Body composition of anorexia nervosa patients assessed by underwater weighing and skinfold-thickness measurements before and after weight gain[1,2]

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ABSTRACT

Background: Weight restoration is a crucial element in the treatment of patients with anorexia nervosa. Therefore, the validity of different methods for measuring body composition is important.

Objective: We tested the concurrent validity of hydrodensitometry (underwater weighing) and anthropometry (12 skinfold thicknesses) and assessed body composition and subcutaneous fat before and after a refeeding program and a multifaceted program of therapy in a specialized inpatient unit for eating disorders.

Design: The body composition of a large sample of anorexia nervosa patients (97 restricting type, 33 binging-purging type) was studied by using 2 methods both before and after weight gain. We applied a behavioral contract for weight restoration with a minimum weekly gain of 700 g and a maximum of 3 kg. Bland-Altman analysis of agreement, Pearson correlation analysis, *t* tests, and analysis of covariance were used.

Results: There was good agreement between the results obtained by underwater weighing and by skinfold-thickness measurement ($r = 0.76$, $P < 0.001$); the results produced by the 2 methods did not differ significantly. On average, a significant weight gain (11.9 kg) was observed, composed of 6.6 kg fat and 5.3 kg fat-free mass.

Conclusions: Body fat estimation by skinfold-thickness equation appeared to be as accurate as underwater weighing. The refeeding program led to a significant increase in body weight, of which 55.5% was body fat. The mean ratio of fat-free mass to fat mass at the end of the treatment was 3.4:1. *Am J Clin Nutr* 2001;73:190–7.

KEY WORDS Anorexia nervosa, body composition, body fat measurement, hydrodensitometry, skinfold-thickness measurement, underwater weighing, weight gain

INTRODUCTION

Weight restoration is one of the most important goals in the treatment of patients with anorexia nervosa (AN). Through food restriction, excessive physical activity, or purging (self-induced vomiting, laxative abuse, or both), AN patients reach their desired goal of extreme slimness, resulting in a body weight ≥15% below the expected weight-for-height (1, 2). The patients' perception of body weight and shape is distorted (3). From both a physiologic and psychological viewpoint, weight and body composition are crucial elements in treatment because the patients are dissatisfied with their body appearance and have unrealistic ideas about the influence of food intake and dieting on body weight and shape. The study of body fat distribution can have important implications for the treatment of AN because of the patients' intense fear of weight gain and becoming fat, which is enhanced by the belief that this would be accompanied by fat distribution in the abdominal region. Hence, the amount of body fat at discharge may influence the further evolution of the disease (4). An earlier study showed that age and duration of illness had no influence on body composition in AN patients before weight restoration (5). However, studies of body composition in AN patients are sparse and mostly based on small samples of 6–32 patients (6–12). Moreover, the effect of weight restoration (pretreatment compared with posttreatment) has been neglected. Orphanidou et al (13) studied short-term weight gain ($n = 26$) and Zamboni et al (14) assessed the effects of weight gain on abdominal fat distribution in AN patients ($n = 14$).

A wide variety of methods are available to measure body composition (for a review *see* reference 15). In this study, the more traditional methods of body-composition measurement, such as the densitometric technique of underwater weighing (UWW) and the anthropometric method of measuring skinfold thicknesses (SFTs), were applied. The aims of this study were *1*) to compare these 2 methods (and test their concurrent validity) for evaluating body composition before and after weight gain, and *2*) to examine the effects of weight changes on body composition and subcutaneous fat after an inpatient treatment that included a refeeding protocol. We hypothesized that the SFT equations would accurately estimate body fat in AN patients and that refeeding would lead to a significant increase in body weight and subcutaneous fat and that body fat would increase most significantly.

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SUBJECTS AND METHODS

Subjects

One hundred thirty female patients consecutively admitted to the inpatient Eating Disorder Unit of the University Center Kortenberg, Belgium, and who finished the whole treatment program were included in the study. Data were collected between 1994 and 1999 by following a standard procedure. All patients met the *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition, diagnostic criteria for AN (1). Patients were classified into 2 subtypes: the "restricting" type, who lost weight only through fasting and eventually rigorous physical exercise (n = 97), and the "mixed" or "binging-purging" type, who intermittently showed episodes of binge eating, self-induced vomiting, or laxative use (n = 33). Patients with concurrent organic illnesses were excluded. At the time of admission, all patients were amenorrheic. Study procedures were integrated into the treatment program and were approved by the Ethical Committee of the University Center Kortenberg.

Procedures

UWW is considered to be the method of reference for body-composition assessment and is considered to have excellent reliability and validity. The measurement of SFTs is a classic technique that measures only subcutaneous adipose tissue, with generally weaker reliability (but usually $r > 0.90$) and lower validity than UWW. The correlation between UWW and SFT measures ranges from 0.65 to 0.93 (15).

A standard protocol for all anthropometric and densitometric assessments was executed within 3 d of admission and once again in the last week before discharge from the hospital by the same highly experienced female investigator (MG). Height was measured to the nearest 0.5 cm by using a stadiometer. Body weight was measured to the nearest 100 g, with the subject wearing only a swimsuit, on a beam balance. The body mass index (BMI; kg/m^2) was calculated.

Twelve SFTs were measured (5, 15–17): biceps, triceps, subscapular, suprailiac, chin, side, waist, abdomen, thigh anterior and posterior, and calf lateral and medial on the left side of the body by using a Harpenden skinfold caliper with electronic readout (18; HERO; Human Biology Laboratory of the Department of Human Sciences, University Loughborough, United Kingdom, and British Indicators, Ltd, St Albans, United Kingdom). The test-retest precision of our SFT measurements fluctuated from $r = 0.93$ (for thigh posterior) to $r = 0.97$ (for suprailiac). The percentage body fat was estimated from the logarithm of the sum of the SFT measurements taken at 4 sites (biceps, triceps, subscapular, and suprailiac) and by using the age-specific prediction equations (density = 1.1599 − 0.0717 × log 4 SFTs) of Durnin and Womersley (19). For girls <16 y of age (n = 18), we used the same formula (density = 1.1549 − 0.0678 × log 4 SFTs) as for girls <20 y of age.

UWW calculates body volume as the difference between body weight measured in air and that measured in water (based on Archimedes' principle that body volume is equal to the loss of weight in water). Modern hydrodensitometry systems consist of a scale within a large heated (37 °C) tank of water. The subject exhales maximally, while totally immersed, and body weight is then recorded. Body weight (accurate to the nearest 10 g) in water is measured ≥6 times. The highest value of the measurements is used. Body density (D) is calculated with the following formula:

$$D = W/[(W - W_w/d_w) - (\mathrm{RV} + \mathrm{GI})] \qquad (1)$$

where W is body weight in air, W_w is body weight in water (after maximal expiration), d_w is the density of the water, RV is the correction for the residual lung volume (measured 2 times at the time of taking W_w by helium dilution), and GI is the correction for the volume of gas in the gastrointestinal tract (150 mL seems the most appropriate correction) (20–22). The test-retest precision of the measurement in our laboratory is $r = 0.96$. The percentage body fat is then calculated by using the Siri (23) equation:

$$\text{Percentage body fat} = (4.95/D - 4.50) \times 100 \qquad (2)$$

Treatment program

All patients were treated at the same specialized inpatient unit by using a multifaceted program of therapy that included the following basic elements.

Food and weight regulation

Restoration of body weight should take place gradually, neither too slowly nor too quickly (24). The weight gain program included the following rules: a minimum weekly weight gain of 700 g was required with a maximum limit of 3 kg; weight increase was not to be >700 g/d (except for the first week of hospitalization). Patients received the regular hospital menu and were not allowed to eat anything else. They were given a 10 460–12 552-kJ (2500–3000 kcal) diet each day that included extra protein drinks.

Psychotherapy

The inpatient treatment program was eclectic and multidimensional, containing cognitive, behavioral, and interactional components (24, 25). Most therapeutic activities took place in 2 groups of 8–9 patients each (all group members were patients with eating disorders). The setting of this group approach can be characterized as highly structured and confrontational, including the following main components: *1*) group psychotherapy, both verbal and nonverbal (art therapy); *2*) body-oriented therapy with videoconfrontation, relaxation training, and various kinds of body expression and dance-movement therapy (26, 27); *3*) sexual education (28); and *4*) parental counseling and regular family or couples meetings (29, 30).

The program was limited to a maximum stay of 6 mo. The use of psychotropic drugs was exceptional. At the end of treatment, patients were invited to join the aftercare program of group meetings every 2 wk for ≤6 mo.

Data analysis

The relations between the body-composition variables were assessed by Pearson product-moment correlation. Differences in body composition within groups were evaluated by using a two-tailed student's t test. The method proposed by Bland and Altman (31) for assessing agreement between 2 methods was used to further assess the accuracy of the SFT prediction before and after weight gain. Differences between individual UWW percentage fat values and individual SFT percentage fat values were plotted against the mean of the 2 measures (UWW + SFT/2). The scatter plot was evaluated by assessing the variability included in 2 SDs above and below the mean. Differences in fat measurements were assessed by using the SFT and UWW procedures. Product-moment correlations, SEEs (where SDx is the SD of the UWW procedure), the percentage of subjects whose SFT percentage fat values were within 3.5% of UWW values, and pure errors ($E = \sqrt{\frac{\Sigma\,(\mathrm{UWW\ \%fat} - \mathrm{SFT\ \%fat})^2}{n}}$) were determined.

TABLE 1
Physical characteristics and body composition of 130 female anorexia nervosa patients before and after weight gain[1]

Characteristics and body composition	Before weight gain	After weight gain
Age (y)	20.1 ± 4.3 (15.0–32.1)	—
Duration of anorexia nervosa (y)	3.7 ± 3.3 (0.4–16)	—
Height (cm)	165.2 ± 6.2 (150–182)	
Weight (kg)	40.7 ± 5.1 (31.2–52.2)	52.6 ± 4.2 (40.0–64.9)
BMI (kg/m²)	14.9 ± 1.5 (11.9–17.5)	19.2 ± 0.9 (16.8–24.8)
Densitometry		
Density (kg/L)	1.06952 ± 0.008 (1.050–1.086)	1.04750 ± 0.007 (1.031–1.064)
Fat-free mass (kg)	35.4 ± 3.8 (27.8–45.3)	40.7 ± 3.3 (31.8–53.7)
Fat mass (kg)	5.3 ± 2.1 (0.5–10.2)	11.9 ± 2.0 (6.9–17.5)
Body fat (%)	12.8 ± 3.6 (5.7–21.1)	22.6 ± 3.0 (15.2–30.0)
Anthropometry		
Density (kg/L)	1.06963 ± 0.009 (1.051–1.097)	1.04761 ± 0.007 (1.029–1.069)
Fat-free mass (kg)	35.4 ± 3.7 (28.3–44.6)	40.7 ± 3.5 (31.7–50.2)
Fat mass (kg)	5.3 ± 2.1 (0.5–10.2)	11.8 ± 1.9 (7.3–16.2)
Body fat (%)	12.8 ± 4.0 (1.3–21.1)	22.5 ± 3.0 (13.0–31.2)

[1] $\bar{x}$ ± SD; range in parentheses.

One-way analysis of variance (ANOVA) was used to compare methods and groups. The difference between initial and final body weight and BMI was analyzed by using a one-factor, repeated-measures ANOVA. Differences in body composition between before and after weight gain were assessed by using a repeated-measures analysis of covariance (ANCOVA) design, with initial body weight as the covariant. The same design was used for the changes in subcutaneous fat. The within-subject independent variable was the body site with 12 body locations. On the basis of differences in percentage body fat at admission before weight gain, patients were divided in 3 subgroups (<10% body fat, n = 33; 10–15% body fat, n = 68; or >15% body fat, n = 39; groups 1–3, respectively). ANOVA with repeated measures was used to analyze the difference in the groups between initial percentage body fat and BMI and percentage body fat after weight gain. The same design was used to assess the effect of days of treatment (<150 d, n = 26; 150–175 d, n = 66; or >175 d, n = 38) and duration of illness (<3 y, n = 80; 3–6 y, n = 21; 6–9 y, or >9 y, n = 13). Post hoc contrasts were conducted by the Scheffe method for complex contrasts. P values < 0.05 were regarded as significant. All data were coded and analyzed by using STATISTICA (version 5; 32).

RESULTS

Descriptive statistics

The patients' physical characteristics and body-composition variables, before and after weight gain, are listed in **Table 1**. The mean (±SD) BMI at admission was 14.9 ± 1.5, indicating severe underweight. The initial percentage body fat was 12.8 ± 3.6%, which is far below normal values for females (23–25%; 33, 34). The period of refeeding was 164 ± 19.8 d (range: 113–215 d).

Body composition measured by anthropometry and densitometry before and after weight gain

The correlations between SFT and UWW percentage body fat values were 0.76 before weight gain and 0.71 after weight gain (**Table 2**). The difference between the mean percentage body fat by SFT measurement and by UWW before refeeding was −0.040%, with a 95% CI of −0.43%, 0.51% (t test statistic 0.17, with 129 df and an associated P = 0.9). After refeeding, the difference between the SFT and UWW measurements was −0.050%, with a 95% CI of −0.35%, 0.46% (t test statistic 0.25, with 129 df and an associated P = 0.8). The results of a t test showed that neither before nor after refeeding were the SFT percentage fat values significantly different from those by UWW.

E values are statistical manipulations that assess the total error derived when one procedure is validated against another. They include variation due to the lack of association between the 2 methods and variation due to the degree of mean difference between predicted and measured body fat (35–37). Therefore, E values will generally be similar in magnitude to SEEs for effective prediction equations. The E values before weight gain were larger than those after weight gain and were within acceptable limits (3.8% fat;

TABLE 2
Comparison of mean percentage body fat (%fat) estimated by underwater weighing (UWW) and by skinfold-thickness (SFT) equation in anorexia nervosa patients before and after weight gain[1]

Method	Percentage body fat	Difference	SD	D	E	SEE	r
	%	%					
Before weight gain							
UWW	12.85		3.57				
SFT	12.81	−0.040 ± 2.70	4.04	81.5	2.69	2.3	0.76 (P < 0.0001)
After weight gain							
UWW	22.57		3.04				
SFT	22.52	−0.050 ± 2.34	3.03	85.4	2.33	2.1	0.71 (P < 0.0001)

[1] n = 130; D, the percentage of subjects with SFT %fat within 3.5% of UWW %fat values; E, pure error $\left(E = \sqrt{\frac{\Sigma\,(\text{UWW \%fat} - \text{SFT \%fat})^2}{n}}\right)$.

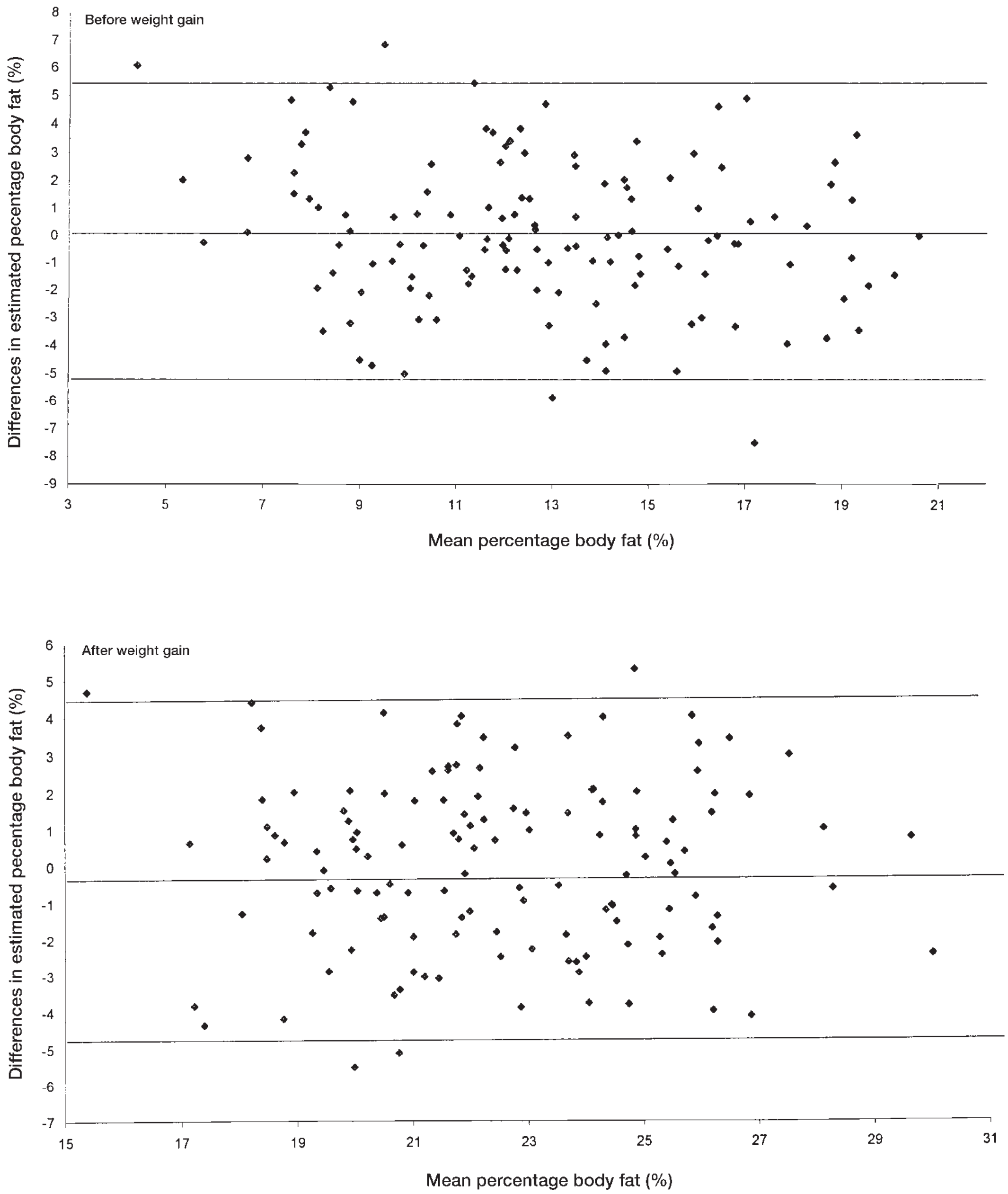

FIGURE 1. Agreement assessment (Bland-Altman method) between percentage body fat estimated by underwater weighing and skinfold-thickness prediction in patients with anorexia nervosa before and after weight gain (n = 130). Means are plotted against the difference between the 2 procedures. The center line represents the mean difference between the 2 methods and the other 2 lines represent 2 SDs from the mean (95% CI).

34, 38). The relation between percentage body fat before and after treatment, measured by rank correlation, was $r = 0.44$ ($P < 0.0001$). These results indicate that the ranking order before therapy was at least partially maintained after therapy (**Figure 1**).

Changes in body composition before and after refeeding

The refeeding protocol induced significant weight gain in all subjects as predicted. The mean weight gain was 11.9 kg ($P <$ 0.0001) after 23 wk, which included significant increases in body fat (6.6 kg), percentage fat (9.8%), and fat-free mass (5.3 kg). We found a greater increase in fat mass (5.3 kg compared with 11.9 kg) than in fat-free mass (35.4 kg compared with 40.7 kg). Of the weight regained, 55.5% was fat. The ratio of fat-free mass to fat mass was 6.7:1 at admission and 3.4:1 at discharge, when ≈22.5% of body weight was fat. After the refeeding program, the mean body weight was only 6% below the ideal body weight (compared with 27% below ideal body weight at admission), according to the tables of the Metropolitan Life Insurance Company (39). After refeeding, only 10 patients had a BMI < 18. One patient reached a BMI >21.

A one-way ANOVA with repeated measures among the 3 subgroups based on the percentage body fat before weight gain for

TABLE 3
Percentage body fat (%fat) and BMI before and after weight gain in 3 groups on the basis of %fat before weight gain[1]

	Group 1 (n = 31)		Group 2 (n = 63)		Group 3 (n = 36)	
	Before	After	Before	After	Before	After
%Fat[2]	8.2 ± 1.1	21.3 ± 2.9[3]	12.6 ± 1.3	22.3 ± 3.0[3]	17.3 ± 1.8	24.1 ± 2.5[3,4]
BMI (kg/m^2)[2]	13.7 ± 1.1	19.0 ± 0.8[3]	14.8 ± 1.3	19.2 ± 1.1[3]	16.0 ± 1.4	19.4 ± 0.6[3]

[1] $\bar{x}$ ± SD. Group 1, <10% fat; group 2, 10–15% fat; group 3, >15%.
[2] Significantly different in all 3 subgroups before weight gain, $P < 0.01$ (Scheffe test, ANOVA with repeated measures).
[3] Significantly different from before weight gain, $P < 0.01$ (Scheffe test, ANOVA with repeated measures).
[4] Significantly different from after weight gain in groups 1 and 2, $P < 0.01$ (Scheffe test, ANOVA with repeated measures).

BMI and percentage body fat separately (**Table 3**) showed a significant effect for BMI ($P < 0.0001$) and percentage body fat ($P < 0.0001$). A post hoc Scheffe test showed significant differences before and after weight gain for all the variables in all groups. The 3 subgroups differed significantly from each other for the variables percentage body fat and BMI before weight gain. After weight gain, there was only a significant difference between the subgroup with >15% body fat and the other 2 subgroups for the variable percentage body fat.

Before weight gain, the AN patients of the restricting type (n = 97) had lower values and differed significantly from the binging-purging type (n = 33) for the variables weight, percentage body fat, fat mass, and fat-free mass measured by UWW (**Table 4**). After treatment, no significant differences were found between the subtypes of AN patients. The results for the estimation by SFT measurement were comparable. ANOVA did not show an effect of duration of illness or duration of treatment on body-composition variables measured by UWW after weight gain. There was no significant relation between duration of illness and the increase in weight, fat mass, or fat-free mass. The increase in percentage body fat was not related to length of treatment (r = 0.13, NS).

Changes in subcutaneous fat

A repeated-measures ANCOVA (Wilks λ = 0.15, $P < 0.001$) indicated that all the SFTs were significantly greater after weight gain. The lowest relative increases in subcutaneous fat thickness (<100%) were at the biceps, subscapular, chin, calf lateral, and calf medial sites. The greatest relative increases (>130%) were measured at the side, waist, thigh anterior, and thigh superior sites (**Table 5**).

Changes measured by SFT were highly correlated with weight gain. The highest correlation was found for the chin (r = 0.66, $P < 0.001$) and the sum of the 12 SFTs (r = 0.69, $P < 0.001$). The lowest correlation was found for the calf medial site (r = 0.35, $P < 0.001$). SFT showed a small correlation with fat-free mass (r = 0.20, $P < 0.05$ and r = −0.29, $P < 0.01$, respectively, before and after weight gain) but was moderately to highly correlated with percentage body fat (before weight gain: r = 0.51, $P < 0.001$ for abdomen to r = 0.74, $P < 0.001$ for triceps; after weight gain: r = 0.31, $P < 0.001$ for calf medial to r = 0.54, $P < 0.001$ for the side). These correlations did not differ markedly among the common sites.

TABLE 4
Body composition in anorexia nervosa (AN) patients of restricting type and binging-purging type before and after weight gain[1]

	Before weight gain	After weight gain
AN restricting type (n = 97)		
Weight (kg)	39.5 ± 4.6[2]	52.2 ± 4.0
Density (kg/L)	1.071 ± 0.009	1.047 ± 0.007
Fat-free mass (kg)	34.5 ± 3.5[2]	40.3 ± 3.2
Fat mass (kg)	5.02 ± 1.8[3]	11.9 ± 2.0
Percentage body fat (%)	12.5 ± 3.5[4]	22.8 ± 3.0
AN binging-purging type (n = 33)		
Weight (kg)	44.0 ± 5.1	53.4 ± 4.0
Density (kg/L)	1.067 ± 0.008	1.049 ± 0.007
Fat-free mass (kg)	37.9 ± 3.7	41.6 ± 3.5
Fat mass (kg)	6.2 ± 2.0	11.8 ± 2.1
Percentage body fat (%)	13.8 ± 3.4	22.2 ± 3.0

[1] $\bar{x}$ ± SD.
[2–4] Significantly different from AN binging-purging type by underwater weighing: [2] $P < 0.001$, [3] $P < 0.05$, [4] $P < 0.01$.

DISCUSSION

The estimation of body composition over time is difficult (34). Therefore, body-composition studies, including assessments of the changes after weight gain in large groups of AN patients, are rare. Nevertheless, this information is important from a medical and psychological viewpoint.

This study simultaneously compared 2 methods for assessing body-composition changes in a large group of AN patients. Bland and Altman (31) stated that the statistical procedure for assessing agreement between 2 methods is more sensitive to differences than to correlations. Two methods may be highly related yet have poor agreement. The agreement assessments in this study clearly show that the SFT method for estimating body fat agreed with the UWW method. For effective estimates of percentage body fat from SFT equations, the SEE should be similar to that obtained when estimating percentage body fat with a recognized standard such as UWW. The SEE values for percentage body fat were within the recommend limits (2.5–3.8%). Some reports (34, 35, 40, 41) suggest that effective SFT equations will generally estimate body fat to within 3.5% of fat values estimated by UWW. In the present study, SFT percentage body fat values within 3.5% of UWW values were measured in 81.5% and 85.4% of the patients, respectively, at the start and the end of treatment. The range of percentage body fat values within the 95% CIs (±2 SDs from the mean of the difference) at the end of treatment (−0.35%, 0.46%) was smaller than the range of 95% CIs for the differences in fat values (−0.43%, 0.51%) before treatment.

TABLE 5
Skinfold thickness in anorexia nervosa patients before and after weight gain

Skinfold	Before weight gain	After weight gain[1]	Absolute change	Relative change
		mm		
Biceps	3.68 ± 1.47[2]	6.79 ± 2.10	3.1 ± 2.2	83.5
Triceps	5.64 ± 2.32	12.25 ± 3.51	6.6 ± 2.8	114.8
Subscapula	5.47 ± 1.56	10.52 ± 277	5.1 ± 2.6	92.9
Suprailiac	4.11 ± 1.39	8.93 ± 2.88	4.8 ± 2.9	116.9
Side	4.54 ± 1.55	10.69 ± 3.39	6.2 ± 3.4	133.2
Waist	6.66 ± 3.39	15.96 ± 5.23	9.3 ± 5.4	141.5
Abdomen	5.59 ± 2.13	11.33 ± 4.24	5.7 ± 4.0	102.9
Chin	4.75 ± 1.93	9.28 ± 2.27	4.3 ± 2.2	87.4
Thigh anterior	9.01 ± 4.69	21.93 ± 7.45	12.9 ± 7.0	140.5
Thigh posterior	9.83 ± 4.93	25.16 ± 6.58	15.3 ± 6.4	151.1
Calf lateral	6.30 ± 3.19	10.85 ± 3.72	4.5 ± 2.6	69.7
Calf medial	5.88 ± 3.05	10.43 ± 3.80	4.5 ± 2.7	75.6
Upper body[3]	26.37 ± 8.9	57.44 ± 15.4	31.1 ± 15.3	117.8
Total body	71.48 ± 26.02	154.2 ± 31.5	82.7 ± 31.8	113.7

[1] Significantly different from skinfold thicknesses before weight gain, $P < 0.001$.
[2] $\bar{x} \pm$ SD; $n = 130$.
[3] Upper body: subscapula, suprailiac, side, waist, and abdomen.

Because there was sufficient agreement between and among the results obtained by UWW and SFT measurement, our findings suggest that for an undernourished population, such as AN patients with relatively little body fat, simple SFT measurements are as useful as more sophisticated measures for the estimation of body composition. This is an important finding because SFT measurements can be used more easily in screening than can many other methods. Moreover, SFT measurement costs less and provides the opportunity to look at fat distribution. This agrees with the findings in the literature for normal subjects (42) and for AN patients (5). To this point, there has been no SFT equation developed specifically for female AN patients. Therefore, we used already published, generalized equations for white female subjects. Heyward and Stolarczyk (33) stated that the use of the Siri (23) equation to estimate percentage body fat from density can be questionable in an anorectic population. The Siri equation assumes that the density of fat-free mass equals 1.10 kg/L, that fat has a density of 0.90 kg/L, and that fat-free mass consists of 72% water ($D = 0.9937$ kg/L), 21% protein ($D = 1.34$ kg/L), and 7% mineral ($D = 3.00$ kg/L). Heyward and Stolarczyk (32) estimated that in AN patients, the components of fat-free mass were 76% water ($D = 0.9937$ kg/L), 17.7% protein ($D = 1.34$ kg/L), and 6.3% mineral ($D = 2.73$ kg/L). They proposed the following formula for calculating percentage body fat from density: percentage body fat $= (5.26/D - 4.83) \times 100$. Compared with the values derived with this formula, the average percentage body fat of anorectic women will be systematically overestimated by 3–4% when the Siri equation is used to estimate percentage body fat from density. However, 2 problems arose when the Heyward and Stolarczyk formula was used: *1*) for some test subjects ($n = 4$; AN restricting type; mean age: 25 y) a negative percentage body fat was obtained when density was calculated on the basis of SFT, and *2*) when we applied this formula at admission, we wondered whether it would still be valid at discharge, when the test subjects would more closely resemble the general population.

The main conclusion of our study is that an inpatient refeeding program led to a significant increase in body weight and that body fat increased most significantly. The refeeding program was well accepted by the patients and no medical problems or adverse effects were observed. The mean weight after refeeding was 4 kg below the average ideal body weight according to the tables of the Metropolitan Life Insurance Company (39). More than half (55%) of the weight increase was attributed to an increase in fat mass. These findings agree with those of previous studies (10, 11, 13, 43) but not with others (6, 7). The low-to-very low percentage body fat findings before refeeding were similar to those reported in other studies that used the same methods. According to the criterion of Lohman (34), ie, percentage body fat <8%, 9.2% of our patients were at serious health risk. The percentage body fat increased on average by 9.8% to 22.6% after 6 mo. Although there is no general consensus in the literature about the normal percentage body fat for the general female population, the results of the refeeding program are in the range of normality (BMI > 18; percentage body fat > 22.5%). The ratio of fat-free mass to fat mass (3.4:1) after the refeeding program is in accordance with that of a normal-weight female population in the United Kingdom. Furthermore, we showed that patients with a low percentage body fat at admission usually had a low percentage body fat at discharge as well, and vice versa.

An analysis of the changes in percentage body fat and BMI between the groups with differing percentages of body fat before weight gain showed that the differences at admission disappeared at discharge. The same is true for the differences in the AN subtypes. Our findings are in accordance with those of Orphanidou et al (13). Additional analysis showed no effect of length of treatment or duration of illness on body composition after treatment. More rapid weight gain does not change the amount of fat gained. The greatest increase is not in the abdominal region, as many patients believe, but instead on the thighs, the waist, and the sides. Orphanidou et al (13) found a larger increase in fat in the abdominal region and less in the arms and calves. Ross et al (44) mentioned that relative increases in SFTs during weight gain may not be the same at different sites. In our study, changes in SFTs correlated highly with weight gain. The weight gain in our patients was substantial but it occurred gradually.

The amount of body fat may also affect the clinical outcome. Menses return with refeeding when patients reach higher percentages of body fat (18%); however, the changes in body fat and the return of menses may also enhance the psychological stress in patients, increasing the likelihood of relapse. The changes in body fat are also in contradiction with what patients want themselves, at least as long as they are anorectic. The mean percentage body fat after refeeding was still lower than in normal-weight females (23–25%), although most patients believe they are too fat and are afraid of becoming overweight. Therefore, it is important to include some sort of body-oriented therapy in the latter part of the treatment in addition to the refeeding program (27). The aim of this therapy is to educate the patients about their bad physical condition and to help them to accept the physical and psychological changes that result from increasing weight. It is possible that a fitness training program (20 sessions, 2 times/wk) during refeeding, supervised by a therapist who is familiar with the physical consequences of undernutrition, could increase their fat-free mass and redirect the patients' hyperactivity in a healthy way, allay their fears of weight gain, and improve their sense of self control (27, 45). The possible influence of an adapted fitness training program on body composition and body experience of AN patients has not been assessed in detail and will be an interesting topic for future research.

The therapeutic implications of this study are that patients have to be informed about the physiologic meaning of body fat. The therapist has to emphasize the importance of body fat for the return of menses and the normalization of reproductive functions. The therapist has to address the effects of low body fat on health, but in young patients in particular, also the effects of low weight on maturation, growth, and osteoporosis. Therapists should be aware that a normalization of body fat may also increase the patient's fat phobia, which led to her pursuit of thinness.

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