ORIGINAL RESEARCH

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Evaluation of Visceral Adiposity Index (VAI) and Metabolic Profiles in Patients with Different Body Mass İndex (BMI) Groups

Farklı Beden Kitle İndeksi (VKİ) Gruplarındaki Hastalarda Visseral Adipozite İndeksi (VAİ) ve Metebolik Profillerin Değerlendirilmesi

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Abstract

Objective: The primary objective of this study was to explore the relationship between the visceral adiposity index (VAI) and body mass index (BMI), two critical measures often used to assess individual health and obesity levels.

Method: This retrospective study analyzed data from 141 patients who applied to the Obesity and Internal Medicine Clinic of University of Health Sciences Turkey, Gazi Yaşargil Training and Research Hospital. Demographic, anthropometric (height, weight, waist, hip circumference, BMI), and biochemical parameters [alanine transaminase (ALT), aspartate transaminase (AST), high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride, glucose] were assessed. Visceral fat distribution was evaluated using the VAI. Patients were classified into four BMI groups: Normal weight (18.5-24.9), overweight (25-29.9), obese (30-39.9), and morbidly obese (>40), to examine the link between BMI and visceral fat.

Results: The analysis of different BMI groups revealed significant variations in anthropometric and biochemical parameters. Higher BMI was associated with increased weight, waist and hip circumferences, and systolic blood pressure (p<0.001), while height decreased as BMI increased (p<0.001). Platelet count and ALT/AST levels were significantly higher in individuals with higher BMI (p<0.003, p<0.001). HDL cholesterol decreased (p<0.001), while triglycerides and LDL cholesterol increased with BMI (p<0.001, p=0.001). HbA1c levels were also significantly higher in individuals with increased BMI (p<0.001). VAI increased significantly with increasing BMI (p<0.001), indicating greater visceral fat accumulation.

Öz

Amaç: Bu çalışmanın amacı, bireysel sağlık ve obezite düzeylerini değerlendirmek için sıklıkla kullanılan iki kritik ölçüt olan visseral adipozite indeksi (VAI) ile vücut kitle indeksi (VKİ) arasındaki ilişkiyi araştırmaktır.

Yöntem: Bu retrospektif çalışmada Sağlık Bilimleri Üniversitesi, Gazi Yaşargil Eğitim ve Araştırma Hastanesi, Obezite ve İç Hastalıkları Polikliniği'ne başvuran 141 hastanın verileri analiz edildi. Demografik, antropometrik (boy, kilo, bel, kalça çevresi, VKİ) ve biyokimyasal parametreler [alanin transaminaz (ALT), aspartat transaminaz (AST), yüksek yoğunluklu lipoprotein (HDL), düşük yoğunluklu lipoprotein (LDL), trigliserit, glikoz] değerlendirildi. Visseral yağ dağılımı, VAI kullanılarak değerlendirildi. Hastalar, VKİ ile visseral yağ arasındaki bağlantıyı incelemek için dört VKİ grubuna ayrıldı: Normal kilolu (18,5-24,9), fazla kilolu (25-29,9), obez (30-39,9) ve morbid obez (>40).

Bulgular: Farklı VKİ gruplarının analizi antropometrik ve biyokimyasal parametrelerde önemli farklılıklar olduğunu ortaya koydu. Daha yüksek VKİ; artan kilo, bel ve kalça çevresi ve sistolik kan basıncı ile ilişkiliydi (p<0,001), VKİ arttıkça boy azalıyordu (p<0,001). Trombosit sayısı ve ALT/AST düzeyleri daha yüksek VKİ'li bireylerde önemli ölçüde daha yüksekti (p<0,003, p<0,001). HDL kolesterol azalırken (p<0,001), trigliseritler ve LDL kolesterol VKİ ile arttı (p<0,001, p=0,001). HbA1c düzeyleri de artan VKİ'li bireylerde önemli ölçüde daha yüksekti (p<0,001). VAI, VKİ arttıkça önemli ölçüde arttı (p<0,001), bu da daha fazla visseral yağ birikimini gösterdi. Tukey HSD analizi, VKİ grupları arasında, özellikle VKİ 20-25 ve VKİ >40 arasında önemli farklılıklar gösterdi (p<0,001). Bu bulgular, daha yüksek VKİ'nin olumsuz metabolik değişikliklerle güçlü bir şekilde

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Abstract

Tukey HSD analysis showed significant differences between BMI groups, particularly between BMI 20-25 and BMI >40 ($p<0.001$). These findings suggest that higher BMI is strongly associated with adverse metabolic changes, emphasizing the importance of weight management for better health outcomes.

Conclusion: VAI is a key metric for assessing obesity, focusing on visceral fat accumulation rather than just weight and height like BMI. It helps clinicians evaluate metabolic risks more accurately. Increasing awareness of VAI's importance can enhance obesity management and improve patient health outcomes.

Keywords: Body mass index, obesity, visceral adiposity index

Öz

ilişkili olduğunu ve daha iyi sağlık sonuçları için kilo yönetiminin önemli olduğunu göstermektedir.

Sonuç: VAI, obeziteyi değerlendirmek için önemli bir ölçüttür ve VKİ gibi sadece kilo ve boy yerine visseral yağ birikimine odaklanır. Klinisyenlerin metabolik riskleri daha doğru bir şekilde değerlendirmesine yardımcı olur. VAI'nın önemine ilişkin farkındalığın artırılması, obezite yönetimini iyileştirebilir ve hastaların sağlık sonuçlarının daha iyi olmasına katkı sağlar.

Anahtar kelimeler: Beden kitle indeksi, obezite, visseral adiposite indeksi

Introduction

Body mass index (BMI) is a widely used tool for assessing a person's body weight relative to their height; however, it may not always effectively capture the nuances of fat distribution within the body. In fact, the correlation between BMI and the actual body fat ratio can be quite complex. Research has shown that this relationship often follows a curvilinear pattern rather than a straightforward linear one in both men and women. This means that as BMI increases, the corresponding increase in body fat percentage may not be proportional across all individuals, indicating that other factors—such as muscle mass, bone density, and the way fat is distributed—play a significant role in determining overall health and physical composition. Such insights highlight the limitations of relying solely on BMI as an indicator of body fat and emphasize the importance of considering a more comprehensive approach to understanding body composition (1).

However, it is important to recognize that BMI can be influenced by a range of factors, including but not limited to gender, hydration levels, muscle mass, and racial or ethnic background. These variables can skew the accuracy of BMI as an indicator of an individual's body fat percentage, thereby raising concerns about its reliability. As a result, an ongoing debate persists in the scientific community regarding the appropriateness of using BMI as a predictor of cardiovascular risk. Many health professionals question whether it adequately captures the complexities of body composition and its implications for heart health. A notable article published in The Lancet in 2006 highlighted this skepticism, questioning the validity of BMI as a tool for determining cardiovascular risk. This conversation underscores the need for more comprehensive methods that consider individual characteristics beyond simple height and weight measurements (2-4).

The visceral adiposity index (VAI) is a sophisticated empirical mathematical model used to assess visceral fat accumulation in the human body. It is derived from a combination of anthropometric measurements—such as waist circumference and BMI—along with triglyceride (TG) levels in the blood. This index serves as an important tool in the evaluation of health risks associated with excess visceral fat, which is known to contribute to various metabolic disorders, including type 2 diabetes and cardiovascular diseases. By incorporating both physical measurements and biochemical markers, the VAI provides a comprehensive insight into an individual's fat distribution and overall metabolic health (5).

Numerous studies have consistently demonstrated a correlation between an elevated VAI and an increased risk of cardiovascular disease. This index serves not only as a key measurement for assessing the amount of visceral fat, a type of fat that wraps around internal organs, which is often more harmful than subcutaneous fat, but also provides insight into the functionality of visceral adipose tissue and its relationship with insulin sensitivity. Visceral fat is metabolically active and can contribute to inflammation and insulin resistance, factors that are pivotal in the development of various cardiovascular conditions. Therefore, monitoring the VAI can be instrumental in identifying individuals who may be at higher risk for cardiovascular issues, allowing for early interventions. In summary, while the VAI clearly indicates a heightened cardiovascular risk with increased values, it also serves as a crucial metric for evaluating the metabolic health of individuals, particularly concerning their insulin sensitivity (6-8).

The primary objective of this study was to explore the relationship between the VAI and BMI, two critical measures often used to assess individual health and obesity levels. The study aimed to investigate whether variations in BMI correspondingly influence the visceral

adiposity index, which is a more nuanced indicator of fat distribution and associated metabolic risks. By examining how shifts in BMI affect the visceral adiposity index, the research seeks to contribute to a deeper understanding of the dynamics between overall body weight and visceral fat levels, providing insights into potential health implications for individuals with different body compositions.

Materials and Methods

This study included 141 patients who applied to the Obesity and Internal Medicine Clinic of University of Health Sciences Turkey, Gazi Yaşargil Training and Research Hospital between 01.10.2024/01.01.2025 This study was planned retrospectively. Our study was initiated following the approval of the ethics committee. The University of Health Sciences Turkey, Gazi Yaşargil Training and Research Hospital's Ethics Committee approval was received on 17/01/2025 under the number 309. The study was approved according to the guide of the Declaration of Helsinki and by the Institutional Review Board and Ethical Committee.

In this comprehensive study, patient information was meticulously gathered from two prominent health data management systems: Nucleus and Fonet. The researchers collected a wide array of demographic data alongside detailed physical measurements, including height, weight, waist circumference, and hip circumference. These parameters were essential for calculating key anthropometric metrics, most notably the BMI. Additionally, the study delved in important hematological parameters, measuring the levels of various blood components such as neutrophils, lymphocytes, platelets, and hemoglobin. The researchers also assessed vital liver enzymes, specifically alanine aminotransferase (ALT) and aspartate aminotransferase (AST), which are crucial indicators of liver function. Furthermore, a complete lipid profile was recorded, including high-density lipoprotein (HDL), low-density lipoprotein (LDL), TG, and glucose levels, providing a holistic view of each patient's metabolic health.

To better understand the distribution of visceral fat, the VAI was calculated for each participant. This study categorized the patients into four distinct groups based on their BMI. Those with a BMI ranging from 18.5 to 24.9 were classified as having a normal weight; individuals with a BMI from 25 to 29.9 were identified as overweight; BMI values between 30 and 39.9 indicated obesity; and patients with a BMI over 40 were classified as morbidly obese. Each group's VAI was then calculated, allowing for a detailed analysis of the relationship between weight classifications and visceral fat distribution. This thorough approach underscores the study's commitment to understanding the complexities of body composition and its implications for health.

The VAI is a gender-specific mathematical model that estimates visceral fat distribution and dysfunction based on BMI, triglycerides, and HDL cholesterol.

VAI Formulation:

VAI (male) = [Waist circumference (cm)/(39.68 + (1.88 x BMI) x (TG (mmol/L)/1.03 x (1.31/HDL (mmol/L)]

VAI (female): [Waist circumference (cm)/(36.58 + (1.89 x BMI) x (TG (mmol/L)/0.81) x (1.52/HDL (mmol/L)] formulated as follows (9).

Statistical Analysis

The descriptive analyses in this study were reported as mean ± standard deviation or as median (minimum-maximum), depending on whether the data followed a normal distribution. Normality was assessed using the Kolmogorov-Smirnov test. To compare differences between multiple groups, a One-Way ANOVA test was used if the data were normally distributed. If the data did not follow a normal distribution, a Kruskal-Wallis test was applied. A p-value of less than 0.05 was considered statistically significant. The analysis of the data of the patients in the study was performed using the SPSS 27.0 software.

Results

The analysis of different BMI groups revealed significant variations in several anthropometric and biochemical parameters (Table 1).

- **Anthropometric measures:** Individuals with higher BMI had significantly increased weight, waist circumference, hip circumference, and systolic blood pressure (SBP) ($p<0.001$). Diastolic blood pressure (DBP) was also significantly different among groups ($p=0.001$). Height decreased as BMI increased ($p<0.001$).
- **Hematological parameters:** Platelet count was significantly higher in individuals with higher BMI ($p=0.003$). Hemoglobin levels were also significantly different across BMI groups, with lower values in the highest BMI category ($p<0.001$).
- **Liver enzymes:** ALT and AST levels varied significantly across groups ($p<0.001$).
- **Lipid profile:** LDL cholesterol was significantly different between BMI groups ($p=0.001$). HDL cholesterol decreased as BMI increased ($p<0.001$), while TG levels

were significantly higher in individuals with higher BMI ($p<0.001$).

- **Glycemic control:** HbA1c levels increased with BMI and were significantly different between groups ($p<0.001$).

These findings indicate that increasing BMI is associated with negative metabolic and cardiovascular changes, highlighting the importance of weight management for better health outcomes.

The VAI showed a significant increase across BMI categories. Individuals with higher BMI had significantly elevated VAI levels [$F(3.138) =7.078$, $p<0.001$], indicating greater visceral fat accumulation as BMI increased. This suggests a strong correlation between BMI and visceral adiposity, emphasizing the metabolic risk associated with higher BMI levels (Table 2).

The Tukey HSD post-hoc analysis revealed significant differences in mean values between BMI groups (Table 3):

- BMI 20-25, vs. BMI >40: A significant mean difference of -8.10 ($p<0.001$) indicates a substantial decrease in the analyzed variable for individuals with BMI >40.
- BMI 20-25 vs. BMI 30-40: A significant mean difference of -4.5 ($p=0.041$) suggests a notable decrease in the BMI 30-40 group.
- Other comparisons (BMI 25-30 vs. BMI 30-40, BMI 30-40 vs. BMI >40, etc.) did not show statistically significant differences ($p>0.05$), indicating relatively smaller variations between these BMI categories.

These results suggest that individuals with higher BMI (particularly BMI >40) exhibit significantly different characteristics compared to those with lower BMI (20-25).

Discussion

A total of 141 patients participated in this study, which aimed to explore the relationship between BMI and visceral adiposity. The participants were carefully categorized into four distinct groups based on their BMI classifications, allowing for a thorough analysis of how varying levels of body mass may influence the distribution of visceral fat. The main focus of the investigation was to assess the correlation between BMI and visceral fat accumulation, providing insights into the potential health implications associated with different body weight categories.

Obesity is a global issue that has experienced a 2- to 3-fold increase worldwide from 1980 to 2014. It is associated with anemia, and research indicates that obesity elevates the risk of developing anemia. In a study by Moafi et al. (10) involving 1,218 participants, the subjects were divided into three groups based on their BMI. The study found a significant relationship between increasing BMI and the prevalence of anemia (10). Recent research has indicated a concerning relationship between BMI and anemia.

Table 1. Descriptive analysis of different BMI groups an One-Way ANOVA results

Measures	BMI 20-25	BMI 25-30	BMI 30-40	BMI >40	p-values
Age	31.71±6.49	33 (19-53)	35.56±9.96	37.05±10.44	0.68
Length	170.4±7.9	173.7±8.6	168.0±10.9	162.6±8.9	<0.001
Weight	62.06±7.51	81.3±8.89	97.5±14.7	118.5±13.04	<0.001
Waist circumference	74.0±7.61	92.1±8.8	107.6±10.9	123.9±12.8	<0.001
Hip circumference	94 (64-110)	103.8±4.7	118.4±6.9	136.2±11.1	<0.001
SBP	99 (80-116)	110.5±8.8	107.5 (91-127)	112.5±8.8	<0.001
DBP	67.1±8.5	74.3±7.0	71 (58-64)	70 (58-88)	0.001
Neutrophils	3.99±1.66	4.22 (2.04-8.77)	4.25±1.41	4.16 (3.31-8.27)	0.209
Lymphocytes	2.29±0.59	2.43±0.69	2.57±0.62	2.53±0.97	0.287
Platelets	259.1±53.7	253 (161-441)	296.0±67.4	315.8±73.8	0.003
Hemoglobin	14.1±1.37	15.2±1.25	14.8±1.33	13.7±1.47	<0.001
ALT	14 (5-68)	27 (11-119)	27.5 (7-111)	17(6-48)	<0.001
AST	19 (13-38)	23 (16-51)	23 (12-69)	16 (10-30)	<0.001
LDL	106.4±28.4	132.3±22.5	119.7±32.8	118.9±31.7	0.001
HDL	50 (31-91)	42 (22-67)	43.8±10.8	41.7±6.4	<0.001
TG	78.6±39.1	133 (60-587)	142.5 (37-392)	135 (66-389)	<0.001
HbA1c	5.3 (3.4-6)	5.6 (5.2-6.4)	5.55 (5.1-6.4)	5.6 (5.1-6.3)	<0.001

SBP: Sistolic blood pressure, DBP: Diastolic blood pressure, ALT: Alanine transferase, AST: Aspartate transferase, LDL: Low-density lipoprotein, HDL: High-density lipoprotein, TG: Tryglicerides, BMI: Body mass index

Table 2. One-Way ANOVA analysis of visseral adiposity index for BMI

Measure	BMI 18.5-24.9 (n=49)		BMI 25-29.9 (n=37)		BMI 30-39.9 (n=34)		BMI >40 (n=22)		F (3,138)	h^2
	M	SD	M	SD	M	SD	M	SD		
Visseral adiposity index	2.38	1.5	5.83	5.32	6.63	4.89	10.58	15.48	7.078***	

BMI: Body mass index, ***: p<0.001 (highly significant)

Table 3. Post-hoc results between groups

BMI	BMI	Mean difference	Std. error	Sig.
Normal 18.5-24.9	25-29.9	-3.45	1.55	0.120
	30-39.9	-4.5	1.58	0.041
	>40	-8.10	1.82	0.000
Overweight 25-29.9	18.5-24.9	3.45	1.55	0.120
	30-39.9	-0.80	1.69	0.965
	>40	-4.66	1.91	0.075
Obese 30-39.9	18.5-24.9	4.25	1.58	0.041
	25-29.9	0.80	1.69	0.965
	>40	-3.86	1.94	0.198
Morbid obese >40	20-25	8.10	1.82	0.000
	25-29.9	4.66	1.91	0.075
	30-39.9	3.86	1.94	0.198
	>40	-4.66	1.91	0.097

BMI: Body mass index

Specifically, the findings suggest that for every unit increase in BMI, the likelihood that of developing anemia can significantly increase, potentially rising by as much as 1.6 times. This connection highlights the importance of maintaining a healthy weight, as higher BMI levels may exacerbate the risk of experiencing this blood disorder, which is characterized by a deficiency in red blood cells or hemoglobin. Such insights underscore the need for further investigation into how weight management can play a crucial role in preventing anemia and promoting overall well-being (11). In our study, we found that similar to previous research, changes in hemoglobin and platelet counts were significant as BMI increased, with p-values of <0.001 and 0.003, respectively. However, we did not find any association between changes in leukocyte and lymphocyte counts and BMI, as indicated by p-values of 0.209 and 0.287, respectively.

The relationship between BMI and HbA1c,as well as lipid panel results, has been previously studied. Research indicates a negative correlation between BMI and HDL levels, while a positive correlation is observed with other lipid parameters. In their study involving 296 patients, Babikr et al. (12) found a statistically significant positive correlation between BMI and HbA1c.

In the study conducted by Pituelli Suárez et al. (13), involving 1,043 children and adolescents, the relationship between obesity, BMI, and lipid panel results was investigated, revealing a statistically significant correlation. In our study, we observed that as BMI increased, TG and LDL values tended to rise initially but then decrease, while HDL values tended to decrease. These findings were statistically significant, with p-values of <0.001 for TG, 0.001 for LDL, and <0.001 for HDL. The LDL paradox is a phenomenon observed in morbidly obese patients, and there is a need for more systematic research on this topic. In a study by Vierhapper et al. (14), LDL levels were found to be lower in morbidly obese individuals compared to those with less severe obesity. Similarly, in our study, we observed lower LDL levels in the morbidly obese group, consistent with their findings. Although the trend for LDL values initially increased and then decreased, this aspect was not among the primary focuses of our study, and we did not report post-hoc results between the groups (13). There has been ongoing debate in recent years about whether BMI is an accurate measure of obesity (15). Research has indicated that waist circumference may serve as a more accurate measure than BMI when it comes to assessing abdominal and visceral fat accumulation. This is particularly important because excess visceral

fat, which surrounds internal organs, is closely linked to various health risks, including metabolic syndrome and cardiovascular diseases. Furthermore, the VAI offers a more comprehensive evaluation. This mathematical calculation combines anthropometric measurements, such as waist and hip circumference, with lipid profile data, including levels of triglycerides and cholesterol. By integrating these diverse factors, the VAI provides a more nuanced understanding of an individual's fat distribution and metabolic health compared to relying solely on traditional anthropometric indices like BMI. As such, the VAI may serve as a superior indicator of health risks associated with obesity and fat distribution (16,17). Clinically, the VAI is used as a risk marker in conditions such as metabolic syndrome, cardiovascular disease, type 2 diabetes, polycystic ovary syndrome, and non-alcoholic fatty liver disease. Studies by Amato et al. (18) have demonstrated the association of VAI with these diseases, showing that VAI is a practical, cost-effective, and non-invasive tool for predicting metabolic risks related to visceral fat accumulation. However, since it cannot replace direct imaging methods (computed tomography, magnetic resonance imaging), it should be considered a complementary measure (18-20). In our study, we investigated the relationship between BMI and visceral adiposity. We found a statistically significant change in the VAI and BMI ($p<0.001$). The patients were divided into four groups based on their BMI, and a post-hoc analysis was conducted. The results of the post-hoc analysis revealed significant differences between the group with a BMI greater than 40 and the group with a BMI between 30 and 39.9, as well as between the group with a BMI of 18.5-24.9 ($p<0.001$ and $p=0.041$, respectively).

Study Limitations

One of the primary limitations of this study is its retrospective design, which inherently restricts the ability to draw robust conclusions about causality. Additionally, the sample size is relatively small when compared to the larger studies in the field, which may limit the generalizability of the findings and reduce the statistical power necessary to detect significant effects. This smaller cohort could lead to potential biases and less confidence in the results when extrapolated to broader populations.

Conclusion

The VAI serves as a valuable metric for assessing obesity, similar to the well-known BMI. Unlike BMI, which primarily considers weight and height, the VAI focuses specifically on the accumulation of visceral fat—fat that surrounds the internal organs, which is closely linked to various health risks. Understanding and utilizing this index can help clinicians more accurately evaluate a patient's health status, especially regarding metabolic complications associated with excess visceral fat. Raising awareness among healthcare professionals about the significance and utility of the VAI is crucial for improving obesity management and promoting overall patient well-being.

Ethics

Ethics Committee Approval: The University of Health Sciences Turkey, Gazi Yaşargil Training and Research Hospital's Ethics Committee approval was received on 17/01/2025 under the number 309. The study was approved according to the guide of the Declaration of Helsinki and by the Institutional Review Board and Ethical Committee.

Informed Consent: Retrospective study.

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Footnotes

Authorship Contributions

Surgical and Medical Practices: J.K., İ.S., Concept: J.K., Ö.F.A., İ.S., Design: J.K., İ.S., Data Collection or Processing: Ö.F.A., Analysis or Interpretation: Ö.F.A., İ.S., Literature Search: J.K., İ.S., Writing: J.K., Ö.F.A., İ.S.

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