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The relationship between visceral adiposity tissue and functional exercise capacity among type 2 diabetes

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Abstract---Aim: To compare the visceral adiposity index and functional exercise capacity between type 2 diabetes mellitus and healthy controls, as well as find out the relationship between visceral adiposity index and functional exercise capacity among type 2 diabetes patients. Methods: Using a purposive sampling strategy, this case-control study included 62 subjects: 31 with T2DM and 31 with healthy controls. All the participants were nonsmokers with no pulmonary problems that could have influenced the 6MWT. Age, sex, and BMI were matched to each of the T2DM and healthy controls. We assessed demographic, anthropometric, and biochemical variables. Based on 6MWD, the maximum oxygen consumption (VO₂ max) was estimated. The waist circumference (WC), BMI, serum triglyceride, and high-density lipoprotein (HDL) cholesterol levels were used to calculate the VAI. Descriptive and inferential statistics were used to analyze the data. P was chosen as the alpha level < 0.05. Results: The mean and standard deviations of 6MWD estimated VO₂ max and VAI were (445.6 ±78.7) for T2DM vs (529.7±70.1) for healthy controls, (17.1±7.6) vs (23.2 ±5.7), and (3.2±1.4) vs (1.9 ±0.8), respectively, while VAI and 6MWD had a negative correlation ($r = -0.728$ at P-value =0.000). Conclusions Type 2 diabetes patients had a lower functional exercise capacity and a higher VAI score compared to healthy controls, as well as a negative relationship between VAI and functional exercise capacity.

Keywords---exercise capacity, 6MWT, T2DM, VAI.

Introduction

Diabetes mellitus is a serious and long-term condition that poses a significant social, epidemiological, and economic burden as a concern for public health defined as a lifestyle disease ¹. Diabetes mellitus has increased in prevalence from 108 million in 1980 to 422 million in 2014 ². Diabetes has nearly doubled in prevalence among adults over the age of 18 since 1980, rising from 4.7 percent in 1980 to 8.5 percent in 2014. In 2015, diabetes caused an estimated 1.6 million deaths. ³. Almost 425 million people worldwide had diabetes in 2017; by 2045, that figure is anticipated to increase to (629) million, according to the International Diabetes Federation (IDF). In 2017, DM took the lives of roughly 4 million adults ⁴.

Diabetes is more common in low- and middle-income countries than it is in high-income ones, a development that has been related to rising obesity rates and population aging. There has been a rise in both the number of deaths and the incidence of hyperglycemia connected to chronic hyperglycemia ⁵. Diabetes is a collection of diseases that lower physical ability and impact pulmonary function. ⁶ Impaired functional exercise capacity is a significant predictor of heart disease and all-cause death rates in type 2 diabetes patients ⁷. Even if they do not have coronary artery disease, people with T2DM are more insulin resistant. They have a poorer functional capacity than comparably active age- and body-weight-matched healthy controls ⁸. Despite rigorous cardiovascular (CV) risk factor therapy, patients with T2DM continue to have an excessive cardiovascular (CV) mortality. "Insulin resistance, endothelial dysfunction, poor myocardial perfusion, cerebral blood flow, and oxygenation deficiencies," changes in cardiac and skeletal muscle activity, as well as other factors, may all be linked to people with T2DM having a lower exercise capacity ⁹. Functional capacity, exercise performance, and exercise endurance are all terms that refer to an individual's ability to undertake a maximal exercise test while exerting their maximum effort. However, these terms are sometimes used to describe a person's ability to undertake sub-maximal activities based on many tests. ¹⁰⁻¹². In type 2 diabetes, the 6MWT may properly reflect functional exercise capability. Because most activities of daily living are conducted at sub-maximal levels of effort, ¹³.

The test could be utilized in clinical settings to assess the influence of several comorbidities on exercise capacity and endurance in older persons, such as cardiovascular disease, lung illness, arthritis, diabetes, cognitive impairment, and depression¹⁴. Patients with T2DM generally have an increased fat mass in addition to a decreased activity capacity. Importantly, people with T2DM have a different body fat distribution. Excess visceral and ectopic fat [deposition in regions not traditionally associated with adipose tissue (AT) storage, such as skeletal muscle, liver, pancreas, and heart] are hallmarks of T2DM patients ¹⁵. In T2DM, the distribution of excess fat mass is a key driver of metabolic and cardiovascular hazards; visceral and ectopic adiposity pose a far greater risk than subcutaneous fat depots ¹⁶. Increased skeletal muscle fat storage has been associated to abdominal obesity, insulin resistance, and T2DM. In contrast, trained endurance athletes with insulin sensitivity had larger skeletal muscle fat levels¹⁷⁻¹⁹. When combined with a sedentary lifestyle and low oxidative capacity, skeletal muscle fat gain may be linked to insulin resistance and poor metabolic consequences. ²⁰. In

many groups, body mass index (BMI) is a predictor of T2D. BMI, on the other hand, is calculated using height and weight data rather than abdominal obesity. As a result, the value of BMI in predicting T2D risk has been questioned, and visceral adiposity appears to be a stronger predictor of T2D risk.²¹ A single anthropometric index appears to be a stronger predictor of metabolic diseases linked with insulin resistance than the visceral adiposity index (VAI).²² The Visceral Adiposity Indicator is a sex-specific mathematical formula that takes into account waist circumference, BMI, triglycerides, and HDL levels, all of which indirectly represent visceral adiposity and insulin sensitivity²³. Rather than a single anthropometric score, the visceral adiposity index is considered to be a good predictor of metabolic problems linked to insulin resistance²¹. optimal VAI (VAI > 2.25 in women and > 1.86 in men)²⁴. The study objectives include:

- To compare the visceral adiposity index and functional exercise capacity between type 2 diabetic patients and healthy controls.
- To find out the relationship between visceral adiposity index and functional exercise capacity among type2 diabetes.

Methodology

Participants and study design

Using a purposive sample strategy, this case-control study selected 31 patients diagnosed with type 2 diabetes from the Al-Wafaa Specialized Center for Diabetes and Endocrinology and 31 healthy controls whose age, gender, and BMI were homogeneous. Type 2 diabetes patients between the ages of 35 and 66 who are non-smokers and attend the Al-Wafaa Specialized Center for Diabetes and Endocrinology. There were also apparently healthy controls with no history or diagnosis of self-reported T2D, and they were non-smokers who matched for age, gender, and BMI. The study excluded participants with a history of ischemic heart diseases, such as MI or angina, musculoskeletal disorders, such as acute osteoarthritis of the knee or hip joint, peripheral vascular disease, or neurological conditions, such as peripheral neuropathy.

Data collection

The goal of the study was explained to participants who met the eligibility requirements before the commencement of the study, and informed consent was obtained. The most important data on demographic characteristics (e.g., age and sex) and disease history were collected through interviews with a questionnaire. Both weight and height measurements were taken on a Tanita BC533 Roman-style scale and a SECA 406 Stadiometer to compute the BMI. A SECA 206 tape was used to measure waist circumferences at the midpoint between the lowest costal margin and the lateral iliac crest.

Biochemical analysis

Participants were said not to eat or drink anything for at least 12 hours before the lipid profile and glycated hemoglobin A1c (HBA1C) measurement the day before the visit. Between the hours of 8 a.m. and 10 a.m., all measurements were

obtained. Enzymatic methods and a chemical analyzer were used to determine the lipid profile. Total cholesterol had a coefficient of variation of 4.3 percent, triglycerides had a coefficient of variation of 6%, and high-density lipoprotein cholesterol had a coefficient of variation of 3%. (HDL-C). The Fried Wald formula was used to determine LDL-C (low-density lipoprotein cholesterol).

Independent variables

The Visceral Adiposity Indicator is a sex-specific mathematical formula that takes into account waist circumference, BMI, triglycerides, and HDL levels, all of which indirectly represent visceral adiposity and insulin sensitivity.²³ Rather than a single anthropometric score, the visceral adiposity index is considered to be a good predictor of metabolic problems linked to insulin resistance²¹. Optimal VAI (VAI > 2.25 in women and > 1.86 in men)²⁴. The Visceral Adiposity scores for males and females were calculated using a formula:

$$\begin{aligned} \text{Men : VAI} \\ &= \frac{\text{WC(cm)}}{39.68 + (1.88 \times \text{BMI})} \times \left(\frac{\text{TG(mmol/L)}}{1.03} \right) \\ &\times \left(\frac{1.31}{\text{HDL - C(mmol/L)}} \right) \end{aligned}$$

$$\begin{aligned} \text{Women : VAI} \\ &= \frac{\text{WC(cm)}}{36.58 + (1.89 \times \text{BMI})} \times \left(\frac{\text{TG(mmol/L)}}{0.81} \right) \\ &\times \left(\frac{1.52}{\text{HDL - C(mmol/L)}} \right) \end{aligned}$$

Functional exercise capacity evaluation

In this study, a 6-minute walk distance (6-MWD) was applied to evaluate functional-exercise -capacity (VO₂ max). Two cones were placed in a 20-meter section of the Al-Wafaa Specialized Centre for Diabetes and Endocrinology for testing. Prior to the test, everyone was given ten minutes of rest in a seated position. Pulse and blood pressure were measured by the electronic blood pressure model DMK-BP-A101, made by Alicn Medical Shenzhen. and then participants were asked to walk from start to finish while striving to cover as much ground as possible in six minutes, as instructed. Count the number of laps to know the distance traveled during this time. At the end of 6 minutes, ask the patient to stand in place and prepare a chair to sit on. Then, measure pulse, blood pressure, and functional capacity (VO₂ max) based on a prediction equation after measuring the full distance walked in six minutes (6MWD) to the nearest meter.

$$\text{VO2max prediction equation: } \text{VO2max (mL/kg/min)} = 12.701 + (0.06 \times 6\text{-minute walk distance in meters}) - (0.732 \times \text{body mass index kg/m}^2) \quad (R^2 = 0.79,)$$

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Data analysis

IBM SPSS Version 26 was used to analyze the data. To see if the distribution was normal, the Kolmogorov-Smirnov test was applied. To summarize the data, descriptive statistics such as mean, and standard deviations were used. To compare VAI and exercise capacity among type 2 diabetes and healthy controls, an independent t-test was utilized, while a simple regression used to find a relationship between VAI and functional exercise capacity. "A P value of less than 0.05 was used to indicate statistical significance."

Results

Table (1) demonstrates that there were sixty-two research participants, with no statistically significant differences in age, gender, and BMI class, indicating homogeneity between study groups. Table (2) shows there were no statistically significant differences in mean $\pm$ standard deviation for age (53.1 $\pm$ 8.7), (51.9 $\pm$ 8.9), height (166.6 $\pm$ 8.3), (168.4 $\pm$ 7), weight (84.9 $\pm$ 15.3), (82.3 $\pm$ 13.1), and BMI (30.6 $\pm$ 5), (29.1 $\pm$ 3.9), but there were highly statistically significant differences in waist circumference (WC) (109.8 $\pm$ 14.5) and (97.9 $\pm$ 12.8). Table (3) there are highly statistically significant differences in VAI between T2DM and healthy controls. Table (4) Shows lower functional capacity in type 2 diabetes patients compared to healthy controls. Table (5) In simple regression, the independent variable explained 65% of the variance in 6MWD, where according to the unstandardized B, an increase in VAI by 1 score predicted a 39.5-meter decrease in 6MWD.

Table 1
Frequency distribution for type 2 diabetics and healthy people

Variables		T2DM		Healthy controls		p-value
		F	%	F	%	
Age.	35<45	8	25.8	10	32.3	0.855
	45<55	11	35.5	10	32.3	
	55-66	12	38.7	11	35.5	
TOTAL		31	100	31	100	
Sex.	Male	20	64.5	20	64.5	1
	Female	11	35.5	11	35.5	
TOTAL		31	100	31	100	
BMI.	Normal	3	9.7	4	12.9	0.586
	Overweight	13	41.9	16	51.6	
	Obese	15	48.4	11	35.5	
	TOTAL	31	100	31	100	

N.: Number of Participants; F: Frequency; %: Percent; BMI: body mass index

Table 2
Descriptive statistics and t-test for age and anthropometrics for both type 2 diabetics and healthy controls

Variables	T2DM	Healthy controls	T-test	P-value
	Mean± SD	Mean SD		
Age	53.1±8.7	51.9±8.9	0.564	0.575
Weight	84.9±15.3	82.3±13.1	0.732	0.467
Height	166.6±8.3	168.4±7	-0.944	0.349
BMI	30.6±5	29.1±3.9	1.269	0.209
WC	109.8±14.5	97.9±12.8	0.209	0.001**

Note: ** = Significance at P. < 0.01, SD: standard deviation; BMI, Body Mass Index; WC, Waist Circumference.

Table 3
Visceral Adiposity Index (VAI) among type2 diabetic and healthy controls

Variables	T2DM	Healthy controls	(t-test)	P-value
	Mean± SD	Mean± SD		
VAI	3.2±1.4	1.9±0.8	4.390	0.001**

Note: ** = Significance at P. < 0.01, N.: Number of Participants, VAI: Visceral Adiposity Index,

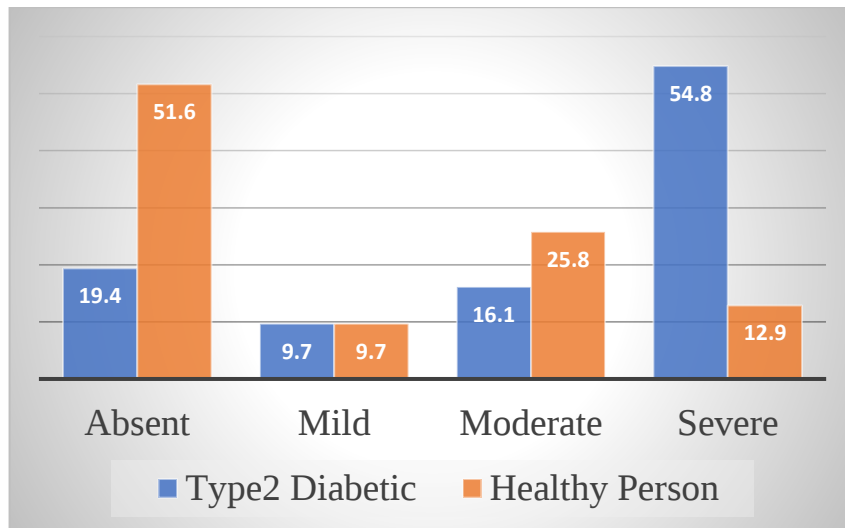


Figure 1. Visceral Adiposity Index (VAI) Categories for Type2 diabetic and healthy controls

Table 4
Functional capacity of type 2 diabetes patients compared to healthy controls

Functional capacity	Type2 Diabetic Mean ± SD	Healthy controls Mean ±SD	t-test	*P-value
6MWD(m)	445.6±78.7	529.7±70.1	-4.459	0.000**
Percentage of expected	80.1 ±9	92.6±5.6	-6.518	0.000**

6mwt%				
VO2 MAX ml/kg/min	17.1±7.6	23.2±5.7	-3.580	0.001**

Note: ** = Significance at P. < 0.01, SD: standard deviation; 6MWD: 6-Minute Walk Distance; VO2MAX: maximum of oxygen consumption.

Table 5

The relationship between functional exercise capacity (6MWD) and study outcome

Parameters	Variables	6MWD	P-Value
		Pearson coefficient(r)	
Anthropometrics	Weight	-0.386	0.032
	Height	0.456	0.010
	BMI	-0.651	0.000**
	WC	-0.626	0.000**
	VAI	-0.728	0.000**
Biochemicals	*LDL	-0.083	0.657
	*HDL	0.177	0.340
	*Triglycerides	-0.653	0.000**
	*HBA1C	-0.551	0.001**

6MWD: 6-Minute Walk Distance; WC, Waist Circumference, VAI: Visceral Adiposity Index

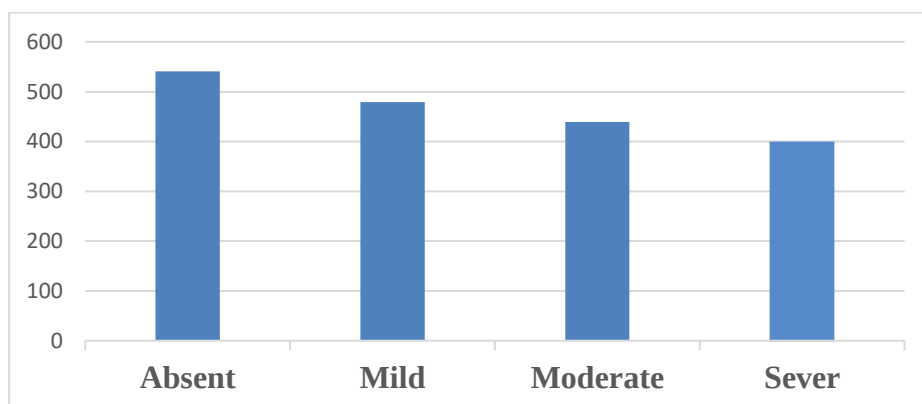


Figure 2. Six-minute walk distance according to VAI class

Discussion

The goal of this study was to compare the visceral adiposity index and functional exercise capacity between type 2 diabetic patients and healthy controls and to find out the relationship between visceral adiposity index and functional exercise capacity among type 2 diabetes. In patients with chronic obstructive pulmonary disease (COPD), pulmonary hypertension, and congestive heart failure, the 6MWT is commonly used to determine functional exercise capacity and prognosis. This test can also be used to see how different interventions, such as rehabilitation, treatment regimen adjustments, and oxygen supplementation, affect patients' walking capacity. There are only a few studies in the literature that look at the

use of the 6MWT in people with diabetes. Diabetes is one of a group of disorders that have a regular impact on one's physical exercise. In our study Table (1): shows no significant differences between T2DM and the healthy control group concerning "age, gender, and body mass index," which indicates matching or homogeneity among T2DM and healthy controls, and these variables do not affect the results of the study. The current research shows that most of the study participants were aged between (55 - and 66), representing 38.7% of type 2 diabetes cases.

A study conducted by ²⁷ agreed with our research when they found that diabetes is expected to afflict less than 2 percent of those aged 16–34, compared to 5.3 percent of those aged 36–55, 14.4 percent of those aged 56–74, and 16.6 percent of those aged over 75. This result can be explained as a definite link between growing age and the prevalence of type 2 diabetes. According to a report from the CDC, adults between the ages of 45 and 64 are the most likely to be diagnosed with diabetes ²⁸. Table (2): shows no statistically significant differences in age, height, weight, and BMI between type 2 diabetic patients and healthy control, which indicates homogeneity, and there are highly statistically significant differences in waist circumference. Our results agree with those of Awotidebe et al. (2014) who discovered that patients with type 2 diabetes and healthy controls were similar in age and sex ($p > 0.05$). Another research was carried out by (Fan et al., 2020) in agreement with our study when it was found that the waist circumference in non-diabetics was (82.6 ± 10.8) and in type 2 diabetics was (87.4 ± 11.4) ($P < 0.001$). These results can be explained by the fact that the patient with type 2 diabetes suffers from high blood sugar caused by insulin resistance, where insulin resistance leads to a decreased metabolic rate and an increase in blood insulin, so increased insulin converts glucose into triglycerides and then leads to increased abdominal obesity.

Table (3): shows highly statistically significant differences in VAI between T2DM and healthy controls. According to the current study, VAI is high in T2DM. A study conducted by ²⁹ agree with our research when they found that "each increase in the higher visceral adiposity index by 1 unit was linked with a 42% higher risk of type 2 diabetes". The following is how this outcome might be explained, as VAI are newly created metrics for determining the fat mass and the degree of visceral adiposity. The findings of our study supported the idea that VAI is linked to poor glucose management, insulin resistance, and b-cell dysfunction. VAI is various components (BMI, WC, TG, and HDL-C) show a better relationship with induced inflammation and adipocytokine production than BMI alone, which could explain why VAI has a higher predictive potential for DM than BMI alone. Table (4): shows highly significant differences in 6MWD and VO₂max estimation between type 2 diabetic patients and healthy controls. Participants with type 2 diabetes had lower exercise capacity than healthy controls, as measured by their six-minute walking distance (6MWD) and maximum oxygen consumption (VO₂max). Our results agree with ³⁰ at ($p < 0.001$), at ($P = 0.001$), and ³¹ and ³² ($P > 0.001$) ³² at ($P > 0.001$).

The current study observed that type 2 diabetes patients without CVD have a lower functional exercise capacity, which may be linked to poor glucose metabolism and unhealthy lifestyles. Our findings support the theory that a

patient with type 2 diabetes has been shown to have impaired nitric oxide-mediated endothelial function in their arteries, resulting in lower steady-state blood flow to their limbs, as well as our research, also supports the previous study³³ finding that type 2 diabetes patients had lower mitochondrial content and increased mitochondrial dysfunction than healthy people. This (mitochondrial dysfunction) could cause changes in the oxidative phosphorylation system, making it more difficult for them to use oxygen during exercise. Table (5): show that height, weight, BMI, waist circumference, and VAI were significantly correlated with the 6MWD. A study conducted by³⁴ agreed with our study when they found the 6MWD associated significantly ($P < 0.05$). Another study conducted by³⁵ agreed with our study when they found The walked distance in the 6MWT was positively associated with height ($r = 0.416$; $p = 0.023$).

In the current study, we found that height was significantly correlated with walking distance within 6 minutes and was also a predicted variable in the regression equation, which could explain that the taller the person, the faster the walking speed. Weight and BMI were also significantly associated with the 6MWD, which supports the pathophysiology of type 2 diabetes sufferers from poor, unhealthy lifestyles and insulin resistance, which cause them to gain weight and become obese. Excess body fat reduces oxygen uptake in skeletal muscles and impairs functional ability. In addition, type I muscle fibers increase in people with a high body mass index, while type II decreases. It can lead to a significant decrease in oxygen uptake, accompanied by decreased functional capacity. Our research found a significant negative relationship between VAI and WC with 6MWD. The results of the current study support the physiological mechanism that the excessive deposition of fat in the diaphragm and visceral abdominal organs affects the mechanism of movement of the diaphragm.

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