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Ankle-Brachial Pressure Index Correlates with Abdominal Volume Index in Normal -Weight Type 2 Diabetes Mellitus Patients

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ABSTRACT

Obesity significantly impacts glycemic control and vascular health in Type 2 diabetes mellitus. **Objectives:** To compare clinical characteristics, obesity indices, and vascular status between normal-weight and obese/overweight Type 2 diabetes mellitus patients. **Methods:** A cross-sectional study was conducted for six months from April 2024 to September 2024 at the Medicine Outpatient Department. This study included 82 Type 2 diabetes mellitus patients divided into two groups: normal-weight (n=34) and obese/overweight (n=48). Clinical parameters such as HbA1c, BMI, abdominal volume index, and ankle-brachial pressure index (ABPI) were measured. Data were analyzed by SPSS version 23.0. **Results:** Obese/overweight patients were significantly older (57.74 ± 8.57 vs. 52.81 ± 9.41 years, p=0.018) and had worse glycemic control (HbA1c: 7.17 ± 0.97% vs. 6.51 ± 0.68%, p = 0.0008) than normal-weight patients. Both BMI (30.57 ± 3.39 vs. 23.13 ± 1.80 kg/m^2) and AVI (16.44 ± 1.58 vs. 11.84 ± 1.61) were higher in the obese/overweight group (both p<0.0001). Ankle-Brachial Pressure Index was lower in obese/overweight patients (0.93 ± 0.15 vs. 0.99 ± 0.08, p=0.033), suggesting poorer vascular health. Negative correlations between ankle-brachial pressure index and obesity indices indicated higher adiposity was linked to vascular dysfunction. **Conclusions:** It was concluded that obese/overweight Type 2 diabetes mellitus patients showed poorer vascular health and glycemic control than normal-weight patients. Abdominal volume index, age, and diabetes duration independently predicted ankle-brachial pressure index, emphasizing the need to address abdominal obesity and glycemic control to mitigate vascular risks in T2 diabetes mellitus patients.

INTRODUCTION

One of the most prevalent metabolic disorders in the world today among people who live in modern society is type 2 diabetes mellitus (T2DM). Numerous studies have demonstrated that being overweight or obese is a significant risk factor for the development of T2DM. Nevertheless, it is crucial to remember that not all fat depots have the same detrimental effects [1]. For instance, subcutaneous adipose tissue is not related to metabolic disorders but visceral adipose tissue affects glucose regulation detrimentally and may be connected to vascular complications; in its turn, excessive visceral fat deposition altogether is directly linked to metabolic abnormality, as well as vascular complications [2, 3]. Moreover, finding prevalence at any age category, abnormal levels of visceral fat can be higher in patients who have a familial history of its distribution, due to which, although relatively lean, these patients may be more vulnerable to type 2 diabetes onset and its associated vascular illnesses [4, 5]. An investigation has revealed that normal-weight patients with increased visceral adiposity who were just diagnosed with T2DM had a

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higher rate of mortality compared to those found suffering from obesity or being overweight [6, 7]. Understanding why vascular function is compromised due to the rise of type 2 diabetes would be an invaluable tool in improving the health of patients with T2DM. Also, the relationship between abdominal obesity as an essential risk factor for metabolic syndrome and vascular illnesses such as heart disease is well-studied. An effective measurement of abdominal obesity can be taken by calculating the Abdominal Volume Index which provides a better idea of the distribution of fat, especially the disturbing vital accumulation of visceral fat, than the more traditional and outdated body mass index does. The vascular health of this type of fat can be further compromised by several metabolic disorders, such as insulin resistance and systemic inflammation [8, 9]. It's interesting to note that concealed adiposity, especially in the abdominal area, might cause negative metabolic effects even in normal-weight persons with type 2 diabetes. These people may have significant visceral fat even when their BMI is within the normal range, which increases their risk of vascular problems. Therefore, evaluating the correlation between Abdominal Volume Index (AVI) and ABPI in this cohort is essential to identify any potential vascular concerns that would not be apparent from normal obesity measures alone [10]. While previous studies have primarily focused on obese T2DM patients, there is limited understanding of how abdominal fat distribution (measured by AVI) may influence vascular function in normal-weight T2DM patients. This study intends to fill this gap by investigating how these obesity indices correlate with vascular health, even in the absence of overt obesity, thus offering insights into the potential vascular risks in normal-weight individuals with T2DM. The inclusion of both normal-weight and obese/overweight groups allows for a comparative analysis to better understand the contribution of abdominal fat and its association with vascular status across different body compositions.

This study aims to compare clinical characteristics, obesity indices, and vascular status between normal-weight and obese/overweight T2DM patients.

METHODS

This cross-sectional study was conducted for six months from April 2024 to September 2024. The participants were recruited from the Medicine Outpatient Department at Rashid Latif Medical College, Hospital. Inclusion criteria were individuals between the ages of 30 and 60 who have been diagnosed with DM type 2, Body Mass Index (BMI) between 18.5 and 24.9 kg/m2, which was considered normal, HbA1c <8%, no prior history of cardiovascular events or peripheral arterial disease (PAD). Exclusion criteria were weight gain or obesity (BMI >25 kg/m^2), pregnant women, hypertension, renal problems, or an ongoing infection. The study used a consecutive sampling method to recruit participants. Patients using antihypertensive or lipid-lowering drugs. The correlation coefficient formula was used to evaluate sample size. This was appropriate since the primary objective was to assess the relationship between two continuous variables (ABPI and AVI). $n = (0.5 \times \ln(1-r1+r)\ Z1-\alpha/2+Z1-\beta)2+3$, significance level α=0.05 confidence level (95% Or 1.96), power (1- β) = 80% (0.84) and effect size (expected correlation coefficient r=0.3). The total number of participants was n=82, distributed in two groups, normal weight group n=34 and obese group n=48. Height, weight, and waist circumference were examples of anthropometric measurements that were used to determine BMI and AVI. [2 × waist circumference^2 (cm) + hip circumference^2 (cm)] ÷ height (cm) was the formula for the Abdominal Volume Index (AVI). Systolic blood pressure (SBP) in the brachial artery (arm) and ankle arteries (posterior tibial and dorsalis pedis) was used to calculate the Ankle-Brachial Pressure Index (ABPI). ABPI was equal to SBP at the brachial artery ÷ SBP at the ankle. Values below 0.9 in the ABPI indicate a possible PAD, but values above 1.3 point to arterial calcification. Data analysis was done using SPSS version 23.0. Utilize SPSS's Kolmogorov-Smirnov (K-S) and Shapiro-Wilk (S-W) tests to assess the normal distribution statistically. When comparing the means of two groups, such as normal vs. overweight T2DM patients, the t-test is utilized. Parameter correlations were investigated using Pearson correlation for parametric data and Spearman correlation for non-parametric data. The link between a dependent variable and one or more independent variables was predicted using linear regression. The study was approved by the Institutional Review Board (IRB) with the reference number (IRB/2024). All participants provided written informed consent before participation.

RESULTS

Significant differences were observed between normal-weight and obese/overweight Type 2 Diabetes Mellitus (T2DM) patients. The obese/overweight group was older (57.74 vs. 52.81 years, p=0.018) and had worse glycemic control (HbA1c 7.17% vs. 6.51%, p=0.0008). The average BMI was higher in the obese/overweight group (30.57 vs. 23.13 kg/m^2, p<0.0001), and abdominal obesity, measured by the Abdominal Volume Index (AVI), was significantly greater (16.44 vs. 11.84, p<0.0001). Additionally, the Ankle-Brachial Pressure Index (ABPI) was lower in the obese/overweight group (0.93 vs. 0.99, p=0.033), suggesting obesity's impact on vascular health (Table 1).

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Table 1: Clinical Characteristics of the Patients

Parameters	Normal-Weight T2DM (n=34)	Obese/Overweight T2DM (n=48)	p-value
Age (Years)	52.81 ± 9.41	57.74 ± 8.57	0.018*
HbA1c (%)	6.51 ± 0.68	7.17 ± 0.97	0.0008**
BMI (kg/m^2)	23.13 ± 1.80	30.57 ± 3.39	<0.0001**
AVI	11.84 ± 1.61	16.44 ± 1.58	<0.0001**
ABPI	0.99 ± 0.08	0.93 ± 0.15	0.033*

In both normal-weight (n=34) and obese/overweight (n=48) Type 2 Diabetes Mellitus (T2DM) groups, Body Mass Index (BMI) showed strong correlations with obesity indices like Waist Circumference (WC), Body Fat Percentage (BFP), Abdominal Volume Index (AVI), and Waist-to-Hip Ratio (WHR). In the normal-weight group, BMI had high correlations with BFP (0.75) and WC (0.70, p<0.001). In the obese/overweight group, BFP had the strongest correlation with BMI (0.80, p<0.0001), followed by AVI (0.72) and WC (0.68), all statistically significant (Table 2).

Table 2: Correlation of BMI with Other Obesity Indices

Parameters	Correlation Coefficient (Normal-weight T2DM, n=34)	p-value	Correlation Coefficient (Obese /Overweight T2DM, n=48)	p-value
Abdominal Volume Index (AVI)	0.65	0.001**	0.72	<0.0001**
Waist Circumference (WC)	0.70	<0.0001**	0.68	<0.0001**
Body Fat Percentage (BFP)	0.75	<0.0001**	0.80	<0.0001**
Waist-to-Hip Ratio (WHR)	0.60	0.004**	0.65	<0.0001**

In the normal-weight T2DM group (n=34), a strong correlation was found between Abdominal Volume Index (AVI) and Waist Circumference (WC) (0.75, p<0.0001), and between AVI and Visceral Fat Percentage (VF%) (0.68, p=0.0003), indicating that larger abdominal volume is linked to higher visceral fat. In the obese/overweight T2DM group (n=48), the correlation between AVI and WC was even stronger (0.82, p<0.0001), and a significant correlation was also found between AVI and VF% (0.78, p<0.0001). These results suggest a robust association between abdominal volume and visceral fat in both groups (Table 3).

Table 3: Correlation of AVI with WC and VF%

Parameters	Correlation Coefficient (Normal-weight T2DM, n=34)	p-value	Correlation Coefficient (Obese /Overweight T2DM, n=48)	p-value
AVI	-	-	-	<0.0001**
Waist Circumference (WC)	0.75	<0.0001**	0.82	
Visceral Fat Percentage (VF%)	0.68	0.0003**	0.78	

In normal-weight T2DM patients, weak to moderate negative correlations were found between ABPI and obesity indices, such as BMI and BAI (p=0.04 and 0.03), as well as AVI and VF% (p=0.02 and 0.05). This suggests that as obesity increases, ABPI tends to decrease, indicating early signs of vascular changes. In the obese/overweight T2DM group, stronger negative correlations were observed with ABPI and obesity indices: BMI (-0.42, p=0.003), WC (-0.46, p=0.002), AVI (-0.48, p=0.001), and VF% (-0.44, p=0.004). These results indicate a higher risk of vascular changes in obese/overweight T2DM patients compared to the normal-weight group (Table 4).

Table 4: Correlation of ABPI with Obesity Indices

Obesity Indices	Correlation Coefficient (Normal-weight T2DM, n=34)	p-value	Correlation Coefficient (Obese /Overweight T2DM, n=48)	p-value
Body Mass Index (BMI)	-0.35	0.04*	-0.42	0.003**
Waist Circumference (WC)	-0.38	0.03*	-0.46	0.002**
Abdominal Volume Index (AVI)	-0.40	0.02*	-0.48	0.001**
Visceral Fat Percentage (VF%)	-0.33	0.05*	-0.44	0.004**

In the normal-weight T2DM group, weak-to-moderate negative correlations were found between ABPI and obesity indices (BMI, WC, AVI, VF%) with significant p-values, indicating that higher obesity levels may signal early vascular changes. In the obese/overweight T2DM group, the correlations were stronger, with significant results for BMI, WC, AVI, and VF%. These findings suggest a higher risk of vascular impairment in obese/overweight T2DM patients. Additionally, a longer duration of diabetes was associated with a decrease in ABPI, with a 0.014-unit reduction per year of diabetes, highlighting the combined impact of obesity, age, and diabetes duration on vascular health (Table 5).

Table 5: Association of ABPI (Dependent Variable) with Key Predictors AVI, Age, Diabetes Duration (Independent Variables)

Variables	Unstandardized Coefficient (B)	Standard Error (SE)	Standardized Coefficient (Beta)	t-value	p-value
Constant	1.125	0.124	––	9.07	<0.001**
Abdominal Volume Index (AVI)	-0.025	0.009	-0.35	-2.78	0.007**
Age (years)	-0.011	0.004	-0.29	-2.75	0.008**
Duration of Diabetes (years)	-0.014	0.006	-0.23	-2.33	0.022*

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DISCUSSION

This study examined the link between individuals with Type 2 Diabetes Mellitus (T2DM) who were overweight or obese and those who were normal weight and the Ankle-Brachial Pressure Index (ABPI) and Abdominal Volume Index (AVI). The results show that age and lengthier duration of diabetes are important predictors of vascular dysfunction, and that more fat is linked to worse vascular health, as indicated by a lowerABPI [11]. The significance of abdominal fat in the emergence of vascular dysfunction is highlighted by the negative connection found between the Abdominal Volume Index (AVI) and ABPI. It is well recognized that endothelial dysfunction and systemic inflammation, two major factors in atherosclerosis and compromised vascular tone are encouraged by abdominal obesity [12]. Similar results were published by Ruze *et al.*, who showed a correlation between an increased risk of peripheral artery disease (PAD) and higher central obesity as evaluated by waist circumference. These findings support our finding that abdominal obesity in T2DM patients, regardless of weight, is associated with worse vascular health [13]. The comparison between normal-weight and obese/overweight T2DM patients showed significant differences in age and glycemic control (HbA1c). Obese/overweight T2DM patients were older compared to normal-weight patients, with a p-value indicating statistical significance. This suggests that obesity is linked to an older age of onset or progression of T2DM. Additionally, obese/overweight patients had higher HbA1c levels compared to normal-weight patients, with a p-value showing strong significance. This indicates poorer glycemic control in the obese/overweight group, supporting the association between obesity and worse diabetes management. These findings emphasize that obesity is linked to both older age at T2DM onset and poorer blood sugar control. The strong correlation between BMI and other obesity measures, emphasizing their role in disease severity. The findings of this study indicate that abdominal obesity has a detrimental effect on vascular health, as seen by the negative correlation between AVI and ABPI. The major risk factor for arterial stiffness and peripheral arterial disease (PAD) is central obesity, rather than general obesity (as determined by BMI). Furthermore, it was noted by Abdel-Galeel *et al.*, that increased abdominal obesity raises the risk of low ABPI readings, which indicate poor peripheral circulation, via promoting atherosclerosis. By validating this correlation within a T2DM group, our study contributes to the body of evidence [14]. Arterial stiffness increases with age and causes a decrease in vascular function. The present findings are supported by the conclusion that aging had a negative impact on ABPI. First, research indicates that persistent hyperglycemia accelerates vascular mortality. Thus, the length of diabetes had a negative correlation with ABPI. Second, peripheral blood flow is reduced due to the transformation of the circulatory system with age, such as a decrease in endothelial function, loss of elasticity, and arterial stiffening. Moreover, aging and continued inflammation are linked to increase oxidative stress, which negatively affects the health of the vessels [15]. The results of the current study finding that ABPI decreased with age in both non-diabetic and diabetic participants and was related to persistent aging of the vasculature, which was more severe for the diabetic group. Therefore, the current research finds that regular vascular examination is essential for aged type 2 diabetes to prevent PAD [16]. The other significant predictor of the decrease in ABPI was the length of time patients had diabetes. In the case of type 2 diabetes, high levels of sugar in the blood for a long period of time leads to the glycation of vascular proteins, producing advanced glycation end-products. This process weakens endothelial function and stimulates increased arterial stiffness. Long-term sugar exposure to people with diabetes weakens the blood vessels in the leg and raises the risk of PAD. This result is in line with two other pieces of research discovered by Chase-Vilchez *et al.* Moreover, the findings highlight the importance of maintaining good glycemic control and regular examination for PAD at an early stage for long-term T2DM patients [17]. In this research, normal-weight, T2DM individuals had relatively higher ABPI values compared to their overweight/obese counterparts despite suffering from diabetes. This is an indicator that vascular function is still enhanced in these patients. However, the onset of vascular damage is probably not instigated in people of normal weight probably owing to less obesity. This is mainly contributed to the reduction of systemic inflammation in these patients because they are slimmer. The inflammation of the endothelium resulting from adipose tissue which releases pro-inflammatory cytokines is a leading cause of vascular damage [18].In the current study finding that, with statistically significant results in the normal-weight and overweight/obese groups, the correlation analysis showed a strong positive connection between AVI and both waist circumference (WC) and visceral fat percentage (VF%). The results of the previous study support the present findings of Wu *et al.*, who discovered that visceral fat and WC are accurate indicators of cardiovascular risk. This supports the utility of AVI as a parameter in clinical practice [19]. It makes sense that AVI and BMI would correlate because

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both indices measure the distribution of body fat. BMI does not take into consideration the location of fat, despite being a valuable indicator of total body fat. However, visceral fat which is linked to increased health risks and has a higher metabolic activity is highlighted in particular by AVI. This study demonstrates that individuals with higher BMI also tend to have elevated AVI, reinforcing the notion that BMI alone may not fully capture the risks associated with abdominal obesity [20]. These findings highlight how crucial it is to control abdominal obesity in diabetic patients as soon as possible because it has a direct impact on vascular health. To stop PAD and other vascular problems, it is crucial to implement diet, exercise, and lifestyle modifications that reduce belly fat. While this study provides valuable insights into the relationship between abdominal obesity and vascular health in Type 2 Diabetes Mellitus (T2DM) patients, several limitations should be noted included Self-Reported Data, limited assessment of confounders and lack of control group of healthy individuals without diabetes.

CONCLUSIONS

It was concluded that clinical interventions should focus on the early identification and management of abdominal obesity in patients with Type 2 Diabetes Mellitus (T2DM). Incorporating targeted lifestyle modifications, such as dietary changes, can help reduce abdominal fat and improve glycemic control, thereby enhancing vascular health and reducing the risk of peripheral artery disease. Additionally, regular monitoring of abdominal fat through indices like the Abdominal Volume Index (AVI) could be integrated into routine clinical assessments to identify at-risk patients and facilitate timely interventions.

Authors Contribution

Conceptualization: SM
Methodology: MAL, RA, MAUR, HZ
Formal analysis: MAL, IJ
Writing review and editing: SM, MAUR

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

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