 4=control with high VAI). Insulin resistance was significantly higher in those with diabetes compared to control, both in case of normal and high VAI. Though significantly higher HOMA-IR was seen in diabetic patients with high VAI, this was not found in the control group. This observation was seen at all cut-offs of VAI.

Table-4b: *Association between HOMA-IR and VAI in the study population (n=439) using VAI cut-off of 2.23*

Variable		HOMA-IR (Mean±SD)	p value
DM (n=269)	Normal VAI (n=72)	6.69±6.45	<0.001
	High VAI (n=197)	9.26±7.7	
Control (n=170)	Normal VAI (n=97)	2.85±2.71	
	High VAI (n=73)	2.8±1.95	

Note: One-way ANOVA test was done. Significant difference was seen between group 1 vs 2 p=0.011, 1 vs 3 p<0.001, 1 vs 4 p=0.001, 2 vs 3 p<0.001, 2 vs 4 p<0.001.

Table-4c: *Association between HOMA-IR and VAI in the study population (n=439) using VAI cut-off of 3.65*

Variable		HOMA-IR (Mean±SD)	p value
DM (n=269)	Normal VAI (n=152)	7.5±6.93	<0.001
	High VAI (n=117)	9.96±7.92	
Control (n=170)	Normal VAI (n=134)	2.76±2.45	
	High VAI (n=36)	3.08±2.24	

Note: One-way ANOVA test was done. Significant difference was seen between group 1 vs 2 p=0.005, 1 vs 3 p<0.001, 1 vs 4 p<0.001, 2 vs 3 p<0.001, 2 vs 4 p<0.001.

Table-5: *Insulin resistance in total population with normal and high VAI (n=439)*

Variable	Normal VAI	High VAI	X^2	p value
		Using cut-off of 1 VAI		
High HOMA-IR (Insulin resistant)	11 (3.6%)	291 (96.4%)	9.0	0.003
		Using cut-off of 2.23 VAI		
	94 (31.1%)	208 (68.9%)	22.21	<0.001
		Using cut-off of 3.65 VAI		
	177 (58.6%)	125 (41.4%)	18.22	<0.001

Note: p value by Chi-square test.

Individuals with a high VAI had high HOMA-IR and the difference was statistically significant. HOMA-IR also had significant association with VAI at cut-off of 2.23. But significant insulin resistance was found at a 3.65 cut-off in normal VAI (Table-5). Pearson's correlation analysis was used to determine the correlations of anthropometric indices (BMI, WC and VAI) with HOMA-IR. Among anthropometric parameters VAI had positive (r=0.21, p<0.001) correlation with HOMA-IR than WC (r=0.10, p=0.043) (Table-6).

Table-6: *Correlation of anthropometric variables with HOMA-IR (n=439)*

Variable	r-value	p value
WC	0.1	0.043
BMI	0.09	0.069
VAI	0.21	<0.001

Note: Pearson's correlation was done.

Table-7: *Multiple linear regression with HOMA-IR as dependent variable (n=439)*

Variable	ß-value	p value
VAI	0.18	<0.001

Note: Linear regression was done.

Visceral fat was linearly related with insulin resistance. When VAI increased by 1 unit, HOMA-IR increased by 0.18 units (ß=0.18, p<0.001) (Table-7). Area under curve was 0.66 which was an acceptable discrimination for insulin resistance. At VAI of 1, sensitivity was 95.7% and specificity was only 9.6%.The cut-off point at which VAI had both greatest sensitivity (70%) and specificity (54.4%) to predict HOMA-IR was 2.23. VAI of 3.65 had the highest specificity of 80%, but sensitivity of only 40% in predicting insulin resistance (Figure 1).

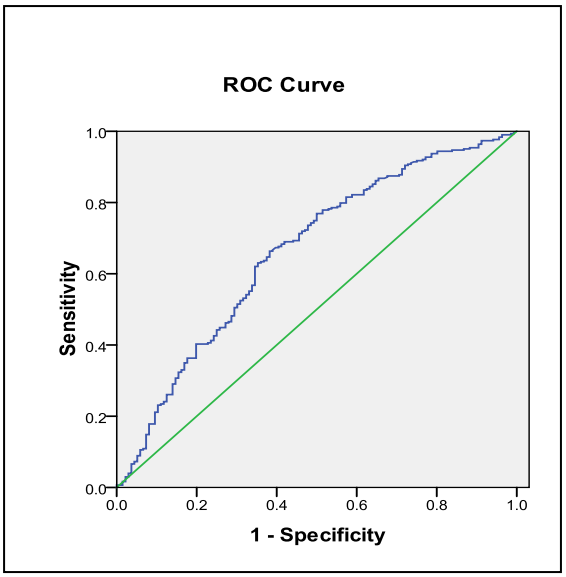

Fig-1: *ROC analysis of VAI to predict HOMA-IR.*

Discussion

This study looked at the association between VAI and insulin resistance in this population. We found a high rate of raised VAI (98.9%) in people with diabetes mellitus and an association with insulin resistance in whole population but not in between control and DM groups.

In this observational study, we found that Bangladeshi adults with diabetes mellitus had high rate of VAI. A cross sectional analysis on Chinese adults showed similarly high VAI values (90%) among people with diabetes [22]. High VAI

observed in people with diabetes may be due to the fact that hypertriglyceridemia and low HDL-c (two of the measures included in calculating VAI) characteristically occur in diabetes [23].

To the best of our knowledge, this is the only study to show the association of VAI with HOMA-IR in diabetes mellitus. Patients with diabetes mellitus who had increased insulin resistance had significantly higher VAI (Table-3). Chen et al. found that there was 2.55 fold risk of diabetes mellitus in the group with highest VAI but they did not examine association of VAI with IR [24]. Few studies confirmed the association of VAI with insulin resistance in young women with polycystic ovary syndrome (PCOS) [25] and in those with arterial stiffness [26].

Control and diabetic populations were classified into normal and high VAI after considering cut-off at 1.0, 2.23 and 3.65 for VAI. Interestingly, analysis showed significant association of HOMA-IR with VAI in diabetic population, but not in control (Table-4a, b, c). Amato et al. also reported VAI cut-off 2.23 for the age group of 30-41 years [12]. At 3.65 we got 80% specificity, but for young Korean women with PCOS optimal cut-off was determined at 1.79 (specificity 84.7%, sensitivity 82.6%) [25]. Possible explanation may be the inclusion of male participants in our study. Further study is required to identify age and sex-specific cut-off points in Bangladeshi population.

We showed insulin resistance was linearly associated with VAI in univariate and multivariate analysis (Table-7). Du et al. also found significant linear association of VAI with HOMA-IR (p=0.034 in men, p=0.042 in women) [27].

VAI includes measurement of WC and biochemical metabolic parameters which are markers of central adiposity. Furthermore, VAI has been shown to correlate well with visceral fat [24]. Central and visceral adiposity predispose to insulin resistance. Moreover, insulin resistance leads to hypertriglyceridemia and low HDL-c [23]. This may explain the association found between VAI and HOMA-IR.

AUC (0.66) showed that VAI can discriminate HOMA-IR, also reported 0.62 by Chen and by Du et al. (0.695 in men and 0.682 in women) [24,27]. Therefore VAI has been suggested as a useful, convenient and applicable surrogate marker for visceral fat distribution and function [26].

In previous studies, visceral adiposity measurement by MRI and CT was done for confirming the association of visceral adiposity with insulin resistance [2,3]. But these gold standards for visceral adipose tissue measurement are not suitable for large epidemiological studies due to their high cost and inconvenience. Simple measures such as WC and BMI cannot reflect the difference between subcutaneous and visceral fat [22]. Since VAI includes anthropometric (BMI and WC) and metabolic (TG and HDL-c) parameters, it indicates both fat distribution and function [24]. VAI correlates with visceral adiposity measured by MRI. In addition, association of visceral obesity with atherogenic lipoprotein (high serum triglyceride) was confirmed by other study [28].

The small number of men and women assessed in this study may limit the interpretation and extrapolation in other populations. Also, it was not possible to use the gold standard euglycaemic clamp method for measurement of insulin resistance. For control oral glucose tolerance test was not done due to technical difficulties. But participants with DM and prediabetes were excluded from control group for better outcome.

Conclusion

There was a high rate of raised VAI in type-2 diabetes mellitus. VAI had positive association with HOMA-IR in diabetes mellitus. Although weak, VAI could discriminate insulin resistance.

Author's contributions

SP developed the concept and supervised the study; TA collected the samples, entered and analyzed the data and contributed to the drafting of manuscript; TH reviewed data analysis, contributed to discussion and drafting and revision of the manuscript; NN drafted the protocol and helped in data collection; NM collected and organized the data; FI, FA and MA Aziz helped in sample collection and clinical management of the volunteers.

Conflict of Interest

The authors declare no conflict of interest.

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References

1. Shuster A, Patlao M, Pinthus JH, Mourtzakis M. The clinical importance of visceral adiposity: a critical review of methods for visceral adipose tissue analysis. *Br J Radiol.* 2012; **85**(1009): 1-10.
2. Fox CS, Massaro JM, Hoffmann U, Pou KM, Maurovich-Horvat P, Liu CY, *et al*. Abdominal visceral and subcutaneous adipose tissue compartments: association with metabolic risk factors in the Framingham Heart Study. *Circulation.* 2007; **116**(1): 39–48.
3. DeNino WF, Tchernof A, Dionne IJ, Toth MJ, Ades PA, Sites CK, Poehlman ET. Contribution of abdominal adiposity to age-related differences in insulin sensitivity and plasma lipids in healthy nonobese women. *Diabetes Care.* 2001; **24**: 925–932.
4. Bu J, Zhang Y, Chen H, Liang YP, Huang JL. Relationship between visceral fat volume by CT and insulin resistance in type 2 diabetes [Article in Chinese]. *Shi Yong Yi XueZaZhi.* 2009; **25**: 2278–2279.
5. Lillioja S., Mott MD, Spraul M, Ferraro R, Foley JE, Ravussin E, *et al*. Insulin resistance and insulin secretory dysfunction as precursors of NIDDM, prospective study of Pima Indians. *N Engl J Med.* 1993; **329**: 1988-1992.
6. Matsuda M, Shimomura I. Increased oxidative stress in obesity: implications for metabolic syndrome, diabetes, hypertension, dyslipidemia, atherosclerosis, and cancer. *Obes Res Clin Pract.* 2013; **7**: e330–e341.
7. Hardy OT, Czech MP, Corvera S. What causes the insulin resistance underlying obesity? *Curr Opin Endocrinol Diabetes Obes.* 2012; **19**(2): 81-87.
8. Pouliot MC, Despres JP, Lemieux S, Moorjani S, Bouchard C, Tremblay A, *et al*. WC and abdominal saggital diameter: best simple anthropometric indices of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. *American Journal Cardiol.* 1994; **73**: 460-468.
9. Despres JP. Is visceral obesity the cause of metabolic syndrome? *Annual Medicine.* 2006; **38**: 52-63.
10. Kershaw EE, Flier JS. Adipose tissue as an endocrine organ. *J Clin EndocrinolMetab.*2004; **89**: 2548-2556.
11. Amato MC, Giordano C, Pitrone M, Galluzzo A. Cut-off points of the VAI identifying a visceral adipose dysfunction associated with cardiometabolic risk in a Caucasian Sicilian population. *Lipids Health Dis.* 2011; **10**:183.
12. Amato MC, Giordano C, Galia M, Criscimanna A, Vitabile S, Midiri M, *et al*. Visceral adiposity index: a reliable indicator of visceral fat function associated with cardiometabolic risk. *Diabetes Care.* 2010; **33**(4): 920-922.
13. Shamima A, Mizanur RM, Sarah AK, Papia S. Prevalence of diabetes & prediabetes and their risk factors among Bangladeshi adults: a nationwide survey. Bulletin of WHO. 2014; **92**: 204-213.
14. IDF Diabetes Atlas, 8th edition. 2017. Available from: https://www.idf.org.
15. World Health Organization. Definition and diagnosis of Diabetes mellitus and intermediate hyperglycemia: Report of a WHO/IDF consultation; 2006.
16. Dahlen EM, Bjarnergard N, Lanne T, Nystorm FH, Ostgren CJ. Sagital abdominal diameter is a more independent measure compared with waist circumference to predict arterial stiffness in subjects with type 2 diabetes-a prospective observational cohort study. *Cardivasc Diabetol*. 2013; **12**: 55.
17. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatric Obesity.* 2012; **7**(4): 284-294.
18. Amato MC, Giordano C, Galia M, Criscimanna A, Vitabile S, Midiri M, *et al*. Visceral Adiposity Index. *Diabetes Care*. 2010; **33**(4): 920-922.

19. Kaplan A, Glucose K. Clin Chem. The C.V. Mosby Co. St Louis. Toronto. Princeton 1984; p. 436.

20. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher BF, Turner RC. Homeostasis model assessment: insulin resistance and b-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*. 1985; **28**: 412–419.

21. Bhowmik B, Siddiquee T, Mujumder A, Rajib MMR., Das CK, Khan MI, *et al*. Identifying insulin resistance by fasting blood samples in Bangladeshi population with normal blood glucose. *J Diabetol.* 2016; **7**(3): 4.

22. Liu PJ, Ma F, Lou HP, Chen Y. VAI Is Associated with Pre-diabetes and Diabetes Mellitus in Chinese Adults Aged 20-50. *Ann Nutr Metab.* 2016; **68**(4): 235-243.

23. Holt RIG, Cockram CS, Flyvbjerg A, Goldstein BJ. Textbook of Diabetes. 4th ed. UK: Wiley – Blackwell; 2011.

24. Chen C, Yan X, Zhi-rong G, Jie Y, Ming W, Xia-shu H. The application of VAI in identifying type 2 diabetes risks based on a prospective cohort in China. *Lipids Health Dis.* 2014; **13**: 108.

25. 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**(8): 1690-1694.

26. Yang F, Wang G, Wang Z, Sun M, Cao M, Zhu Z, *et al*. Visceral adiposity index may be a surrogate marker for the assessment of the effects of obesity on arterial stiffness. *PLoS ONE.* 2014; **9**(8): e 104365.

27. Du T, Gang Y, Muxun Z, Xingrong Z, Xingxing S, Xuefeng Y. Clinical usefulness of lipid ratios, visceral adiposity indicators and the triglycerides and glucose index as risk markers of insulin resistance. *Cardiovasc Diabetol.* 2014; **13**: 46.

28. Nieves DJ, Cnop M, Retzlaff B, Walden CE, Brunzell JD, Knopp RH, *et al*. The Atherogenic Lipoprotein Profile Associated With Obesity and Insulin Resistance Is Largely Attributable to Intra-Abdominal Fat. *Diabetes.* 2003; **52**: 172-179.