Turkish Journal of Endocrinology and Metabolism, (1999) 2 : 81-86 **ORIGINAL ARTICLE**

The Effect of Total Body Fat and Its Distribution on Respiratory Functions in Obese Women

Rümeyza Kazancıoğlu* Neşe Özbey* Cüneyt Tetikkurt Yusuf Orhan***

Istanbul Medical Faculty, Istanbul

** Department of Internal Medicine*

*** Department of Respiratory Diseases*

Obesity is found responsible for respiratory system disorders such as; obstructive sleep apnea and obesity related hyperventilation syndrome. In our study we investigated the effect of body fat distribution on respiratory function tests in obese female patients. 116 patients followed up at the Obesity Outpatients' Clinic of Istanbul Faculty of Medicine were included in our study. Their mean age was 36.14 ± 11.37 years. The criteria for obesity was BMI ≥ 27 kg/m^2. The control group consisted of 42 females with a mean age of 26.60 ± 6.72 years. Waist/hip ratio was used to define both peripheral (<0.80) and central obesity (≥0.80). Patients with BMI>40 kg/m^2 were defined as morbid obese. The demographic and spirometric parameters of the control group and obese patients, of mildly and morbidly obese as well as of peripherally and centrally obese patients were compared. Vital capacity, functional residual capacity and expiratory reserve volume (ERV) were significantly lower in the obese patients ($p<0.05$). 25% of forced vital capacity, peak expiratory flow and ERV were significantly lower in morbidly obese patients ($p<0.05$). ERV was significantly lower in the centrally obese patients ($p=0.023$). It is concluded that the amount and distribution of body fat contribute to alterations in respiratory function tests in obese females but, excluding central and morbid obesity, deterioration of respiratory function tests in obese female patients could point to an intrinsic pulmonary disease.

KEY WORDS Obesity, respiratory function, total body fat

Introduction

Obesity and ischaemic heart disease are both among the most common diseases observed in developed countries. The close relationship between obesity and early coronary heart disease, non-insulin dependent diabetes mellitus and dyslipidemia is already well established (1). Obesity is also found responsible for respiratory system disorders (2,3). In many obese people respiratory function tests and arterial CO_2 levels are generally normal, but specific changes can be observed in the respiratory mechanics and gas exchange (4). Hypoventilation, hypercapnia and somnolence may be present in some of the patients (5). As a result of these changes, obstructive sleep apnea and obesity related hyperventilation syndrome can develop. Burwell and et al. termed a syndrome of gross obesity, somnolence, periodic breathing, cyanosis, right heart failure, raised $PaCO_2$ and polycythaemia as 'Pickwickian syndrome' in the honour of the fat boy Joe in Dickens' Pickwick Papers who displayed some of those features (6).

Lung capacity is reduced in obese people; especially when they are in the supine position, expiratory reserve volume (ERV) is decreased (7). In some obese patients respiratory function tests were reserved better than expected due to the increase in muscle volume (8,9). Respiratory function tests have been applied to many obese patients but the effect of body fat distribution on these tests is not

Correspondence address:

Rümeyza Kazancıoğlu, M.D.
Çilekli Cad. No: 24 Levent-İstanbul
Fax: 0 212 635 21 15
E-mail: rumeyza@hotmail.com

fully established. The respiratory function test results are expected to detoriate more in patients with upper body obesity (android, central obesity) than in patients with lower body obesity (gyneoid, peripheral obesity) (10). The increase in abdominal fat mass acting on the diaphragm might also be expected to alter respiratory function (7,9). The aim of the present study was to investigate the effect of total body fat and its distribution on respiratory functions in obese female patients.

Materials and Methods

One hundred sixteen female patients being followed up at the Obesity Outpatients' Clinic of the Internal Medicine Department were included in the study. None of the patients had a history of smoking or a respiratory disorder. Obesity was defined as a body mass index (BMI) greater than 27 kg/m^2. The age of the patients varied between 14 and 65 with a mean of 36.1 ± 11.4 years (median 36.0). The mean BMI of the patients was 36.72 ± 6.05 kg/m^2.

Forty two females among the medical students and staff of the Faculty were included in the study as the control group. The mean age of the control group was 26.60 ± 6.72 (median 26.00) years. The mean BMI of the control group was 22.16 ± 1.56 kg/m^2.

After taking medical history and performing a physical examination, demographical (age, maximum and minimum blood pressure), anthropometric (height, weight, BMI, waist and hip circumferences, waist/hip ratio, midarm and neck circumferences), and plicometric (triceps, biceps, suprailiac, supscapular and umbilical skinfold thicknesses) parameters were investigated. After a fourteen hour overnight fasting blood samples were taken for the evaluation of biochemical and hematological parameters (serum glucose, creatinine, uric acid, cholesterol, HDL-cholesterol, LDL-cholesterol, VLDL-cholesterol, triglyceride, fructosamine and hemoglobin, hematocrit and erythrocyte volume) both in the obese patient and the control group.

Spirometry was performed by the Respiratory Diseases Department using a calibrated 'Sensor Medics 2400, Bilthover, Netherland' during the mornings while the patients were seated. Among all the respiratory function test parameters, vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1 sec (FEV1), FEV1/FVC, maximum expiratory flow as 25% and 50% of vital capacity is forced (FEF 25%, FEF50%), total lung capacity (TLC), residual volume (RV), functional residual capacity (FRC), expiratory residual volume (ERV) and inspiration capacity (IC) were mainly analysed as these parameters are widely used in obesity studies.

The weight of the patients was measured with a classical weight beam scale and height with a stadiometer. All the measurements were taken with house clothing without shoes in the fasting patients. Body mass index was calculated by dividing the weight in kilograms into the square of height in meters. All the circumferences were measured with a nonelastic meter while the patients were in an upright position. Waist circumference was the smallest diameter between the costae and the processus spina iliaca anterior. Hip circumference was the largest diameter between the gluteus maximus at the back and symphsis pubis at the front (11). Waist/hip ratio (WHR) was calculated by dividing the waist circumference into hip circumference, both in centimeters. Midarm circumference was measured on the midpoint between the acromion and olecranon and the neck circumference was measured just beneath the laryngeal protrusion (12).

The skinfold thicknesses (sft) were measured on the non dominant side of the body. Biceps sft was measured directly on the biceps muscle; triceps sft was measured directly on the posterior triceps muscle between the acromion and olecranon proccessus. Suprailiac sft was measured on the midaxillary line and umbilical sft was measured 3-4 cm's next to the umbilicus on the horizontal plane. Subscapular sft was measured just beneath the scapula. Skinfold thickness was assessed with a Lange skinfold caliper in milimeters (13).

Patients with WHR less than 0.80 were grouped as peripheral obesity group (POG) and patients with WHR equal to or greater than 0.80 were grouped as central obesity group (COG). Patients with BMI greater than 40 kg/m^2 were defined as morbidly obese.

The blood pressure was measured with a standard anerobic sphingomanometer after three minutes rest. Biochemical parameters were evaluated with a DAX-72 autoanalyzer and hematological parameters with a H-2 hemogram analyzer at the central biochemical laboratory.

The demographic, spirometric, biochemical and hematological parameters of the normal control group and obese patients, mildly and morbidly obese patients as well as POG and COG patients among themselves were compared.

The statistical analysis was performed with a dBase IV V 2.0 (Borland, USA) and SPSS (Statistical Package for Social Sciences)/PC plus V 4.0 (SPSS Inc, Chicago, Illinois, USA) using unpaired t-test and regression analysis.

Results

A. Obese patients and normal control group: Age, weight, BMI, waist and hip circumference, WHR, triceps, biceps, suprailiac, umbilical and subscapular sft, midarm and neck circumferences, serum glucose, fructosamine, cholesterol, VLDL-cholesterol, tryglyceride, uric acid and creatinine levels were significantly higher in the obese patient group. There was no difference in hematological parameters between the control and obese patient group. Forced vital capacity, FEV0.5, FEV3, maximum expiratory midflow (FEF 25-75%), FIV1/FIVC, VC, FRC and ERV were significantly lower in the obese patient group than in the control group (Table1).

Table 1. The anthropometric, biochemical and respiratory parameters in obese patients and control group.

	Obese patients			Normal control group			p ≤
Age (years)	36.16	±	11.37	26.60	±	6.72	0.001*
Weight (kg)	88.84	±	15.36	55.67	±	4.82	0.001*
BMI (kg/m^2)	36.72	±	6.05	22.16	±	1.56	0.001*
Waist circumference (cm)	97.02	±	12.82	70.40	±	5.36	0.001*
Hip circumference (cm)	120.79	±	11.55	98.29	±	4.97	0.001*
WHR	0.80	±	0.07	0.72	±	0.04	0.001*
Triceps Sft (cm)	3.28	±	0.89	1.40	±	0.51	0.001*
Biceps Sft (cm)	2.72	±	0.90	0.82	±	0.40	0.001*
Suprailiac Sft (cm)	4.06	±	1.22	1.94	±	0.66	0.001*
Umbilical Sft (cm)	4.45	±	1.15	2.10	±	0.76	0.001*
Subscapular Sft (cm)	3.75	±	1.20	1.38	±	0.40	0.001*
Neck circumference (cm)	38.33	±	2.65	33.20	±	6.85	0.001*
Midarm circumference (cm)	34.62	±	3.96	26.95	±	9.85	0.001*
Glucose (mg/dL)	102.75	±	25.25	88.86	±	8.22	0.001*
Fructosamine (mmol/L)	2.28	±	0.33	2.17	±	0.19	0.045*
Cholesterol (mg/dL)	208.78	±	40.14	186.60	±	53.80	0.006*
VLDL-cholesterol (mg/dL)	35.03	±	21.16	22.50	±	35.93	0.008*
Tryglyceride (mg/dL)	175.16	±	105.78	112.50	±	179.67	0.008*
Uric acid (mg/dL)	4.56	±	1.37	3.20	±	0.80	0.001*
Creatinine (mg/dL)	0.92	±	0.11	0.88	±	0.09	0.024*
FVC (L)	3.29	±	0.61	3.50	±	0.60	0.045*
FEV0.5 (L)	2.06	±	0.41	2.28	±	0.38	0.026*
FEV3 (L)	3.14	±	0.64	3.54	±	0.62	0.013*
FEF25-75% (L/san)	3.06	±	0.89	3.62	±	0.95	0.001*
FIV1/FIVC (%)	82.81	±	8.89	87.38	±	7.66	0.004*
VC (L)	3.30	±	0.58	3.69	±	0.60	0.022*
FRC (L)	2.66	±	1.72	3.11	±	0.66	0.040*
ERV (L)	0.72	±	0.32	1.22	±	0.28	0.001*

B. Mildly and morbidly obese patients: Age, weight, BMI, waist and hip circumference, WHR, triceps, biceps, suprailiac, umbilicus and subscapular sft's, midarm and neck circumferences, maximum and minimum blood pressures, serum glucose levels were significantly higher in the morbidly obese patients (Table 2). Vital capacity was 3.37 ± 0.55 L for mildly obese and 3.11 ± 0.65 L for morbidly obese patients (p=0.05). Functional residual capacity was 130.05 ± 123.01% for mildly and and 90.44 ± 68.18% for morbidly obese patients (p= 0.012). Expiratory reserve volume was significantly lower in the morbidly obese patients (0.48 ± 0.22 L, p<0.001). Serum fructosamine, cholesterol, VLDL-cholesterol, tryglyceride, uric acid and hematological parameters did not differ between the two groups.

C. Centrally and peripherally obese patients: Weight, BMI, waist circumference, WHR, triceps and subscapular sft's midarm and neck circumferences, maximum and minimum blood pressure, serum glucose,VLDL-cholesterol, tryglyceride and uric acid levels were significantly higher in the centrally obese group (Table 3). Age, height, hip circumference, biceps, suprailiac and umbilical sft's, serum fructosamine, cholesterol, HDL-, LDL-cholesterol, creatinine and hematological parameters were not significantly different between the two groups (Table 3). Among all the other tests, only expiratory reserve volume (0.66 ± 0.36 L for centrally, 0.79 ± 0.26 L for peripherally obese patients, p=0.023) and FRC were significantly lower in the centrally obese group (98.56 ± 52.63% for centrally obese and 143.67 ± 151.09% for peripherally obese patients, p= 0.038).

D. Significant correlations between anthropometric parameters and respiratory function tests are shown in Table 4. There was a negative correlation between BMI and FEF50%, FVC and ERV, between WHR and FVC, ERV, VC and FEF50%. There

Table 2. The anthropometric, biochemical and respiratory parameters in mildly and morbidly obese patients.

	Mildly obese patients	Morbidly obese patients	p ≤
Age (years)	35.08 ± 11.34	39.13 ± 11.11	0.090
Weight (kg)	82.18 ± 9.88	107.13 ± 12.62	0.000*
BMI (kg/m^2)	33.76 ± 3.49	44.85 ± 3.60	0.000*
Waist circumference (cm)	91.46 ± 7.93	112.26 ± 11.25	0.000*
Hip circumference (cm)	115.68 ± 7.35	134.81 ± 9.11	0.000*
WHR	0.79 ± 0.06	0.84 ± 0.07	0.002*
Triceps Sft (cm)	2.98 ± 0.72	4.09 ± 0.14	0.000*
Biceps Sft (cm)	2.43 ± 0.74	3.52 ± 0.84	0.000*
Suprailiac Sft (cm)	3.81 ± 1.04	4.76 ± 0.26	0.000*
Umbilical Sft (cm)	4.18 ± 1.04	5.22 ± 1.11	0.000*
Subscapular Sft (cm)	3.42 ± 0.97	4.86 ± 1.25	0.000*
Neck circumference (cm)	37.60 ± 2.46	40.40 ± 2.03	0.000*
Midarm circumference (cm)	33.34 ± 3.19	38.87 ± 3.29	0.000*
Glucose (mg/dL)	99.58 ± 12.57	111.23 ± 43.23	0.000*
Fructosamine (mmol/L)	2.24 ± 0.25	2.37 ± 0.47	0.099
Cholesterol (mg/dL)	207.71 ± 40.79	211.65 ± 38.83	0.643
VLDL-cholesterol (mg/dL)	32.77 ± 21.81	41.03 ± 18.22	0.064
Triglyceride (mg/dL)	163.83 ± 109.20	205.13 ± 91.08	0.064
Uric acid (mg/dL)	4.49 ± 1.37	4.71 ± 1.37	0.478
Creatinine (mg/dL)	0.94 ± 0.11	0.88 ± 0.09	0.022*
FVC (L)	3.36 ± 0.56	3.09 ± 0.71	0.034*
VC (L)	3.37 ± 0.55	3.11 ± 0.65	0.050*
FRC (%)	130.05 ± 123.01	90.44 ± 68.18	0.012**
ERV (L)	0.80 ± 0.31	0.48 ± 0.22	0.001*

Table 3. The anthropometric, biochemical and respiratory parameters in centrally and peripherally obese patients.

	Peripherally obese patients	Centrally obese patients	p ≤
Age (years)	34.69 ± 11.54	37.53 ± 11.14	0.181
Weight (kg)	86.41 ± 15.27	91.12 ± 15.22	0.099
BMI (kg/m^2)	35.29 ± 5.78	38.06 ± 6.04	0.013*
Waist circumference (cm)	90.29 ± 9.28	103.30 ± 12.53	0.000*
Hip circumference (cm)	120.50 ± 10.84	121.07 ± 12.26	0.793
WHR	0.75 ± 0.04	0.85 ± 0.45	0.000*
Triceps Sft (cm)	3.11 ± 0.84	3.44 ± 0.90	0.042*
Biceps Sft (cm)	2.57 ± 0.79	2.86 ± 0.98	0.081
Suprailiac Sft (cm)	3.87 ± 1.19	4.24 ± 1.23	0.108
Umbilical Sft (cm)	4.43 ± 1.29	4.47 ± 1.00	0.834
Subscapular Sft (cm)	3.40 ± 1.11	4.11 ± 1.18	0.003*
Neck circumference (cm)	37.09 ± 2.51	39.45 ± 2.27	0.000*
Midarm circumference (cm)	33.84 ± 3.71	35.40 ± 4.09	0.048*
Glucose (mg/dL)	96.45 ± 11.71	108.61 ± 32.29	0.010*
Fructosamine (mmol/L)	2.22 ± 0.27	2.33 ± 0.37	0.103
Cholesterol (mg/dL)	202.33 ± 38.97	214.80 ± 40.60	0.098
VLDL-cholesterol (mg/dL)	29.27 ± 22.22	40.30 ± 18.82	0.005*
Triglyceride (mg/dL)	146.37 ± 111.07	201.51 ± 94.10	0.005*
Uric acid (mg/dL)	4.26 ± 1.46	4.86 ± 1.21	0.031*
Creatinine (mg/dL)	0.93 ± 0.10	0.92 ± 0.11	0.547
FVC (L)	3.34 ± 0.51	3.24 ± 0.69	0.357
VC (L)	3.34 ± 0.50	3.27 ± 0.65	0.539
FRC (%)	143.67 ± 151.09	98.56 ± 52.63	0.038*
ERV (L)	0.79 ± 0.26	0.66 ± 0.36	0.023*

was also a negative correlation between weight and both FEF50% and ERV. There was no particular correlation between neck circumference and these parameters (data not shown).

Table 4. The significant correlations between respiratory functions and anthropometric measurements.

	Weight (kg)	BMI (kg/m^2)	WHR
FVC (L)	r:-0.0551 p=0.491	r:-0.1859 p=0.019*	r:-0.2133 p=0.007*
FEF25%(L/san)	r:-0.1036 p=0.226	r:-0.1602 p=0.061	r:-0.0869 p=0.311
FEF50%(L/san)	r:-0.1572 p=0.049*	r:-0.2208 p=0.005*	r:-0.1821 p=0.022*
VC (L)	r:-0.0199 p=0.827	r:-0.1804 p=0.046	r:-0.2171 p=0.016*
ERV (L)	r:-0.4240 p<0.001*	r:-0.5562 p<0.001*	r:-0.3994 p<0.001*

Discussion

Starting from 1936 with Kerr and Lagen, attention has been given to the fact that some obese persons develop respiratory signs and symptoms (14) Later, in 1956, 'Pickwickian syndrome' was defined but still, disturbances in respiratory function in obese subjects were under investigation. Especially after 1990, increased risk of cardiovascular and metabolic diseases associated with obesity led to more detailed studies of total body fat content and the effects of its distribution.

As Raison (19) indicated, the most encountered disturbances in respiratory function associated with obesity are the reduction in FRC, ERV and hypoxaemia. We also found that, FRC, VC and ERV were significantly lower in the obese patients, than in the control lean group. Expiratory residual volume is one of the most sensitive respiratory function tests applied to obese people and it is nearly always decreased among them (14,15).

The decreæse in ERV increases the inspiratory force leading to Pickwickian syndrome at the end. The deterioration of chest wall compliance in obese persons negatively affects the respiratory functions. Upper airway resistance may also increase in them but we could not establish any correlation between neck circumference and the respiratory functions. Inspiratory functions are generally mainted as observed in our groups (16,17).

In the age-matched mildy and morbidly obese patients, FRC, ERV and VC were markedly reduced in the severely obese patients with BMI over 40. This finding was consistent with Raison's (19) and Collins's (18) observations.

In the centrally obese patients only a decrease of ERV, indicating a restrictive type of abnormality in respiratory functions, was observed when compared to the peripherally obese age matched group. A greater deterioration of respiratory functions is expected in centrally obese patients than in peripherally obese patients because the abdominal fat limits the movement of the diaphragm. In a study of obese male patients (18), FVC, FEV1 and TLC were found to be significantly lower in patients with upper body obesity.

The limited change in respiratory function tests in our centrally obese patients could be a result of the anthropometric parameters used. The measurement of body fat distribution depending on the WHR scala may not truly reflect the intrathoracic fat deposition.

In our study reductions in FVC1, FEF25%, FEF 50% and VC are related to the degree of obesity i.e., higher BMI or weight levels are associated with lower FVC, FEF25%, FEF50% and VC. As an index of abdominal fat distribution, WHR correlates negatively with both FVC and VC.

In conclusion, the amount and distribution of body fat contribute to alterations in respiratory function tests in obese females but, excluding central and morbid obesity, deterioration of respiratory function tests in obese female patients could point to an intrinsic pulmonary disease.

References

1. Desprès JP, Moorjani S, Lupien PJ, Tremblay A, Nadeau A, Bouchard C. Regional distribution of body fat, plasma lipoproteins and cardiovascular disease. *Arteriosclerosis* **10:** 497-511, 1990.
2. Gastaut H, Tassinari CA, Duron B. Polygraphic study of the episodic diurnal and nocturnal (hypnic and respiratory) manifestations of the Pickwick syndrome. *Brain Res* **2:** 167-186, 1966.
3. Guilleminault C, Tilkian A, Dement WC. The sleep apnea syndrome. *Ann Rev Med* **27:** 465-484, 1976.
4. Carraro R, Vianello A, Busetto L, Bevilacqua M, Enzi G. Respiratory disturbances in central obesity. Primary and secondary eating disorders. A psychoneuro-endocrine and metabolic approach, (Ed: Ferrari E, Brambilla F, Solerte SB) Oxford, Pergamon Press, 1993, 343-355.
5. Caro CG, Butler J, Dubois AB. Some effects of restriction of chest cage expansion on pulmonary function in man. An experimental study. *J Clin Invest* **39:** 573-583, 1960.
6. Burwell CS, Robin ED, Whaley RD, Bickelmann AG. Extreme obesity associated with alveolar hypoventilation. A Pickwickian syndrome. *Am J Med* **21:** 811-818, 1956.
7. Naimark A, Cherniak RM. Compliance of the respiratory system and its components in health and obesity. *J Appl Physiol* **15:** 377-381, 1960.
8. Zerah F, Harf A, Perlemuter L, Lorino H, Lorino AM, Atlan G. Effects of obesity on respiratory resistance. *Chest* **103:** 1470-1476, 1993.
9. Leech JA, GhezzoH, Stevens D. Respiratory pressures and functions in young adults. *Am Rev Respir Dis* **128:** 17-23, 1983.
10. Waltemath CL, Bergaman NA. Respiratory compliance in obese patients. *Anesthesiology* **41:** 84-88, 1974.
11. Durnin JVGA, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness. Measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr* **32:** 77-97, 1974.
12. Cassuto D, Panotopoulos G, Orvoen-Frija E, Saci B, Basdevant A, Guy-Grand B: Anthropometric and respiratory characteristics of obese subjects with nocturnal oxygen desaturation. Obesity in Europe 93, (Ed: Ditschuneit H, Gries FA, Hauner H, Schusdziarra V, Wechsler JG), London, John Libbey and Co., 1994, 459-462.
13. Albrink MJ, Meigs JW. Interrelationship between skinfold thickness, serum lipids and blood sugar in normal man. *Am J Clin Nutr* **15:** 255-261, 1964.
14. Bedell GN, Wilson WR, Seebohm PM. Pulmonary function in obese persons. *J Clin Invest* **37:** 1049-1060, 1958.
15. Cullen JH, Formel PE. The respiratory defects in extreme obesity. *Am J Med* **32:** 525-531, 1962.
16. Emirgil C, Sobol BJ. The effects of weight reduction on pulmonary function and the sensitivity of the respiratory center in obesity. *Am Rev Respir Dis* **108:** 831-842, 1973.
17. Gilbert R, Sipple JH, Auchincloss Jr JH. Respiratory control and work of breathing in obese subjects. *J Appl Physiol* **16:** 21-26, 1961.
18. Collins LC, Hoberty PD, Walker JF, Fletcher EC, Peiris AN. The effect of body fat distribution on pulmonary function tests. *Chest* **107:** 1298-1302, 1995.
19. Raison J, Cassuto D, Orvoen-Frija E, Dore MF, Rochemaure J, Guy-Grand B: Disturbances in respiratory functions in obese subjects. Obesity in Europe 91 (Ed: G Ailhaud etal) London, John Libbey and Co., 1991, 227-230.