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Body composition analyses in normal weight obese women

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Abstract. – The purpose of this study was to identify new indexes of body composition that characterize the normal weight obese (NWO) women. We measured body composition by dual energy x-ray absorptiometry (DXA) and resting metabolic rate (RMR) by indirect calorimetry in a cohort of seventy-five healthy Italian women, subdivided into three groups (nonobese/controls, NWO, preobese-obese women). Despite a normal body mass index (BMI), the NWO women have a higher body fat mass percentage (FAT %) (38.99 ± 6.03) associated to a significant (*p* = 0.02) lower amount of lean mass of legs (12.24 ± 1.31) and lean mass of left leg (6.07 ± 0.64) with respect to the control group. The NWO group showed a significant (*p* = 0.043) lower RMR (1201.25 ± 349.02) in comparison with nonobese and preobese-obese women. To classify NWO individuals among general population, we identified three significant body composition indexes: abdominal index, leg index and trunk index. The NWO women showed significant increased value in the three indexes (*p* < 0.001). Our results suggest that, despite a normal BMI, the NWO women displayed a cluster of anthropometric characteristics (body fat mass percentage, leg indexes) not different to obese women ones. An appropriate diet-therapy and physical activity may be protecting NWO individuals from diabetes and cardiovascular diseases associated to preobese-obese women.

Key Words:

Body mass index, Fat mass, Lean mass, Metabolic diseases, NWO.

Introduction

Obesity, a global epidemic recognized by international health organization (WHO)[1] is becoming the major cause of mortality and morbidity for associated clustering of metabolic disorders and cardiovascular disease (CVD). According to the WHO criteria, 33.4% of the females and 39.5% of the males were overweight (BMI > 25) and 31.4% of females and 14.6% of males were preobese-obese (BMI > 30). However, as previous described by De Lorenzo et al.[2], a considerable number of subjects, both males and females, will not be classified as obese based on their body mass index (BMI) alone. To overcome misclassifications, direct measurements of fat mass percentage (FAT %) would be a better tool for diagnosing obesity (25% in male and 35% in female)[3]. According to Istituto Nazionale di Statistica (ISTAT) data, it has been reported that 33.1% of Italian population was overweight with a BMI higher than 25, and fat% over 25% in male and 35% in female subjects.

Up to now, three subtypes of obesity were known: the "at risk" obese with metabolic syndrome (MS), the metabolically healthy but obese individuals (MHO), and the metabolically-obese normal weight subjects (MONW)[4]. The "metabolically-obese" normal weight (MONW), first described and recently revisited by Ruderman[5-7] represents a subset of individuals who have normal weight and body mass index (BMI) (18 ÷ 25), but display a cluster of metabolic characteristics that may increase the possibility to develop the metabolic syndrome (MS), in the same manner of so called "at risk" obese individuals. In 2001, the National Cholesterol Education Program (NCPE) defined the criteria to diagnose the MS[8]. Interesting, central obesity, gain in abdominal fat correlates closely with both hyperinsulinemia and insulin resistance and with the possibility to develop type 2 diabetes and coronary heart

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disease, both in preobese-obese and non preobese-obese individual[9]. Additionally, high serum level of triglycerides and low HDL cholesterol as well as high systolic and diastolic blood pressure correlate with hyperinsulinemia[10].

MONW individuals are not obese but characterized by hyperinsulinemia, dyslipidemias and an excess visceral fat[11]. Interesting, they usually have a large increase in the thickness of their sub scapular skin fold, and represent a particular group in whom genetic factors predisposing to insulin resistance, hypertension and cardiovascular diseases, as referred for the metabolic syndrome[12,13]. However, it has been shown that increased visceral fat and serum levels of triglycerides are associated with insulin resistance in Japanese MONW subjects even if with normal glucose tolerance[14].

Recently, De Lorenzo et al., have observed a new syndrome, related Normal Weight Obese (NWO) individuals, characterized by normal body weight and BMI, but high fat mass percentage[15]. Since, NWO subjects do not present MS they are distinguished from Metabolic Obese Weight Normal (MOWN) individuals.

In this study, we measured in Italian women the body composition (fat mass, lean mass and fat%) and the metabolic parameters [oxygen consumption (VO_2), carbon dioxide production (VCO_2), resting metabolic rate (RMR)] without impaired glucose tolerance or diabetes. The purpose of the present study was to identify new significant and predictive indexes based on body composition, rather than exploring the clustering of multiple factors of metabolic syndrome, that could characterize NWO women with respect to nonobese and preobese-obese individuals.

Materials and Methods

Subjects

Seventy-five Caucasian Italian women (aged 20 to 45 years) participated in the study, recruited at the Unit of Human Nutrition of the "Tor Vergata" University (Rome, Italy). We identified three groups: (1) 25 nonobese (controls) with normal weight and BMI < 25; (2) 25 NWO with normal weight, BMI < 25 and FM% > 30% and (3) 25 preobese-obese with BMI > 25 and FM% > 30%. The subjects were classified nonobese or preobese-obese according to the National Cholesterol Education Program NCEP criteria[16]. The NWO group was distinguished from Control women on the basis of their FM distribution using DXA, namely the FM percentage (FM%) classification criterion. All the women were free from hypertension, cardiovascular diseases and alcohol abuse and were in good general health; none smoked or took any drug. All subjects provided consent to take part to the study according to the guidelines of the "Tor Vergata" University Medical Ethical Committee, Rome, Italy.

Anthropometric Measurements

We measured anthropometric parameters for all participants according to standard methods[17]. Subjects were instructed to take off their clothes and shoes before performing all the measurements. Body weight (kg) was measured to the nearest 0.1 kg, using a balance scale (Invernizzi, Rome, Italy). Height (m) was measured using stadiometer to the nearest 0.1 cm (Invernizzi, Rome, Italy). Two circumferences were measured (waist and hip) with a flexible steel metric tape to the nearest 0.5 cm. Abdominal circumference was defined as the horizontal distance around the abdomen at the umbilicus. Hip circumference was measured as the distance passing horizontally through the two superior iliac bones. Body mass index (BMI) was calculated using the formula: BMI = (kg)/height (m^2).

Dual X-ray Absorptiometry (DXA)

Total body composition was assessed by dual-energy x-ray absorptiometry (DXA) (Lunar DPX, Milan, Italy). Subjects were required to remove all clothing except undergarments including shoes, socks and jewels prior to being positioned on the DXA table. Scans were performed with subjects in supine position. The entire body was scanned beginning at the top of the head and moving in rectilinear pattern down the body to the feet. Mean measurement time was 15 min. Radiation exposure was < 8 SV.

Resting Metabolic Rate (RMR) measurement

RMR was measured by indirect calorimetry. The oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured for a 30 min period by an open circuit indirect calorimeter using a face mask (Sensormedic 2900, California, USA). The gas analysers were calibrating daily for pressure and gas concentrations following the instruction of the manufacturer.

Subjects were instructed to drink only water, consume no alcohol, no proteins for 12 hrs before testing and refrain from sport activity for 24 hrs before testing. Prior to the RMR measurements, the subjects lay supine for 25-30 min in a quiet room. All tests were performed in supine position of the subjects. The temperature of the room was fixed at an average of 22°C. For additional quality control two different certified oxygen/carbon dioxide gas mixtures (SIAD Ltd Co, Rome, Italy) were used.

RMR was calculated from oxygen consumption and carbon dioxide production according to the formula of Weir[18]. RMR = 1.44 × (3.91 × VO_2 (ml) + 1.106 × VCO_2 (ml)

For the calculation of RMR, only data of subjects in apparently steady-state conditions (i.e.,VO_2 and VCO_2 did not vary more than 5% from the mean value of the 30 min measurement period) were used.

The respiratory quotient (RQ) is calculated dividing carbon dioxide production (VCO_2) by oxygen consumption (VO_2): RQ = VCO_2/VO_2.

Statistical Analysis

Statistical data analysis was performed using SPSS statistical package (SPSS/PC + Version 5.0., Chicago, IL. 1992). Descriptive values are expressed as mean ± standard deviation (SD). The significance of the differences between means was calculated using Student's *t* test. Group differences have been determined using a one way variance analysis (One-Way Anova) and differences between pair of means by a post hoc test (Tukey HSD test) were applied to compare the three groups in terms of different variables. Differences with *P* values ≤ 0.05 were considered to be significant.

Results

Seventy-five women completed the study. Body composition, body fat, lean distribution, oxygen consumption, carbon dioxide production and resting metabolic rate were calculated in the entire cohort. We identified three groups: (1) 25 women with normal weight and BMI < 25 (control, nonobese); (2) 25 NWO women with normal weight and BMI < 25, FM% > 30% and (3) 25 preobese-obese women with BMI > 25 and FM% > 30%.

The body composition parameters of three groups are shown in Table I. There were no statistical differences in age, weight, height, BMI, total lean mass, waist and hip circumferences and waist/hip ratio between NWO and nonobese control group. However, in the same groups we found significant differences in fat mass (*p* = 0.01),

Table I. Body composition parameters of NWO, nonobese and preobese-obese women.

Value	NWO (n = 25)		Nonobese (n = 25)		Preobese-obese (n = 25)		NWO vs nonobese (p)	NWO vs preobese-obese (p)
	Mean	*S D*	*Mean*	*S D*	*Mean*	*S D*		
Age (yrs)	34.65	13.18	25.38	5.15	39.63	13.85	NS	NS
Weight (kg)	59.57	5.82	53.95	4.76	77.80	15.08	NS	< 0.001
Height (cm)	160.94	6.09	163.19	7.96	159.42	5.68	NS	NS
*BMI (kg/m^2)	22.96	1.41	20.29	1.67	30.62	5.85	NS	< 0.001
*FAT (kg)	21.42	3.78	12.38	1.76	36.75	10.11	0.01	< 0.001
LEAN (kg)	35.27	3.30	39.08	3.61	38.04	6.09	NS	NS
LE ANLEGS (kg)	12.24	1.31	14.06	1.99	13.09	1.88	0.02	NS
LE ANLEGL (kg)	6.07	0.64	7.07	0.95	6.53	0.94	0.01	NS
*FAT (%)	38.99	6.03	20.01	1.53	53.20	4.61	< 0.001	< 0.001
TISSUE (kg)	56.69	5.62	51.46	45.71	74.80	15.02	NS	< 0.001
WAIST (cm)	71.84	4.80	66.87	3.35	90.17	13.97	NS	< 0.001
HIP (cm)	96.05	8.07	92.00	3.06	108.76	23.06	NS	0.01
W/H	0.75	0.09	0.73	0.04	3.64	1.46	NS	NS

BMI = Body mass index; FAT = Fat body composition; LEAN = Lean body composition; LEANLEGS = Lean of the legs by DXA; LEANLEGL = Lean of left leg by DXA; FAT% = Fat percentage; TISSUE = Tissue body composition; WAIST = Circumference of waist; HIP = Circumference of hip; W/H = Ratio waist to hip.
The data are expressed as mean ± SD. The statistical analysis was assessed through the post hoc Tukey's test. Differences with P values ≤ 0.05 were considered to be significant. NS = not significant value.

Table II. Body index of NWO, nonobese and preobese-obese women.

Index	NWO (n = 25)		Nonobese (n = 25)		Preobese-obese (n = 25)		NWO vs nonobese (p)	NWO vs preobese-obese (p)
	Mean	S D	Mean	S D	Mean	S D		
Leg	0.719	0.135	0.447	0.063	1.065	0.302	0.011	< 0.001
Abdominal	0.655	0.170	0.253	0.067	1.156	0.201	< 0.001	< 0.001
Trunk	0.793	0.141	1.462	0.234	0.510	0.083	< 0.001	< 0.001
Total	1.690	0.296	3.203	0.469	1.071	0.190	< 0.001	< 0.001

Leg Index = Legs Lean/Legs Fat; Abdominal Index = Abdominal Lean/Abdominal Fat; Trunk Index = Trunk Lean/Trunk Fat; Total Index = Total Lean/Total Fat.
The data are expressed as mean ± SD. The statistical analysis was assessed through the post hoc Tukey's test. Differences with P values ≤ 0.05 were considered to be significant.

FAT% (p = 0.001), lean legs values (p = 0.02) and lean left leg (p = 0.01). Significant differences were observed between NWO and preobese-obese women in values of body weight (p < 0.001), BMI (p < 0.001), fat (p < 0.001), fat% (p < 0.001), waist (p < 0.001), hip (p = 0.01), circumference (p < 0.001) and total mass of tissue (kg) (p < 0.001).

To better characterise NWO subjects, we measured the other body indexes, as the leg index (legs lean/legs fat), the abdominal index (abdominal fat/abdominal lean mass), the trunk index (trunk lean/fat mass) and the total index (total body lean/total body fat mass). As shown in Table II, NWO women showed significant increased values in the three indexes (p < 0.001) as compared to nonobese controls and preobese-obese individuals (p < 0.001).

Table III reported the RMR, VO_2, VCO_2 and RQ values of nonobese controls, NWO and preobese-obese groups. Significant differences in RMR and VCO_2 values were observed between NWO and nonobese control women (p = 0.043 and p = 0.05, respectively). As compared the NWO to obese-preobese groups, were found statistically higher values of RMR and VO_2 (p = 0.029 and p = 0.043, respectively). No differences were observed between controls and preobese-obese women.

Discussion

The purpose of this study was to identify new body composition indexes that characterize the NWO.

According to the definition of World Health Organization, obesity is a condition characterised by a large increase of body fat[1]. Pathogenic events related to changes in fat mass are basis of the obesity: fat amount and its distribution is a critical value. It has been reported that "ectopic" fat stored in visceral adipocytes, myocytes and hepatocytes, plays a pathogenic role in the insulin resistance and cardiovascular risks[19]. It is necessary to classify obesity condition on the ba-

Table III. Metabolic parameters of NWO, nonobese and preobese-obese women.

	NWO (n = 25)		Nonobese (n = 25)		Preobese-obese (n = 25)		NWO vs nonobese (p)	NWO vs preobese-obese (p)	Nonobese vs preobese-obese (p)
	Mean	S D	Mean	S D	Mean	S D			
RMR (kcal)	1201.25	349.02	1395.73	161.90	1399.39	318.03	0.043	0.029	NS
VO_2 (ml)	174.55	47.27	197.63	23.77	199.73	48.17	NS	0.043	NS
VCO_2 (ml)	149.28	42.16	181.38	26.60	167.73	42.99	0.050	NS	NS
RQ	0.87	0.15	0.92	0.11	0.84	0.14	NS	NS	NS

RMR = Resting Metabolic Rate; VO_2 = Oxygen consumption; VCO_2 = Carbon Dioxide production; RQ = VO_2/VCO_2. The comparison between means for two groups of cases was assessed through Independent-Samples T Test procedure.

sis of body fat composition and distribution, rather than simply on the increase of body weight. Therefore, the BMI, usually used in population studies to correlate overweight and obesity to morbidity and mortality, leads to a large error and misclassification.

Diagnosis, therapy and follow up of all subtypes of obesity must not be based on "body weight" parameter, but body composition parameters and energy expenditure are required. Direct body fat mass percentage measurement would be a better tool for diagnosing any kind of obesity. An effort should be made to provide such data. A correct diagnosis of fat content and distribution is important to estimate not only overweight and obesity but also risk factors for cardiovascular and metabolic diseases.

It has reported that visceral fat accumulation may play a role for the development of metabolic syndrome[20]; we can suggest that also a decreasing of lean in the legs is an important parameter of distinction.

De Lorenzo et al. have identified a new syndrome, typical of pre-menopausal women, called Normal Weight Obese syndrome (NWO). Despite NWO showed a reference body weight and Body Mass Index, they showed some obesity-related abnormalities, such Fat Mass percentage[15].

Our present data showed that the NWO body composition parameters was significant different with respect to nonobese and preobese-obese women.

To classify NWO individuals among general population, we identified three significant body composition indexes: abdominal index, leg index and trunk index. We found that NWO women showed significant increased value in all body index with respect to controls and preobese-obese individuals ($p < 0.001$). On the basis of body composition, it is possible to formulate that abdominal, leg and trunk indexes could be significant and predictive indexes. Indeed, these indexes well define the groups and NWO show intermediate values respect to normal and preobese-obese women.

In Italian males and females, the relationship between with body composition and anthropometric parameters and resting metabolic rate was well described by De Lorenzo et al.[21,22]. On the basis of their results, we investigated the effects of body composition on resting metabolic rate of NWO women, making a comparison with both normal and preobese-obese women. A significant difference ($p < 0.05$) is observed between NWO and controls, as well as NWO and preobese-obese women. We conclude that the measurement of energy expenditure normalised to metabolically active mass should provide a tool to define hyper- and hypo-metabolic state at early stage.

Our data suggest that, despite a normal Body Mass Index, NWO apparently healthy women displayed a cluster of risky body composition characteristics.

In conclusion, we believe that the abdominal, leg and trunk indexes derived from body composition analysis are promising clinical tools for diagnosing the new subset of Normal Weight Obese syndrome and for predicting, years in advance, diabetes and cardiovascular disease.

An appropriate diet-therapy and physical activity may be protecting NWO individuals from diabetes and cardiovascular diseases associated to preobese-obese women.

References

1) WHO 1998 Obesity. Preventing and managing the global epidemic. Report on a WHO Consultation of Obesity. Geneva, 3-5 June, WHO/NUT/NCD/98.1 1998; Geneva, Switzerland.
2) De Lorenzo A, Deurenberg P, Pietrantuono M, Di Daniele N, Cervelli V, Andreoli A. How fat is obese? Acta Diabetol 2003; 40: S254-S257.
3) WHO Physical Status. The use and interpretation of anthropometry. Technical Report Series 854. 1995; WHO, Geneva, Switzerland.
4) Karelis AD, St Pierre DH, Conus F, Lhoret RR, Poehlman ET. Metabolic and body composition factors in subgroups of obesity: what do we do? J Clin Endocrinol Metab 2004; 89: 2569-2575.
5) Ruderman NB, Schneider SH, Berchtold P. The metabolically-preobese-obese, normal weight individual. Am J Clin Nutr 1981; 34: 1617-1621.
6) Ruderman NB, Berchtold P, Schneider S. Obesity associated disorder in normal weight individual: some speculation. Int J Obesity 1982; 6: 151-157.
7) Ruderman N, Chisholm D, Pi-Suneir X, Schneider S. The metabolically preobese-obese normal weight revisited. Diabetes 1998; 47: 699-713.
8) Expert Panel on detection, Evaluation, and Treatment of High Blood Cholesterol in Adults 2001, Executive Summary of the third Report of the National Cholesterol Education Program (NCPE) Expert Panel on detection. Evaluation and Treatment

of High Blood Cholesterol in Adults (Adult Treatment Panel II). JAMA 2001; 285: 2486-2497.

9) Zavaroni I, Bonora E, Pagliara M, Dall'Aglio E, Luchetti L, Buonanno G, Bonati PA, Bergonzani M, Gnudi L, Passeri M. Risk factor for coronary artery disease in healthy person with hyperinsulinemia and normal glucose tolerance. N Eng J Med 1989; 320: 702-706.

10) Dvorak RV, De Nino F, Ades AP, Poehkman ET. Phenotipic characteristics associated with insulin resistance in metabolically preobese-obese but normal weight young women. Diabetes 1999; 48: 2210-2214.

11) You T, Ryan AS, Nicklas J. The metabolic syndrome in preobese-obese postmenopausal women: relationship to body composition, visceral fat, and inflammation. J Clin Endocrinol Metab 2004; 89: 5517-5522.

12) Wajchenberg BL, Malerbi DA, Rocha MS, Lerario AC, Santomauro AT. Syndrome X: a syndrome of insulin resistance: epidemiological and clinical evidence. Diabetes Metab Rev 1994; 10: 19-29.

13) Waichemberg BL. Subcutaneous and visceral adipose tissue: their relation to the metabolic syndrome. Endocr Rev 2000; 21: 697-738.

14) Katsuki A, Sumida Y, Urakawa H, Gabazza EC, Murashima S, Maruyama N, Morioka K, Nakatani K, Yano Y, Adachi Y. Increased visceral fat and serum levels of triglyceride are associated with insulin resistance in Japanese metabolically preobese-obese, normal weight subjets with normal glucose tolerance. Diabetes Care 2003; 26: 2341-2344.

15) De Lorenzo A, Martinoli R, Vaia F, Di Renzo L. Normal Weight Obese (NWO) women: an evaluation of candidate new syndrome. Nutr Metab Cardiovasc Dis 2006 (in press).

16) Executive Summary of the third Report of the National Cholesterol Education Program (NCPE) Expert Panel on detection, evaluation and treatment of high blood cholesterol in adults (Adult Treatment Panel III). JAMA 2001; 285: 2486-2497.

17) Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference manual: Human kinetics. 1998; Champaing, IL.

18) Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol 1949; 109: 1-9.

19) Yki-Jarvinen H. Ectopic fat accumulation: an important cause of insulin resistance in humans. J R Soc Med 2002; 95: 39-45.

20) von Eyben FE, Mouritsen E, Holm J. Intra-abdominal obesity and metabolic risk factors: a study of young adults. Int J Obes Relat Metab Disord 2003; 27: 941-949.

21) De Lorenzo A, Tagliabue A, Andreoli A, Testolin G, Comelli M, Deurenberg P. Measured and predicted resting metabolic rate in Italian males and females, aged 18-59 y. Eur J Clin Nutr 2001; 54: 208-214.

22) De Lorenzo A, Andreoli A, Bertoli S, Testolin G, Oriani G, Deurenberg P. Resting metabolic rate in Italians: relation with body composition and anthropometric parameters. Acta Diabetol 2000; 37: 77-81.