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The effects of body fat distribution on cardiopulmonary function in obese women

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Abstract. *Aim*. The purpose of this study was to investigate the effects of body fat distribution on oxygen uptake, cardiac output and spirometric measurements in healthy obese women. *Material and Method*. Forty obese women (age: 37.72±2.28 years, height: 158.67±5.64 cm, body weight (BW): 85.97±11.79 kg, Body Mass Index (BMI): 34.12±4.17 kg/m²) voluntarily participated to this study. The participants were divided into two groups according to waist circumference and than their spirometer test, gas analysis, indirect cardiac output (Q) measurement and anthropometric measurements were performed. Descriptive statistics, including mean and SD, independent t test and Pearson correlation coefficient for variables were calculated. The level of significance was set at $p<0.05$. *Results*. The findings showed that there were statistically significant differences VO_2max, sistolic and diastolic blood pressure parameters between two groups that advantage of gynoid group ($p<0.00$). But there were not statistically significant differences Q and pulmonary functions parameters between two groups. *Conclusion*. In addition to, there were statistically negative relationship between VO_2max and the body fat percentage (BF %), BMI, waist circumference, waist-to-hip ratio (WHR), waist to height ratio (WHtR) while there were not statistically relationship between Q, pulmonary function parameters and anthropometric parameters. Consequently, we found that increased upper body fat deposition caused to increased arterial blood pressure and decreased oxygen uptake in obese women.
Key words: *obesity, maximal oxygen uptake, cardiac output, pulmonary function test.*

Introduction

Obesity is a disease which triglyceride accumulation has been associated with several health problems and chronic diseases. Obesity is the result of an imbalance between energy intake and energy expenditure (1-3). However, more recent research has suggested that genetic, physiological, and behavioral factors also play a significant role in the etiology of obesity (3).

Anthropometric indexes such as the BMI, WHR, waist circumference and WHtR remain the most commonly used methods for assessing body composition because of their simplicity and low cost (4, 5). The region of the fat deposits is important to determine whether the obesity is a risk to health. Recent studies have shown that region of the fat deposits more effective rather than excess fat deposits in obesity related diseases. Several studies have found that relations between abdominal obesity and various diseases (3, 6-8). For example, it has been shown that the presence of intra-abdominal fat deposit is a better predictor of coronary heart disease than the BMI (9). WHR, waist circumference or WHtR are the most popular anthropometric indexes for assessing android or gynoid obesity (1,10-12). In android obesity type patterns, fat is deposited around the waist and upper body region, particularly the abdomen. The gynoid type distribution of body fat is usually seen in women. The fat is deposited around the hips, thighs, and buttocks (13-20).

Q is the volume of blood being pumped by the heart, in particular by a left or right ventricle in the time interval of one minute. The association between obesity and Q has been observed since the 1950s (21). Stroke volume (SV) and Q are both increased in morbidly obese. These changes in blood volume and most likely due to the increased metabolic demand (3,21,22). Furthermore, due to the fat excess metabolism obese patients have a greater absolute oxygen consumption and a greater carbon dioxide production. Morbidly obese individuals have poorer exercise capacity and may also have poorer exercise capacity and may also have poorer pulmonary gas exchange because of the added energy needed to move fat mass (23).

Additionally, several studies reported inverse relations between lung functions and measurements of central adiposity such as the waist circumference and the WHR (9, 24). Because, fat accumulation at intercostals muscle, diaphragm and intra-abdominal is associated with decreased chest wall compliance (8).

Our first aim was to determine the influences cardiopulmonary functions of the regional fat distribution in android obese women compared with gynoid obese women. And second aim was to determined to relationship between cardiopulmonary functions and morphologic structure in healthy obese women.

Material and Method

Participants: Forty healthy obese women (Android; n:25 age: 38.20±2.23years, height: 157.92±5.63cm, body weight (BW): 89.72±12.25kg, body mass index (BMI): 35.87±4.31kg/m². Gynoid; n: 15, age: 36.93±2.21years, height: 159.93±5.62cm, body weight (BW): 79.73±7.95kg, body mass index (BMI): 31.20±1.40kg/m²) were recruited. All participants were volunteers and signed an institutionally approved informed consent statement.

Material. Ergospirometer (Quark PFT, Cosmed, Italy), skinfold caliper (Harpenden, England), anthropometric set (Harpenden, England), tapemeter, ergometer bycycle, electronic scale.

Anthropometric Measurements. The anthropometric measurements included height, weight, waist and hip circumference, and BF %.

WHR: The circumference of the waist was measured between iliac crest and the last costa with tapemeter. The circumference of the hip was measured maximum of gluteus maximus muscle with the standing position. The WHR was calculated as waist circumference divided by hip circumference. WHtR: waist circumference divided by measured height in centimeters. BF % measurement: Skinfold thickness were measured three area using the standard methods for percent fat. And than body density was calculated with three area and then body fat was found as Jackson et al.'s formule for fat mass (7, 25).

Furthermore, biceps brachii, chest, subscapula and abdomen skinfolds were measured for total skinfold thickness

Body density = 1.0994921- 0.0009929(Σ3f) + 0.0000023 (Σ3f)² - 0.0001392 (age)

Fat% = (4.95/Body Density) - 4.5) x 100(Σ3f = triceps SF + thigh SF + suprailiac SF)

Maximal Oxygen Uptake (VO_2max) Measurement.. Ergospirometric test was performed on a treadmill as a Bruce protocol. Calibrations were performed prior to each test. Gas analysis was performed by otomotic each of 3-4 second while subjects is walking and running on the treadmill. Test was finished when they happened volitional exhaustion, R greater than 1.10 and not increase maximal oxygen uptake anymore (2).

Cardiac Output (Q): Q was measured by an indirect Fick procedure on a bicycle ergometer. Subjects pedaled at 100 watt and at 50 rpm after 90 sec until steady state. The subjects breathed air from a cardiac output balloon during the 20 sec at the end of the expiration. After the test, cardiac output was calculated from the following formula (Q (L/min)=VO_2/(CaO_2-CvO_2) (26).

Pulmonary Function: All subjects underwent standard spirometry and lung volume determinations according to the guidelines of the American Thoracic Society. Each subject were made two acceptable FVC, and MVV maneuvers according to standard methods. FVC test wase performed with the subjects in the standing position while MVV test was performed with the subjects in the sitting position (26).

Blood Pressure: Resting blood pressure was measured using a sphygmomanometer.

After all measurements, subjects were divided into two groups according to their waist circumference measurement. Afterwards, they were classified as android obese (≥88 cm), and gynoid obese (<88 cm) (13, 27).

Statistical Analysis. For data analysis, SPSS 11.5 packet pragramme was used. Each parameters were calculated as mean±standart derivation (SD). Differences between the android and gynoid groups were tested using "independent t test". Furthermore, Pearson correlation coefficients analysis was used to relationship between anthropometric parameters and cardiopulmonary parameters. The level of significance was set at $p<0.05$.

Results

The mean, and standard deviations on physical characteristics and anthropometric parameters according to waist circumference measurement groups were presented in Table I.

All anthropometric parameters were higher in android obese group than gynoid obese group except height parameter in Table I.
The mean, and standard deviations and t test results on gas analysis, Q and spirometric measurement of the participants were shown in Table II and III.

Android group showed significant higher values for sistolic ($p<0.00$) and diastolic ($p<0.02$) blood pressure and showed significant lower value for VO_2max ($p<0.00$) when compared with the gynoid group. No significant difference in Q measurement and spirometric parameters were noted between the android and the gynoid group.

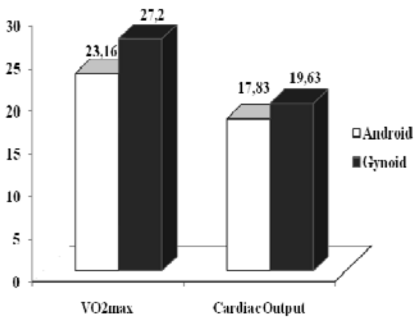
Table I. Means and standart deviations of physical parameters and anthropometric parameters in android and gynoid obese women

	Android (n=25) X ± Sd	Gynoid (n=15) X ± Sd	Total (n=40) X ± Sd
Age (y)	38.20 ± 2.23	36.93 ± 2.21	37.72 ± 2.28
Height (cm)	157.92 ± 5.63	159.93 ± 5.62	158.85 ± 5.71
BW (kg)	89.72 ± 12.25	79.73 ± 7.95	85.97 ± 11.79
BMI (kg/m^2)	35.87 ± 4.31	31.20 ± 1.40	34.06 ± 4.23
Waist Circumference (cm)	98.14 ± 7.64	85.58 ± 3.29	93.43 ± 8.82
WHR	0.81 ± 0.05	0.75 ± 0.06	0.79± 0.06
WHtR	0.61 ± 0.04	0.52 ± 0,01	0.58 ± 0.05
BF %	40.64 ± 3.41	37.69 ± 3.17	39.53 ± 3.58
Total SF	257.80 ± 24.88	228.74 ± 26.87	246.90 ± 29.04

Table II. Means, standart deviations, and t test scores of oxygen cosumpation and cardiac output parameters in android and gynoid obese women.

	Android (n=25) X ± Sd	Gynoid (n=15) X ± Sd	p
Resting pulse (Beat/min)	81.96 ± 8.57	78.40 ± 7.89	
Sistolic Blood pressure (mm/Hg) *	127.16 ± 16.47	109.00 ± 14.26	0.00
Diastolic Blood pressure (mm/Hg) *	81.40 ± 8.03	73.86 ± 11.78	0.02
Maximum RF (min)	42.80 ± 6.81	45.40 ± 9.18	
Maximum TV (L)	1.72 ± 0.35	1.71 ± 0.37	
Maximum VE (L)	69.25 ± 10.68	73.36 ± 10.50	
VO_2 (ml/min)	2072.82 ± 350.95	2166.64 ± 225.50	
VCO_2 (ml/min)	2292 ± 56	2353 ± 301.45	
VO_2max (ml/min/kg) *	23.16± 3	27.20 ± 3.72	0.00
Cardiac Output (Q) (L/min)	17.83 ± 6.62	19.63 ± 11.89	
StrokeVolume (SV) (ml)	124.28 ± 46.98	138.93 ± 21.89	

(RF (respiratory frequency); TV (Tidal volume); VE (minute ventilation); VO_2 (oxygen consumption per minute); VCO_2 (carbon dioxide production per minute); VO_2max (maximal oxygen uptake).



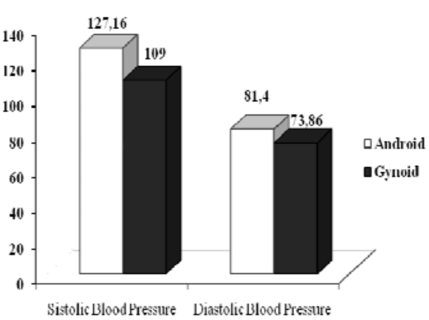


Figure 1. Q, VO_2max, and sistolic-diastolic blood pressure in android ve gynoid obese women

Table III. Spirometric Parameters in android and gynoid obese women (n=40)

	Android (n=25) X ± Sd	Gynoid (n=15) X ± Sd	**p**
FVC (Lt)	2.41 ± 0.44	2.54 ± 0.59	
FEV1 (Lt)	2.29 ± 0.44	2.41 ± 0.52	
FEV1/FVC (Lt)	92.95 ± 12.56	96.53 ± 3.57	
EVC (Lt)	2.85 ± 0.5	3.0 ± 0.5	
ERV (Lt)	0.76 ± 0.5	0.70 ± 0.4	
MVV (Lt/min)	98.78 ± 16.27	102.11 ± 14.64	

FVC: Forced Vital Capacity; FEV1: Forced Expiratory Volume in 1 second;
ERV: Expiratory Reserve Volume; MVV: Maximum Voluntary Ventilation).

Pearson correlation analysis were performed to determine the linear relationships between the anthropometric and cardiopulmanary functioning values. The relationship between the anthropometric measurements and cardiopulmanary function in two groups were shown in Table IV ($p<0.05$). There were significant negative relationship between waist circumference, BMI, WHtR, BF % with VO_2max parameters, and positive correlation between waist circumference, BMI, WHR and WHtR with arterial blood pressure parameters. However, there were not significant relationship between anthropometric measurements with Q and spirometric parameters.

The moderately correlation between the waist circumference and VO_2max (-0.43) and resting blood pressure (systolic) (0.46) are shown in Figure 2.

Table IV. Relationship between anthropometric measurements and cardiopulmanary function in obese women

Parameters	r	p	Parameters	r	p
Waist Circumference –Sistolic Blood Pressure	0.46	0.00	WHR - Sistolic Blood Pressure	0.40	0.00
Waist Circumference –Diastolic Blood Pressure	0.33	0.03	WHtR – Sistolic Blood Pressure	0.51	0.00
Waist Circumference - VO_2max	-0.43	0.00	WHtR - Diastolic Blood Pressure	0.36	0.02
Waist Circumference – Exercise Time	-0.34	0.03	WHtR - VO_2max	-0.38	0.01
BMI - Sistolic Blood Pressure	0.39	0.02	WHtR - Exercise Time	-0.35	0.02
BMI - VO_2max	-0.47	0.00	BF % - VO_2max	-0.55	0.00
BMI - Exercise Time	-0.54	0.00	BF % - Exercise Time	-0.48	0.00

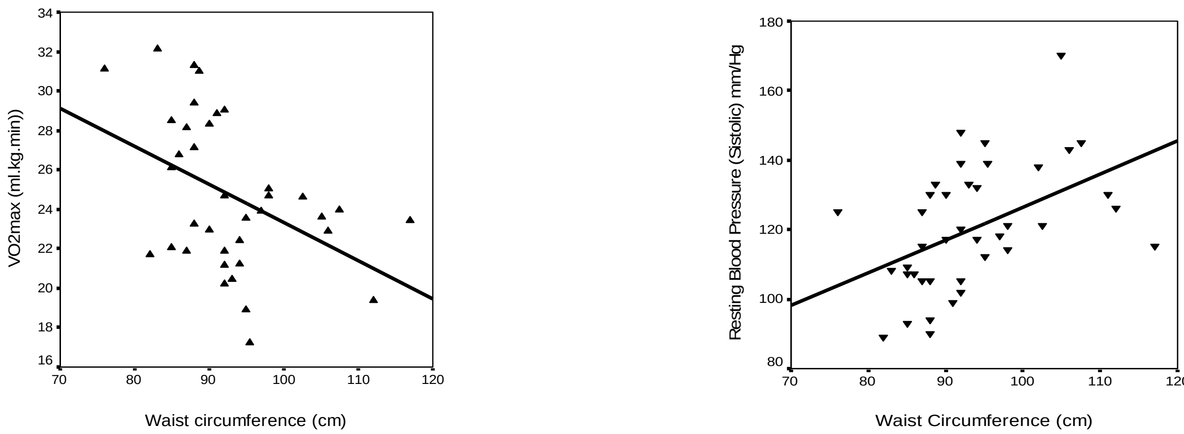


Figure 2. Relationship between waist circumference-VO_2max, and waist circumference-sistolic blood pressure measurements in obese women.

Discussion

The purpose of the present study was twofold: (1) to compare pulmonary functions, oxygen cosumpution, and Q values in gynoid obese group and android obese group and (2) to determined relations between antropometric parameters and cardiopulmonary functions. In the present study, the participants were divided into two groups based on waist circumference, before the independent t-test was used to identify the difference between cardiopulmonary parameters and regional fat distribution. It is well known that not only BF% but also regional fat distribution is closely linked to hypertension and cardiovascular diseases (28, 29). In this study, systolic and diastolic blood pressure and VO_2max values were determined significant differences between two groups in favour of gynoid type obese.

Several studies have documented the association of arterial blood pressure with android obesity. Janssen et al. divided into 2 groups in participants for the waist circumference and 3 groups for the BMI as normal weight, over weight, and obese. And they determined significant increased high systolic and diastolic blood pressure in all three groups with high waist circumference values compared with normal waist circumference values (13). Namely, the subjects with high waist circumference values had a greater health risk compared with those with low waist circumference values within the same BMI category.

In this study, while there were significant relationships between systolic blood pressure with waist circumference, WHR, WHtR and BMI, diastolic blood pressure was not relationship between these anthropometric parameters. In particular, it was determined that the most significative parameters are WHtR (0.51) and waist circumference (0.46). Daniels et al.(12) found a significant relationship between regional fat distrubition and systolic blood pressure among children and adolescents, but not diastolic blood pressure. However, Deshmukh et al. (4) found a significant positive relationship between BMI and waist circumference values with both systolic and diastolic blood pressure values.

According to Table IV, while there were significant relationships between cardiopulmonary functions and waist circumference, they were not as strong as the rela- tionship between cardiopulmonary functions and WHR. The reason why WHR is not associated with cardiopulmonary functions, it could be that hip circumference. Because even though the waist circumference of a person is more than 88 cm, if hip circumference is wide due to the structure of the pelvis it might cause that the WHR is observed lower. Thereby classification of the obesity risk depending on regional fat distribution, such WHR may be misleading. But, Zavorsky et al. indicated that the waist circumference explained a small part of the variance in pulmonary gas exchange between morbidly obese subjects, while the WHR explained a larger part of the variance (23)

Additionally, a significant relationship between WHtR and sistolic and diastolic blood pressure, VO_2max, duration of the exercise was found. Importance of waist circumference, WHR, WHtR have been recognized for estimating cardiovascular disease risk factors, particularly due to their positive association with hypertension. In the present study, mean values of the blood pressure values were significantly higher in android group than in gynoid group. The findings were similar to many studies (12). Schneider et al. indicated that the WHtR and waist circumference measurements better indicators of cardiovascular risk factor than the BMI (5).

One explanation for higher blood pressure in android group also could be that older than gynoid group. In this study, participants were determined within a limited range of age and BMI for obesity determination to participate. When the participants were separated into two groups according to waist circumference, the parameters, such as age and body weight in the android group obese higher than gynoid group were observed.

As indicated in Table II, VO_2max values were found 27.20 ml/kg/min in gynoid group and 23.16 ml/kg/min in the android group which was evaluated using Bruce protocol on the treadmill. This difference was significant ($p<0.00$) in favour of gynoid type obese when compared with the android obese group. Li et al. (30) have shown that cardiopulmonary endurance in morbidly android obese women is lower than in morbidly gynoid obese women. Meyers et al. (31) also found that higher values for VO_2max in obese men with lower WHR than higher WHR in the age of 40-79 years.

Especially, morbidly obese individuals have poorer exercise capacity and may also have poorer pulmonary gas exchange compared to nonobese counterparts because of the added energy needed to move fat mass (23).

Also, it was found that relations between VO_2max values with antropometric parameters such as waist circumference, BMI, WHtR, and BF%. Especially, the highest correlation with BF% (-0.55), and, the lowest correlation with WHtR (-0.38) were found. Similar findings were described in healthy obese men age 45-79 by Meyers et al. (31).

Previous studies have reported that Q values higher the obese individuals than normal individuals (22, 29, 31). It is likely that the greater Q in the overweight and obese individuals was due to an increased SV resulting from an expanded blood volume. Vella et al. demonstrated that Q values higher at rest and during exercise in overweight adults compared with normal weight adults (29). Rowland et al. also indicated that Q and SV values in obese adolescent girls higher than their normal weight peers during exercise (32). As shown in Table 2, it was found that higher Q values in gynoid group than in gynoid group. But it was seen that regional fat distribution, there was no significant difference between the two groups. Previous studies have reported that Q values higher the obese participants with wide waist circumference than the obese participants with narrow waist circumference (22, 29). Simone et al. (22) reported that Q and SV values higher in android obese than in gynoid obese.

It is known that Q is closely related to body size, mostly as a result of metabolic requirements of fat-free body mass. In this study, while we not found a significant correlation between the anthropometric parameters with Q and SV parameters, Collins et al. (21) found the significant relationships between Q parameters with BMI, WHR in the obese. Moreover, Jern et al (28), also determined Q and SV were positively correlated to BMI, but inversely to WHR. The absence of significant associations between these parameters might partially be explained by small number of participants.

Fat accumulation at intercostals muscles, diaphragm and intra abdominal is associated with decreased chest wall compliance and is a known cause of impaired lung expansion (8). In this study, when we examined the pulmonary functions, significant differences were not found, although all parameters higher gynoid groups than android groups. Numerous studies have documented that abdominal obesity is associated with lack of pulmonary functions (33, 34). Bring et al. (33) found significant decrease FVC, FEV1, ERV, FRC and MVV values in obese with high WHR, when classification is based on WHR. Chen et al (35) also indicated the FVC and FEV1 values decreased with increasing proportion of body fat. But these negative effects were found more significant in male than female.

Many studies have shown that the waist circumference and WHR parameters are related to FVC and FEV1 in obese (28), especially, demonstrated a strong relationship in man (33, 34). When Harik-Khan et al. (34) determined that strong negative relationship between WHR with FVC and FEV1 parameters in male obese, but not in female obese. Conversely, it has also been shown that lung function was more strongly negatively correlated with BMI than WHR (21, 24). The absence of significant associations between regional fat and pulmonary functions might partially be explained by the genders of participants. Because, according to recent studies have reported regional fat accumulation more negative effects in men than women (33-35).

In conclusion, we have shown that android obese women have lower oxygen consumption and higher systolic and diastolic pressure compared to gynoid obese women. Whereas, Q and pulmonary functions were not significant affected regional fat distribution in obese women. Furthermore, it was found that stronger relations between waist circumference and WHtR parameters with cardiopulmonary functions than the other anthropometric parameters.

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