The Effects of Weight Reduction to Ideal Body Weight on Body Fat Distribution

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Obesity is a well-known health risk factor. Several studies have demonstrated that upper-body fat distribution plays a major role in the association between increased adiposity and metabolic disorders. The present study was undertaken to evaluate changes in intraabdominal and subcutaneous fat areas in obese subjects undergoing a weight reduction to their ideal body weight (IBW), as defined by a body mass index (BMI) no greater than 21 or body fat less than 30%, and compare the fat distribution at IBW with that of never-obese control subjects. We studied 33 obese women (151% ± 1% of IBW; BMI, 31.6 ± 2.5 [mean ± SE]) before and after weight loss and a control group of 16 never-obese women (101.0% ± 1.0% of IBW; BMI, 21.2 ± 1.1). Eighteen obese women successfully achieved and stabilized at IBW for at least 2 months. Nonsuccessful obese subjects were significantly younger than reduced-weight subjects, but other physical characteristics were similar. In obese, reduced-obese, and never-obese groups, weight was 85 ± 2.0, 62 ± 1, and 58 ± 1 kg; percent body fat was 41% ± 1%, 24% ± 2%, and 23% ± 1%; intraabdominal fat area was 82 ± 5, 28 ± 3, and 25 ± 4 cm^2; waist subcutaneous fat area was 275 ± 15, 120 ± 9, and 81 ± 7 cm^2; hip subcutaneous fat area was 416 ± 17, 204 ± 10, and 195 ± 7 cm^2; and waist to hip ratio (WHR) was 0.84 ± 0.02, 0.77 ± 0.01, and 0.73 ± 0.01, respectively. Our findings indicate that with weight reduction to IBW, intraabdominal and hip subcutaneous fat areas are the same as in individuals who are at IBW, BMI 21.1, and have never been obese. WHR and waist subcutaneous fat area remain significantly increased as compared with those in never-obese controls ($P < .05$).

SINCE THE EARLY STUDIES reported by Vague,[1] who drew attention to the association of waist-predominant obesity with diabetes and atherosclerosis, numerous epidemiologic and clinical studies have further defined these relationships. Positive relationships have been demonstrated between the ratio of waist girth to hip girth (waist to hip ratio [WHR]) and diabetes,[2-4] hypertension,[5,6] hyperlipidemia,[2,4,6,7] gallbladder disease,[2] low high-density lipoprotein cholesterol,[8,9] and elevated insulin[10-12] and free testosterone levels.[13] In addition, subjects with a high WHR have been shown to have more intraabdominal fat[14,15] and have been shown in several studies to be more insulin-resistant than those with a lower WHR.[13] Although the risks and metabolic abnormalities associated with upper-body obesity have been shown in several studies, there are few studies that have attempted to assess the changes in obesity patterns with weight reduction[13,16-20] and no studies that have looked at the changes in intraabdominal and subcutaneous adipose tissue with weight reduction to a body mass index (BMI) of 21 or less than 30% body fat. Gray et al[18] evaluated magnetic resonance imaging (MRI) scans on 10 nondiabetic females before and after 10 weeks of a very–low-calorie diet. They demonstrated significant decreases in both intraabdominal and subcutaneous fat with a mean weight loss of 10.6 kg. However, of interest, there was a 28% decrease in intraabdominal fat area and a 13% decrease in subcutaneous fat area. Similar results were reported by Bosello et al.[13] They evaluated computed tomographic scans on 19 obese females before and after 2 weeks on a very–low-calorie diet and a weight change of 6.7 kg. Although visceral adipose tissue declined 20.3%, there was only a 5.5% decrease in abdominal subcutaneous adipose tissue, a nonsignificant difference. Ross and Rissanen[21] recently reported a preferential loss of visceral abdominal fat with diet and exercise in subjects with a weight loss of 10 kg.

In the present studies, we performed MRI scans of the abdomen on 33 obese subjects, of whom 18 were evaluated after reduction and stabilization at ideal body weight (IBW), and on 16 never-obese women at IBW. The results indicate significant correlations between intraabdominal and subcutaneous fat areas and weight, with the greatest correlation between weight and hip subcutaneous area. With reduction to IBW, intraabdominal fat area and hip subcutaneous fat area normalized, whereas waist subcutaneous fat area remained elevated, as compared with areas in the never-obese control group. These studies agree with and extend previous findings, and indicate that even at IBW subcutaneous waist fat area in previously obese subjects is increased. The possible metabolic consequences of this are unknown.

SUBJECTS AND METHODS

Subjects

All subjects accepted into the study were healthy, nondiabetic, nonpregnant, nonsmoking, premenopausal women with normal menstrual cycles. Body composition characteristics and metabolic rates of the subjects have been previously reported.[22] All subjects had normal glucose tolerance[23] and no known family history of diabetes. The lean control women had a body fat level less than 30% by ^{40}K measurement or were less than 10% of IBW, calculated by assuming that the ideal BMI is 21. Obese subjects at entry were 135% to 161% of IBW. This degree of obesity was chosen because it represents a modest degree of obesity that is prevalent and because weight loss to IBW is achievable. The normal-weight women were paid to participate in the study. Included in this study are 18 obese women who were successful at achieving and

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Submitted July 29, 1994; accepted March 21, 1995.

Supported by National Institutes of Health Grants No. DK40816, RR00044, and RR000125.

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0026-0495/95/4411-0008$03.00/0

stabilizing at IBW and 15 obese women who were unsuccessful. All volunteers gave verbal and written consent to participate in the study after all procedures were explained orally and in writing.

Weight Loss Protocol

Obese subjects were entered into a weight loss program that consisted of a 420- to 800-kcal/d formula diet (Medibase, Monterrey, CA) until they achieved a weight of 120% above IBW as determined by BMI. Every sixth week, they consumed a minimum of 800 cal/d. At 120% of IBW, all subjects consumed an 800- to 1,200-kcal/d diet until their body fat was less than 30% as estimated by ^{40}K measurement or until their BMI was less than 25.2. All subjects were seen weekly at the Clinical Research Center for a medical evaluation and to attend a behavior-modification class. All diets were prescribed by the Clinical Research Center dietician to ensure nutritional adequacy. Exercise was encouraged, but there were no specific exercise plans or classes. Once the weight loss goal was achieved, subjects entered a weight-maintenance phase for a minimum of 2 months and consumed a diet containing approximately 55% carbohydrate, 30% fat, and 13% protein.

Body Composition

Weight was determined to the nearest 10 g on 2 separate days 2 weeks apart. Lean body mass (LBM) was estimated in duplicate by ^{40}K counting[24] before weight loss and after stabilizing at IBW. We assumed that the K content of a fat-free body was 64.2 mmol/kg.[24] WHR was calculated by measuring the minimum waist circumference at the umbilicus and the maximum hip circumference.

MRI

MRI was performed by a 1.5-T MRI system (Sigma, General Electric, Milwaukee, WI). Abdominal MRIs were performed with relative T1 weighting and with respiratory gating. Slice thickness is 1 cm, skip 0, with a single echo spin echo series using a TR of 600 milliseconds and a TE of 20 milliseconds. A field of view of 36 cm with a 256 × 128 matrix and one excitation permits acquisition of 12 axial images using an imaging time for this series of approximately 1.5 minutes. Intraabdominal and subcutaneous fat areas were measured using a planimeter linked to an IBM personal computer (White Plains, NY).

Data Analysis

Data analysis was performed using BMDP Statistical Software.[25] Unpaired *t* tests were used to compare mean values of normal-weight and overweight groups, and paired *t* tests were used to examine changes after weight loss. Linear regression was used to determine correlation coefficients and regression coefficients.

Fat areas were measured in cross-sectional MRI images. Hip subcutaneous area was from an image at the femoral heads. Waist subcutaneous area was from an image 8 cm above the iliac crest when normalized to a height of 5 ft 5 in. Intraabdominal fat area was measured in an image at the iliac crest. The iliac crest was chosen because of the relative abundance of abdominal fat at this level and the ease of visualization of this location between individuals.

RESULTS

Characteristics of the patient groups are shown in Table 1. Compared with the normal-weight group, the obese group weighed 47% more and had an 18% increase in mean LBM and an 86% increase in body fat. In addition, intraabdominal fat area, waist subcutaneous fat area, hip subcutaneous fat area, and WHR were increased 232%, 237%, 113%, and 15% in the obese group as compared with control normal-weight subjects. The reduced-obese group was significantly older and weighed more than the normal lean subjects, although LBM, percent fat, and percent IBW were not different. Intraabdominal fat area and hip subcutaneous fat area were not significantly different in reduced-obese and control subjects, whereas WHR and waist subcutaneous fat area were significantly greater in reduced-obese subjects. Reduced-obese subjects were different from obese subjects in all characteristics except height. Obese subjects who were successful in achieving and stabilizing at IBW were the same as those who were not successful in

Table 1. Body Composition of Control, Obese, and Reduced-Obese Subjects

Characteristic	Control (n = 16)	Obese Before Weight Loss (n = 33)	Reduced-Obese (n = 18)
Age (yr)	34.0 ± 1.5	36.0 ± 1.0	41.0 ± 1.0*
Weight (kg)	58.0 ± 1.0	85.0 ± 2.0‡	62.0 ± 1.0*†
Height (cm)	165.0 ± 1.5	164.0 ± 1.5	164.0 ± 1.5
% IBW	101.0 ± 1.0	151.0 ± 1.0‡	109.0 ± 1.0†
BMI	21.1 ± 0.27	31.6 ± 0.62	22.6 ± 0.22
LBM (kg)	44.8 ± 1.0	53.0 ± 1.0‡	46.9 ± 1.2†
Fat (%)	22.6 ± 1.0	42.0 ± 1.0‡	23.7 ± 1.7†
Fat area (cm^2)			
Intraabdominal	24.6 ± 3.8	81.6 ± 5.4‡	27.8 ± 3.0†
Waist subcutaneous	81.0 ± 6.6	275.4 ± 15‡	120.0 ± 9.0†§
Hip subcutaneous	195.0 ± 6.6	416.0 ± 17‡	204.0 ± 10.0†
WHR	0.73 ± 0.01	0.84 ± 0.02‡	0.77 ± 0.01*†

NOTE. Results are the mean ± SE.
*$P < .05$ *v* control groups.
†$P < .05$ *v* before weight loss.
‡$P < .001$ *v* control groups.
§$P < .01$.

Table 2. Baseline Characteristics of 18 Reduced-Obese Subjects and 15 Subjects Who Did Not Complete the Weight Loss Program

Characteristic	Completed Weight Loss Program (n = 18)	Did Not Complete Weight Loss Program (n = 15)
Age (yr)	39.5 ± 1.0	32.7 ± 1.6*
Weight (kg)	83.7 ± 2.0	86.5 ± 3
Height (cm)	164.0 ± 1.5	163.1 ± 1.7
% IBW	148.0 ± 1.8	154.7 ± 3.9
BMI	30.8 ± 0.41	32.4 ± 0.83
LBM (kg)	52.0 ± 1.4	52.9 ± 1.4
Fat (%)	41.0 ± 1.4	43.0 ± 1.0
Fat area (cm^2)		
Intraabdominal	83.0 ± 5.3	81.0 ± 5.0
Waist subcutaneous	249.8 ± 17	301.0 ± 15
Hip subcutaneous	400.0 ± 21.5	431.6 ± 16
WHR	0.84 ± 0.01	0.84 ± 0.02

NOTE. Results are the mean ± SE.
*$P < .01$ by unpaired *t* test.

Table 3. Correlations Between Fat Areas and Weight, LBM, and WHR

Fat Area	Weight	LBM	WHR
Intraabdominal	.69	.37	.49
Waist subcutaneous	.83	.51	.57
Hip subcutaneous	.86	.33	.42

achieving IBW in all characteristics except age (Table 2). The successful group was significantly older.

Table 3 illustrates the relationship between fat areas by MRI and weight, LBM, and WHR. All three are significantly correlated with weight, although the correlations with hip subcutaneous fat area (r = .86) and waist subcutaneous fat area (r = .83) are greater than with intraabdominal fat area (r = .69). Correlation coefficients were lower for LBM and waist subcutaneous fat area (r = .51), hip subcutaneous fat area (r = .33), and intraabdominal fat (r = .37). Correlation coefficients for WHR and fat areas were also less than for weight and fat areas. The coefficients were approximately the same with hip subcutaneous area (r = .42) and intraabdominal fat (r = .49) and slightly greater with waist subcutaneous fat area (r = .57).

DISCUSSION

Obesity is a well-known health risk factor. In the last 10 to 15 years, various studies have demonstrated that body fat distribution plays a major role in the association between increased adiposity and metabolic disorders.[1-14] Mainly, the excess of intraabdominal visceral fat has been implicated in the development of insulin resistance, hyperinsulinemia, carbohydrate intolerance, hypertriglyceridemia, and hypertension.[2-7,10-12] It has been proposed that since intraabdominal visceral fat drains directly into the portal circulation, an increase in this fat depot may lead to high concentrations of free fatty acids reaching the liver, causing glucose intolerance via the glucose–fatty acid cycle and hypertriglyceridemia due to an excess of substrate.[26-28] Therefore, if upper-body fat distribution is predictive of metabolic derangements, it will be important to measure different fat depots and their response to weight reduction. A few studies have reported such data, but none have reported these measurements before and after obese subjects have reached IBW. The present study was undertaken to evaluate changes in intraabdominal and subcutaneous fat areas in obese subjects under such conditions. We studied 33 obese but otherwise healthy women before weight reduction, 18 of them after achieving and stabilizing at IBW for 2 months. Adipose tissue areas and distribution were assessed by MRI, which has the advantage that subjects are not exposed to ionizing radiation as in computed tomography.

Our results indicate that weight reduction to IBW effectively reduced all fat areas. Intraabdominal fat decreased 66%, subcutaneous fat at the waist 56%, and subcutaneous hip fat 51%. Thus, the intraabdominal depot is more labile than the subcutaneous depot. This is in agreement with data reported by Gray et al[18] and Bosello et al.[13] Our data are unique in that they demonstrate that obese subjects reduced to and stabilized at IBW have normal intraabdominal fat and hip subcutaneous fat areas, whereas waist subcutaneous fat remains increased. Also, our data are the first to demonstrate that there is no difference in subcutaneous or intraabdominal fat in patients who are successful and unsuccessful at achieving IBW. This suggests that the type of obesity as reflected in body fat distribution does not affect a person's ability to lose weight.

Intraabdominal and subcutaneous fat areas correlated significantly with weight, but correlation coefficients for LBM and fat areas were lower. Correlations between WHR and fat areas were less than with weight and fat areas. Also, the correlation between WHR and subcutaneous fat was slightly greater than the correlation between WHR and intraabdominal fat.

Several investigators have attempted to evaluate the relationships between abdominal subcutaneous and intraabdominal fat areas and various parameters of morbidity in obese subjects,[3-6,11,12,14] as well as whether WHR correlates better with intraabdominal or subcutaneous fat.[5,16,18,29] The data are not always in agreement as to whether subcutaneous or intraabdominal fat or WHR correlates best with metabolic parameters, such as plasma insulin and glucose in fasting and postprandial states, plasma lipids, blood pressures, and others. Although it is generally agreed that increased intraabdominal adipose tissue is associated with many of the health risks of obesity,[30] our data suggest that to the extent this is true, the return of intraabdominal fat area to normal after achieving and stabilizing at IBW should reduce the risk of adverse metabolic events associated with obesity. However, the failure of subcutaneous fat area and WHR to normalize perhaps suggests that not all the risks of obesity will disappear with achievement of IBW.

In summary, our data show that with reduction to IBW, intraabdominal and hip subcutaneous fat areas are the same as in individuals who are at IBW and have never been obese. However, WHR and waist subcutaneous fat area remain significantly increased as compared with those in never-obese controls. Whether this translates into increased risk for obesity-related complications in reduced-obese women and how this relates to the importance of subcutaneous adipose tissue as opposed to intraabdominal adipose tissue in relation to the complications of obesity must be the subject of future investigations.

ACKNOWLEDGMENT

We wish to acknowledge the secretarial assistance of Nancy Canetti and Sharon Harris.

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