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Evaluation of Visceral Adiposity Indexes Associated with Atherogenic Plasma Index in Individuals with Type 2 Diabetes

Tip 2 Diyabetli Bireylerde Aterojenik Plazma İndeksi ile İlişkili Visseral Adipozite İndekslerinin Değerlendirilmesi

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ABSTRACT

Aim: This study was aimed to investigate visceral adiposity indicators and the atherogenic index of plasma (AIP) in type 2 diabetes mellitus (T2DM) patients.
Material and Methods: A total of 353 adults aged between 18 and 74 years were included in this study. Bodyweight, height, waist, and hip circumference were measured; fasting blood glucose, HbA1c, and lipid profile (total cholesterol, triglyceride, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol) values were analyzed. Visceral adiposity index (VAI), lipid accumulation product (LAP), body adiposity index (BAI), body shape index (ABSI), body roundness index (BRI), conicity index (CI), and AIP levels were calculated.
Results: The study included 116 (32.9%) males and 237 (67.1%) females, with a mean age of 57.8±11.5 years. AIP z-scores were found to be directly related to T2DM (OR, 5.03; 95% CI: 1.95-13.01), while VAI z-scores were less associated with T2DM (OR, 1.10; 95% CI: 1.03-1.18). According to the ROC curve analysis, although the area under the curve (AUC) is weak to distinguish diabetic patients with VAI, LAP, and AIP, it is statistically significant ($p<0.001$, AUC: 0.619, cut-off= 5.1, 95% CI: 0.561-0.677; $p=0.007$, AUC: 0.583, cut-off= 63.2, 95% CI: 0.523-0.642; and $p=0.001$, AUC: 0.606, cut-off= 0.4, 95% CI: 0.547-0.665, respectively).
Conclusion: VAI, LAP, and AIP are strong predictors of diabetes, AIP is a better predictor of predicting diabetes than VAI and LAP.
Keywords: Atherogenic plasma index; visceral adiposity index; lipid accumulation product; type 2 diabetes.

ÖZ

Amaç: Bu çalışmanın amacı tip 2 diyabet (T2DM) hastalarında visseral yağlanma göstergelerini ve aterojenik plazma indeksini (atherogenic index of plasma, AIP) araştırmaktır.
Gereç ve Yöntemler: Bu çalışmaya 18 ve 74 yaşları arası toplam 353 yetişkin birey dahil edildi. Vücut ağırlığı, boy uzunluğu, bel ve kalça çevresi ölçüldü; açlık kan şekeri, HbA1c ve lipid profil (total kolesterol, trigliserit, düşük dansiteli lipoprotein kolesterol ve yüksek dansiteli lipoprotein kolesterol) değerleri analiz edildi. Visseral adipozite indeksi (visceral adiposity index, VAI), lipit birikim ürünü (lipid accumulation product, LAP), vücut adipozite indeksi (body adiposity index, BAI), vücut şekli indeksi (body shape index, ABSI), vücut yuvarlaklık indeksi (body roundness index, BRI), koniklik indeksi (conicity index, CI) ve AIP seviyeleri hesaplandı.
Bulgular: Çalışmaya, yaş ortalaması 57,8±11,5 yıl olan 116 (%32,9) erkek ve 237 (%67,1) kadın dahil edildi. AIP z-skorlarının doğrudan T2DM ile ilişkili olduğu (OR, 5,03; %95 GA: 1,95-13,01), VAI z-skorlarının T2DM ile daha az ilişkili olduğu (OR, 1,10; %95 GA: 1,03-1,18) belirlendi. ROC eğrisi analizine göre, eğri altında kalan alan (area under the curve, AUC) VAI, LAP ve AIP ile diyabetik hastaları ayırt etmekte zayıf olsa da istatistiksel olarak anlamlıdır (sırasıyla $p<0,001$; AUC: 0,619; kesme değeri= 5,1; %95 GA: 0,561-0,677; $p=0,007$; AUC: 0,583; kesme değeri= 63,2; %95 GA: 0,523-0,642 ve $p=0,001$; AUC: 0,606; kesme değeri= 0,4; % 95 GA: 0,547-0,665).
Sonuç: VAI, LAP ve AIP diyabetin güçlü prediktörleridir, AIP diyabeti öngörmede VAI ve LAP'den daha iyi bir prediktördür.
Anahtar kelimeler: Aterojenik plazma indeksi; visseral adipozite indeksi; lipid birikim ürünü; tip 2 diyabet.

INTRODUCTION

Diabetes mellitus (DM) is the ninth leading cause of death globally. One out of every eleven adults worldwide is diagnosed with DM, and Type 2 diabetes mellitus (T2DM) accounts for about 90% of cases (1). According to the Turkey Nutrition and Health Survey (TBSA) findings, conducted in 2017, the prevalence of the disease was found to be 9.1% in adults over 19 years old in our country (2).

It has been proven that excess body fat has been linked to an increased risk of cardiometabolic disorders, inflammatory diseases, and metabolic diseases such as DM (3-5). Obesity's harmful effects are caused by adipose tissue distribution in the body, especially central obesity, which is closely linked to T2DM patients' morbidity and mortality (6,7). Assessment of obesity, abdominal obesity, and adiposity as diabetes determinants who people with diabetes are becoming more significant (8). Obesity is assessed using a globally agreed body mass index (BMI), but BMI is inadequate for determining "body fat mass" and "lean body mass", which determine abdominal (central) or visceral obesity (9).

Dual-energy X-ray absorptiometry (DEXA), computed tomography (CT), magnetic resonance imaging (MRI), and dual bioelectrical impedance analysis (BIA) may all be used to reliably calculate adipose tissue. However, due to factors such as the need for specialized medical personnel, time limitations, radiation exposure, and high costs, they are not appropriate for regular clinical use (10,11).

Waist circumference, visceral adiposity index (VAI), body adiposity index (BAI), body shape index (ABSI), body roundness index (BRI), conicity index (CI), and lipid accumulation product (LAP) are all used to identify visceral adiposity (8,12,13). Obesity and insulin resistance are factors that lead to diabetic dyslipidemia and cardiovascular disease risk in people with T2DM, which is characterized by hypertriglyceridemia, low serum "high-density lipoprotein cholesterol (HDL-C)", and high serum "low-density lipoprotein cholesterol (LDL-C)" levels. In recent years, the atherogenic index, a newly developed parameter, has been used to measure plasma atherogenicity in T2DM patients, and it has been proposed that it is related to T2DM (14).

In people with type 2 diabetes, it's crucial to look at obesity, visceral adiposity, and cardiovascular disease risk factors all at once (15). Waist circumference, VAI, BAI, LAP, BRI, ABSI, and CI are all used to estimate the risk of T2DM from cardiometabolic diseases, but it's unclear which index is a better predictor (15-18). The aim of this study was to determine visceral adiposity indicators and the atherogenic plasma index in T2DM patients.

MATERIAL AND METHODS

This study is designed as descriptive, and cross-sectional. Individuals who applied to the Internal Medicine Polyclinic of Erzincan Mengücek Gazi Training and Research Hospital between December 2019 and May 2020 comprise the study's population. By not using any sample selection method in the study, 353 adults who voluntarily agreed to participate with the full count method were included. The study included individuals of ages 18 to 74 with a BMI of 18.5 to 35 kg/m^2 and no other chronic conditions (cardiovascular diseases, polycystic ovary syndrome, thyroid dysfunction, asthma, etc.) other than T2DM, those not on hormone therapy, and those not using lipid-lowering agents; while excluding pregnant and lactating women and those with any malignant and inflammatory diseases or acute infections. Individuals who volunteered to take part in the study were enrolled after reading and signing an informed consent form. Descriptive characteristics, anthropometric measurements, and biochemical parameters were used to collect data for the analysis.

The ethics committee approval dated 03.12.2019 and numbered 12-10 was received by Erzincan Binali Yıldırım University Human Research Ethics Committee for this research. The researchers' information form contains questions about the individuals' socio-demographic characteristics, introductory characteristics, and disease states. With a precision scale (sensitive to ±0.1 kg) that was adjusted at regular intervals, body weight was measured without shoes and in light clothing. Height was measured with a wall-mounted stadiometer with an accuracy of 0.1 cm. BMI was evaluated according to the classification of the World Health Organization (WHO) by calculating kg/m^2 with the body weight / height formula (19). A non-stretch tape measure was used to measure the circumference of the waist (WC), passing across the midpoint between the lower costal border and the iliac crest. The hip circumference was determined with a non-stretch tape measure from the highest point on the hip on the right side of the individual. A doctor assessed the blood pressure in the right arm in a sitting position using an accurate sphygmomanometer after 15 minutes of rest.

Blood samples were collected from individuals in the morning hours following a 12-hour fast to test serum biochemical parameters. The results of biochemical parameters demanded by the patients' physicians (fasting blood glucose (FBG), glycated hemoglobin (HbA1c), total cholesterol, triglyceride (TG), LDL-C, HDL-C) were used. The spectrophotometric method was used to calculate FBG and lipid profile from serum using a Beckman Coulter Olympus AU2700 Plus Chemistry Analyzer (Beckman Coulter, Tokyo, Japan) unit. HbA1c was analyzed by an HPLC analyzer (G8 Tosoh, Japan). Individuals with HbA1c ≥6.5% were diagnosed with T2DM. Values of VAI, LAP, BAI, ABSI, BRI, CI, and atherogenic index of plasma (AIP) were calculated with the formulas given below:

VAI (male) = [WC (cm) / (39.68 + (1.88xBMI)] x (TG/1.03) x (1.31/HDL-C)

VAI (female) = [WC (cm) / (36.58 + (1.89xBMI)] x (TG/0.81) x (1.52/HDL-C)

LAP (male) = [WC (cm)-65] x [TG (mmol/L)]

LAP (female) = [WC (cm)-58] x [TG (mmol/L)]

BAI = [Hip circumference (cm) / Height (m)$^{1.5}$]-18

ABSI = [WC (cm) / (BMI$^{2/3}$ x Height$^{1/2}$)]

BRI = 364.2-365.5 x [1 - (WC/2π)^2 / (0.5 × Height^2)$^{1/2}$]

CI = WC (m) / [0.109 x (√Body weight (kg) / Height (m)]

AIP = Log10 [TG/HDL-C]

Statistical Analysis

In the analysis of data, the IBM SPSS v.22.0 (IBM Corp. Armonk, N.Y., USA) package program was used. The normality of the distribution of numerical variables was evaluated using the Kolmogorov-Smirnov test. Descriptive statistics for continuous variables were shown

as mean, standard deviation, median, minimum-maximum. Mann-Whitney U test or Independent samples t-test was used for continuous variables. When testing the diagnostic value of VAI, LAP, and AIP; the receiver operator characteristics (ROC) curve analysis was used. The association between different obesity measures (VAI, LAP, AIP) and DM was evaluated by logistic regression analysis, followed by the calculation of the odds ratio (OR) with a corresponding 95% confidence interval (95% CI). The model was adjusted for age and gender. Hosmer-Lemeshow goodness-of-fit test was used for evaluating the model fit. Additionally, chi-square test statistics of models and Nagelkerke R^2 were presented. The significance level was accepted as $p<0.05$ for statistical tests.

RESULTS

This research included 116 (32.9%) males and 237 (67.1%) females, with a mean age of 57.8±11.5 years. Table 1 displays the characteristics of individuals based on their diabetes status. VAI (p<0.001), LAP (p=0.007), AIP (p=0.001), systolic blood pressure (SBP, p=0.002), diastolic blood pressure (DBP, p=0.011), FBG (p<0.001), HbA1c (p<0.001), total cholesterol (p=0.002), triglyceride (p=0.001), and LDL-C (p=0.009) values were all higher in people with diabetes than in those without diabetes, while HLD-C (p=0.010) values were lower.

Table 2 was shown the relationship between VAI, LAP, AIP, and DM in adult individuals evaluated using an adjusted logistic regression model. After adjusting for age and gender, AIP z-scores were found to be directly related to DM (OR, 5.03; 95% CI: 1.95-13.01), while VAI z-scores were less associated with DM (OR, 1.10; 95% CI: 1.03-1.18).

Compared to other indices, VAI has the highest area under the curve (AUC) in the ROC analysis (Figure 1). When the ROC curves are examined, the AUC is weak to differentiate patients with VAI, LAP, and AIP diabetes, but it is statistically significant (p<0.001, cut off= 5.1, AUC: 0.619, 95% CI: 0.561-0.677; p=0.007, cut off= 63.2, AUC: 0.583, 95% CI: 0.523-0.642; p=0.001, cut off= 0.4, AUC: 0.606, 95% CI: 0.547-0.665), respectively).

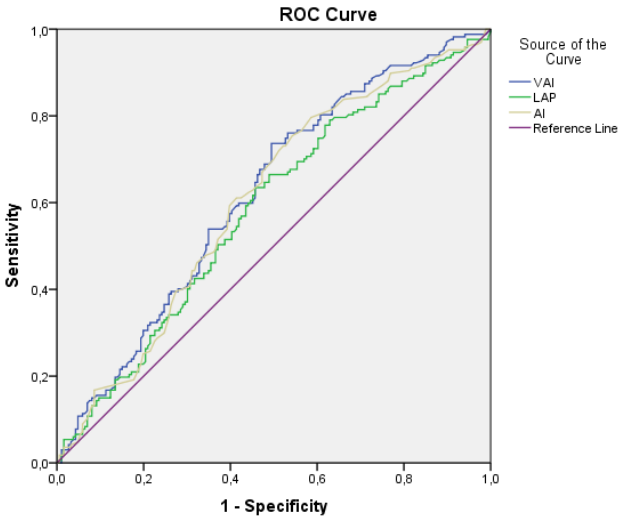

Figure 1. ROC curves for VAI, LAP, and AIP as predictors for diabetes

ROC: receiver operator characteristics, VAI: visceral adiposity index, LAP: lipid accumulation product, AIP: atherogenic index of plasma

Table 1. Characteristics of individuals with and without diabetes

	No (n=186)	Yes (n=167)	p
Age (year)	56.7±11.7	59.1±11.1	0.051
Body mass index (kg/m^2)	30.1±4.5	29.7±4.5	0.556
Waist circumference (cm)	100.7±12.0	101.4±12.3	0.455
Hip circumference (cm)	110.1±10.4	109.9±11.2	0.825
Waist/hip	0.9±0.1	0.9±0.1	0.482
VAI	3.9 (2.6-7.2) [1.4-23.9]	5.8 (3.5-8.1) [1.3-22.1]	**<0.001**
LAP	53.9 (35.3-92.5) [14.2-489.3]	71.5 (44.3-98.5) [14.0-336.0]	**0.007**
Body adiposity index	34.5±6.5	34.7±7.1	0.764
Body shape index	0.8±0.1	0.8±0.1	0.064
Body roundness index	5.8±1.8	6.0±1.9	0.391
Conicity index	1.3±0.1	1.3±0.1	0.082
AIP	0.3 (0.2-0.5) [0.1-1.2]	0.4 (0.3-0.6) [0.0-1.0]	**0.001**
SBP (mmHg)	13 (12-14) [9-16]	14 (12-15) [9-16]	**0.002**
DBP (mmHg)	7 (6-8) [5-10]	8 (6-8) [5-10]	**0.011**
FBG (mg/dL)	113 (98-169) [74-566]	156 (112-219) [74-591]	**<0.001**
HbA1c (%)	6.1 (5.5-7.1) [5.2-11.9]	7.1 (6.3-9.2) [4.8-14.2]	**<0.001**
Total cholesterol (mg/dL)	209.4±50.1	226.9±53.2	**0.002**
Triglyceride (mg/dL)	123 (90-184) [45-487]	158 (109-191) [45-525]	**0.001**
LDL-C (mg/dL)	129.9±39.5	141.1±41.3	**0.009**
HDL-C (mg/dL)	55 (45-59) [28-84]	50 (45-56) [28-94]	**0.010**

VAI: visceral adiposity index, LAP: lipid accumulation product, AIP: atherogenic index of plasma, SBP: systolic blood pressure, DBP: diastolic blood pressure, FBG: fasting blood glucose, LDL-C: low-density lipoprotein cholesterol, HDL-C: high-density lipoprotein cholesterol, descriptive statistics were shown as mean±standard deviation or median (Q1-Q3) [min-max]

Table 2. The relationship of VAI, LAP, and AIP indices with diabetes

	VAI z-score (Model 1)		LAP z-score (Model 2)		AIP z-score (Model 3)	
	OR (95% CI)	**p**	**OR (95% CI)**	**p**	**OR (95% CI)**	**p**
Model	1.10 (1.03-1.18)	**0.005**	1.01 (1.00-1.09)	0.056	5.03 (1.95-13.01)	**0.001**
Hosmer-Lemeshow	χ^2:10.297 p=0.225		χ^2:3.880 p=0.868		χ^2:7.246 p=0.510	
Model χ^2 and p	χ^2:15.541 p=0.001		χ^2:10.812 p=0.013		χ^2:18.450 p<0.001	
Nagelkerke R^2	0.057		0.040		0.068	

VAI: visceral adiposity index, LAP: lipid accumulation product, AIP: atherogenic index of plasma, OR: odds ratio, CI: confidence interval, model adjusted for age and gender

DISCUSSION

Obesity is a worldwide epidemic and leads to a 20% increased risk of acute myocardial infarction and obesity plays a major role in the development of T2DM. T2DM is a major risk factor for cardiovascular disease (20). Visceral obesity has been proven to be a more critical risk factor for T2DM (21). VAI, and LAP are indicators that express central fat accumulation and have been developed to be independently associated with impaired fasting glucose, type 2 diabetes, and coronary heart disease (22). AIP could predict the size of lipoprotein particles, subsequently showing a positive correlation with the risk of cardiovascular disease. Furthermore, AIP can provide information on the severity of insulin resistance, which is associated with impaired glucose metabolism (23).

When age and gender were included in the model, VAI, LAP, and AIP were found to be statistically significant in identifying patients with diabetes, and AIP was found to be better predictive of T2DM than VAI and LAP.

Concentrations of TG and HDL-C, as well as BMI and WC, are used to calculate the visceral adiposity index and should be an easy tool to assess the risk of metabolic disorders associated with insulin resistance (24). VAI has been shown in research to be a method for distinguishing patients with T2DM (16,25-27). This research supports the previous studies, as well.

Lipid accumulation product is uncomplicated, cheap, and could be a useful index combining WC and TG (28). LAP was found to be effective in distinguishing people with diabetes in a study (26). In research by Tian et al. (18) LAP was found to be linked to diabetes. It was determined in this study that LAP can be used to distinguish patients with diabetes, but that once age and gender are included in the model, it is no longer useful in defining diabetes.

Visceral adiposity index and LAP levels are very efficient in predicting cardiovascular disease risk factors in various clinical studies (20-22,29-31). In people with T2DM and visceral obesity, lipid and lipoprotein metabolism problems are common, resulting in diabetic dyslipidemia and a high risk of cardiovascular disease. The lipid profile of a person with diabetes who is obese and has impaired glycemic control is negatively affected (14). AIP, a new atherogenicity indicator, is easily measured as "the logarithm of the ratio of TG/HDL-K" levels, and it rises as the risk of atherosclerosis rises, outperforming conventional lipid profiles in predicting atherosclerosis and cardiovascular disease. AIP levels grow much faster as obesity, especially abdominal obesity, grows (32,33). While TG and HDL-K levels are appropriate when calculating AIP levels, BMI and WC levels must be used in conjunction with these parameters when calculating VAI levels, and WC and TG must be used when calculating LAP levels (30). When examining the literature, it has been proposed that AIP is a strong predictor of increased cardiovascular risk in people with T2DM (23,34-38).

Improved glycemic control and lifestyle changes in diabetic patients (increasing physical activity, adopting healthier eating patterns, and so on), obesity, visceral adiposity, and lipid control may lower cardiovascular disease risk.

One of the limitations of the study is as a cross-sectional study, and thus a causal association between VAI, LAP, AIP, and diabetes cannot be determined. Second, a small patient population was observed, and data was obtained from a single center. There is a need for research with a large patient group from different centers.

CONCLUSION

Visceral adiposity index, LAP, and AIP are both efficient predictors of diabetes, with AIP outperforming VAI, and LAP in terms of predicting diabetes.

Ethics Committee Approval: The study was approved by the Human Research Ethics Committee of Erzincan Binali Yıldırım University (03.12.2019, 12-10).

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REFERENCES

1. Zheng Y, Ley SH, Hu FB. Global etiology and epidemiology of type 2 diabetes mellitus and its complications. Nat Rev Endocrinol. 2018;14(2):88-98.
2. T.C. Sağlık Bakanlığı Halk Sağlığı Genel Müdürlüğü. Türkiye beslenme ve sağlık araştırması (TBSA). Sağlık Bakanlığı Yayın No: 1132. Ankara:Tiraj; 2019.
3. Darroudi S, Fereydouni N, Tayefi M, Ahmadnezhad M, Zamani P, Tayefi B, 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(1):35-42.
4. Han TS, Al-Gindan YY, Govan L, Hankey JR, Lean MEJ. Associations of BMI, waist circumference, body fat, and skeletal muscle with type 2 diabetes in adults. Acta Diabetol. 2019;56(8):947-54.
5. West-Eberhard MJ. Nutrition, the visceral immune system, and the evolutionary origins of pathogenic obesity. Proc Natl Acad Sci USA. 2019;116(3):723-31.
6. Sam S. Differential effect of subcutaneous abdominal and visceral adipose tissue on cardiometabolic risk. Horm Mol Biol Clin Investig. 2018;33(1).
7. Lee SW, Son JY, Kim JM, Hwang SS, Han JS, Heo NJ. Body fat distribution is more predictive of all-cause mortality than overall adiposity. Diabetes Obes Metab. 2018;20(1):141-7.
8. Marcadenti A, Fuchs FD, Moreira LB, Gus M, Fuchs SC. Adiposity phenotypes are associated with type-2 diabetes: LAP index, body adiposity index, and neck circumference. Atherosclerosis. 2017;266:145-50.
9. Javed A, Jumean M, Murad MH, Okorodudu D, Kumar S, Somers VK, 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(3):234-44.
10. Fang H, Berg E, Cheng X, Shen W. How to best assess abdominal obesity. Curr Opin Clin Nutr Metab Care. 2018;21(5):360-5.
11. Omura-Ohata Y, Son C, Makino H, Koezoka R, Tochiya M, Tamanaha T, et al. Efficacy of visceral fat estimation by dual bioelectrical impedance analysis in detecting cardiovascular risk factors in patients with type 2 diabetes. Cardiovasc Diabetol. 2019;18(1):137.
12. Bertoli S, Leone A, Krakauer NY, Bedogni G, Vanzulli A, Redaelli VI, et al. Association of body shape index (ABSI) with cardio-metabolic risk factors: a cross-sectional study of 6081 Caucasian adults. PLoS One. 2017;12(9):e0185013.
13. Sözmen K, Ünal B, Sakarya S, Dinç G, Yardım N, Keskinkılıç B, et al. Association of anthropometric measurement methods with cardiovascular disease risk in Turkey. Dicle Med J. 2016;43(1):99-106.
14. Zhu XW, Deng FY, Lei SF. Meta-analysis of the atherogenic index of plasma and other lipid parameters in relation to risk of type 2 diabetes mellitus. Prim Care Diabetes. 2015;9(1):60-7.
15. Küçükerdönmez Ö, Karaçil Ermumcu MŞ, Seçkiner S, Köksal E. Evaluation of abdominal obesity/adiposity and atherogenic predictors in individuals with type 2 diabetes. Bes Diy Derg. 2018;46(1):7-15.
16. Alkhalaqi A, Al-Naimi F, Qassmi R, Shi Z, Ganji V, Salih R, et al. Visceral adiposity index is a better predictor of type 2 diabetes than body mass index in Qatari population. Medicine (Baltimore). 2020;99:35(e21327).
17. Liu J, Fan D, Wang X, Yin F. Association of two novel adiposity indicators with visceral fat area in type 2 diabetic patients: Novel adiposity indexes for type 2 diabetes. Medicine (Baltimore). 2020;99(19):e20046.
18. Tian T, Pei H, Chen Z, Hailili G, Wang S, Sun Y, et al. Comparison of lipid accumulation product and body mass index as indicators of diabetes diagnosis among 215,651 Chinese adults. Peer J. 2020;8:e8483.
19. Pekcan G. Beslenme durumunun saptanması. In: Baysal A, Aksoy M, Besler HT, editors. Diyet el kitabı. 7th ed. Ankara: Hatiboğlu; 2013.
20. Golabi S, Ajloo S, Maghsoudi F, Adelipour M, Naghashpour M. Associations between traditional and non-traditional anthropometric indices and cardiometabolic risk factors among inpatients with type 2 diabetes mellitus: a cross-sectional study. Int J Med Res. 2021;49(10):3000605211049960.
21. Li X, Li HY, Yu ZW, Zhang YT, Tong XW, Gao XY. Association among lipid accumulation product, Chinese visceral obesity index and diabetic retinopathy in patients with type 2 diabetes: a cross-sectional study. Diabetes Metab Syndr Obes. 2021;14:4971-9.
22. Shu L, Zhao Y, Shen Y, Jia L, Zhang J. Interaction analysis of lipid accumulation product and family history of diabetes on impaired fasting glucose and diabetes risk in population with normotension in Eastern China: a community-based cross-sectional survey. Research Square. 2022. doi: 10.21203/rs.3.rs-226460/v2
23. Fu L, Zhou Y, Sun J, Zhu Z, Xing Z, Zhou S, et al. Atherogenic index of plasma is associated with major adverse cardiovascular events in patients with type 2 diabetes mellitus. Cardiovasc Diabetol. 2021;20(1):201.
24. Oh JY, Sung YA, Lee HJ. The visceral adiposity index as a predictor of insulin resistance in young women with polycystic ovary syndrome. Obesity (Silver Spring). 2013;21(8):1690-4.
25. Silva NF, Pinho CPS, Diniz AS, Arruda IKG, Leão APD, Rodrigues IG. The applicability of the visceral adiposity index (VAI) for predicting visceral fat. Rev Bras Cineantropom Desempenho Hum. 2022;24:e83146.
26. Ahn N, Baumeister SE, Amann U, Rathmann W, Peters A, Huth C, et al. Visceral adiposity index (VAI), lipid accumulation product (LAP), and product of triglycerides and glucose (TyG) to discriminate prediabetes and diabetes. Sci Rep. 2019;9(1):9693.
27. Elizalde-Barrera CI, Rubio-Guerra AF, Lozano-Nuevo JJ, Olvera-Gomez JL. Triglycerides and waist to height ratio are more accurate than visceral adiposity and body adiposity index to predict impaired fasting glucose. Diabetes Res Clin Pract. 2019;153:49-54.
28. Khan HS. The lipid accumulation product is better than BMI for identifying diabetes. Diabetes Care. 2006;29(1):151-3.
29. Gârgavu SR, Clenciu D, Roşu MM, Ţenea Cojan TŞ, Costache A, Vladu IM, et al. Visceral adiposity index (VAI) - a potential marker of cardiometabolic risk. Arch Balk Med Union. 2018;53(2):246-51.
30. Pekgor S, Duran C, Eryılmaz MA, Berberoglu B. The comparision of visceral adiposity index and atherogenic index of plasma in overweight and obese patients. Acta Medica Mediterr. 2020;36(2):813-19.
31. Abolnezhadian F, Hosseini SA, Alipour M, Zakerkish M, Cheraghian B, Ghandil P, et al. Association metabolic obesity phenotypes with cardiometabolic index, atherogenic index of plasma and novel anthropometric indices: A link of FTO-rs9939609 polymorphism. Vasc Health Risk Manag. 2020;16:249-56.
32. Sayın S, Kutlu R, Koçak A. The relationship between atherogenic index of plasma and major risk factors of cardiovascular disease in obese and non-obese individuals. Eur J Res. 2019;5(4):678-85.

33. Shen SW, Lu Y, Li F, Yang CJ, Feng YB, Li HW, et al. Atherogenic index of plasma is an effective index for estimating abdominal obesity. Lipids Health Dis. 2018;17(1):11.
34. Phapale YS, Badade ZG, Kaul SK, Rai S. Assessment of atherogenic indices in type 2 diabetes mellitus. J Clin Diagn Res. 2019;13(12):BC10-3.
35. Rawat S, Kumar S, Arora M, Iqbal S, Batra J, Sharma S, et al. Assessment of atherogenic index of plasma, non-HDL cholesterol and other cardiac indices as risk factors for CVD in type II diabetes. Int J Health Clin Res. 2020;3(5):137-41.
36. Randrianarisoa E, Lehn-Stefan A, Hieronimus A, Rietig R, Fritsche A, Machann J, et al. Visceral adiposity index as an independent marker of subclinical atherosclerosis in individuals prone to diabetes mellitus. J Atheroscler Thromb. 2019;26(9):821-34.
37. Atalay H, Böyük B, Değirmencioğlu Ş, Güzel S, Çelebi A, Ekizoğlu i. Effect of the atherogenic index of plasma on microvascular complications associated with type 2 diabetes mellitus. Istanbul Med J. 2015;16(3):111-5.
38. Gebreyesus HA, Abreha GF, Besherae SD, Abera MA, Weldegerima AH, Gidey AH, et al. High atherogenic risk concomitant with elevated HbA1c among persons with type 2 diabetes mellitus in North Ethiopia. PLoS One. 2022;17(2):e0262610.