Body composition in female anorexia nervosa patients

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For the first time, body composition has been studied in a very large sample of female anorexia nervosa patients (*n* 200) using two methods: anthropometry (skinfold thickness) and densitometry (underwater weighing). The concurrent validity of both methods appeared to be good (*r* 0·84). Although the mean percentage of body fat (13·5) in our sample corresponds with most of the previous reports, the range (4·3–24·8) is great. Our study shows that BMI is not a good measure of fatness. Age and duration of illness were not related to body fat. Percentage fat was found to be different (*t* 2·76, $P < 0·01$) according to the diagnostic subtype of anorexia nervosa: restricters (12·9) *v.* bingers and/or purgers (14·7).

Anorexia nervosa: Body composition: Anthropometry: Densitometry: Underwater weighing

The decrease in body fat in anorexia nervosa (AN) patients due to a prolonged restriction of oral nutrient intake and weight loss has important physiologial consequences with respect to morbidity and mortality (Russell *et al.* 1983). Knowledge of body composition in these patients is, therefore, clinically most relevant. Body-composition studies are generally based on the principle that one can estimate the relative proportion of two components: fat mass (FM) and fat-free mass (FFM; water, proteins and minerals). A wide variety of methods, from relatively simple and cheap to sophisticated and expensive ones, are available to measure body composition (for a recent review, see Heymsfield *et al.* 1995). The published studies on body composition in eating disorders are difficult to compare and mostly based on very small groups. We have found only a few studies (Pirke *et al.* 1986; Charest-Lilly *et al.* 1987; Mayo-Smith *et al.* 1989; Hannan *et al.* 1990, 1993*a*, *b*; Vaisman *et al.* 1991; Russell *et al.* 1994; Young *et al.* 1994) in which more than fifteen patients have been investigated.

In the context of a large research and treatment project on psychological and physiological aspects of how AN patients feel and think about their own body (Probst *et al.* 1995) we applied two methods of body composition assessment: the densitometric technique of underwater weighing (UWW) and the anthropometric approach of measuring skinfold thickness (SFT). UWW is considered to be the method of reference for body composition with reliability coefficients (test–retest correlations) above *r* 0·95 and concurrent validity coefficients usually above *r* 0·80 (Heymsfield *et al.* 1995). SFT is a classic technique with a generally weaker reliability (but usually above *r* 0·90). The standard error for prediction of fat percentage from SFT is in general 2·6–3·4% of body weight, which is not very different from the standard error obtained with UWW. Since SFT measures only subcutaneous adipose tissue, its validity is somewhat lower. The correlation between UWW and SFT ranges from 0·65 to 0·93 (Heymsfield *et al.* 1995).

The aims of our study were: (1) to estimate body composition in a large group of AN patients who were all in a starvation state; (2) to test the concurrent validity of the methods used (UWW and SFT); (3) to study the relationship between FFM and BMI and (4) to assess the impact of age and clinical variables such as duration of illness and diagnostic subtype (restricters *v*. bingers and/or purgers) on body composition.

METHOD

Subjects

Female patients (*n* 200) consecutively admitted between 1988 and 1995 to the Eating Disorder Unit of the University Center St Joseph in Kortenberg (Belgium) participated in the study. They all consented to the overall regimen of our inpatient treatment (Vandereycken & Meermann, 1984). All met both the DSM-III-R and DSM-IV diagnostic criteria for AN (American Psychiatric Association, 1994) and were classified in two subtypes: the 'restricting' type of AN patients who only lost weight through fasting and eventually rigorous physical exercise (*n* 131), and the 'mixed' type of anorectics who (intermittently) showed episodes of binge-eating and/or self-induced vomiting and/or laxative use (*n* 69). Patients with concurrent organic illnesses were excluded. At the time of assessment all were amenorrhoeic and not taking oestrogens or other hormonal therapy. Procedures were approved by the Ethical Committee of the University Center (including informed consent from the patients or, in case of minors, from the parents).

Procedure

All anthropometric and densitometric assessments were executed during the first week of treatment by the same highly experienced female investigator. Height was measured to the nearest 5 mm using a stadiometer. Body weight was measured, with the subject wearing underclothes only, using a beam balance, to the nearest 100 g. The Quetelet index or BMI (kg/m^2) was calculated.

Twelve skinfolds were measured (Weiner & Lourie, 1969; Brown & Jones, 1977; Goris, 1984): biceps, triceps, subscapular, suprailiac, chin, side, waist, abdomen, thigh anterior and posterior, calf lateral and medial) using a Harpenden electronic read out (HERO) skinfold caliper (Jones *et al.* 1979). The precision (test–retest) of our skinfold measurement fluctuated from r 0·93 (for thigh posterior) to r 0·97 (for the suprailiac; Goris, 1984). The percentage body fat was estimated from the logarithm of the sum of the skinfold measurements taken at four sites (biceps, triceps, subscapular and suprailiac) and the prediction equations, using the age-specific equations (Durnin & Womersley, 1974). For girls below 16 years we used the same formula as that used for girls below 20 years.

Hydrodensitometry (UWW) calculates body volume as the difference between body weight measured in air and 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 tank of water (37°). The subject exhales maximally, submerges, and body weight is then recorded. The body weight (accurate to the nearest ± 10 g) in water is measured at least six times. The highest value of the measurements is taken. Body density (D) is calculated by the following formula:

$$D = \frac{W}{W - Ww/dw - (RV + GI)},$$

where W is body weight in air, Ww is body weight in the water (after maximal expiration), dw is the density of the water, RV is the correction for the residual lung volume (measured twice at the time of taking Ww by He dilution), and GI is the correction for the volume of gas in the gastrointestinal tract; 150 ml seems the most appropriate correction (Leusink, 1964; Lasser *et al.* 1975, 1976; Biersteker *et al.* 1983). The precision of the measurement (test–retest) in our laboratory is r 0·96 (Goris, 1984). The percentage of fat is calculated by the Siri (1956) equation:

$$\text{percentage fat} = (4{\cdot}95/D - 4{\cdot}50) \times 100.$$

Data analysis

Relationships between variables were assessed by Pearson product moment correlations. One-way ANOVA was used for group comparison. Differences found on the one-way ANOVA were evaluated by the Tukey test (for unequal samples, $P < 0{\cdot}01$). Within-group differences were evaluated using a two-tailed Student's t test. All data were coded and computerized using *Statistica* (Statsoft Inc., 1991).

RESULTS

Comparison of two methods

The mean percentage of body fat (PBF) estimated by UWW and SFT was 13·5; 25% of the patients had a PBF less than 10, 61% below 15, and 7% above 20. As shown in Table 1, SFT and UWW gave approximately the same values (means and standard deviations and ranges) for PBF, FFM, and FM. Indices from the two methods had good correlations: D r 0·84, $P < 0{\cdot}0000$; FFM r 0·96, $P < 0{\cdot}0000$, standard error of estimate (SEE) 1·09 kg; FM r 0·90, $P < 0{\cdot}0000$, SEE 1·04 kg; PBF r 0·84, $P < 0{\cdot}0000$, SEE 2·6%. In addition, a two-tailed t test indicated that there were no significant differences between values for PBF (t 1·80, df 185), FM (t 1·85, df 185), and FFM (t 1·58, df 185) calculated by SFT *v.* UWW.

Relationship between body fat and BMI

Only 2% of the AN patients had a BMI higher than 17, and 67% had a BMI of 15 or less. The correlation between BMI and PBF estimated by SFT and by UWW was high (r 0·75 and 0·72, SEE 3·1 and 2·8% respectively). Nevertheless, only 56·2 (SFT)–51·8% (UWW) of the variance (r^2) in PBF could be predicted by BMI. PBF data for each BMI point are shown in Table 2. The variations in PBF at any given BMI were great; with a BMI of 13, for example, the PBF varied from 7 to 17%.

Age and duration of illness

We expected a higher PBF in older and more chronic patients. Indeed, univariate ANOVA for age confirmed this using UWW (F(2, 183) 7·32, $P < 0{\cdot}001$). *Post hoc* comparison did not show a difference between adolescents (< 19 years, n 82) and young adults (20–29 years, n 88), but both groups differed significantly from the oldest group (> 30 years, n 30). More detailed analysis of the adolescent group did not reveal differences on PBF between subgroups of ages (years; 14 n 11, 15 n 14, 16 n 18, 17 n 12, 18 n 15 and 19 years n 12). Unexpectedly, an ANOVA did not show an effect of duration of illness (years; < 3, n 96, 3–6 n 39, 6–9 n 27, > 9 n 42) on PBF measured by UWW.

Restricters v. bingers and/or purgers

The PBF of the mixed type differed significantly from that of the restricting type using UWW (t 2·8, df 123, 63; $P < 0{\cdot}000$). As shown in Table 3, significant differences were found in all variables except abdomen SFT (t 1·74, df 123, 63).

Table 1. *Clinical features and body composition in female anorexia nervosa patients (n 200)*

(Mean values and standard deviations, with ranges)

	Mean	SD	Range
Age (years)	22·7	6·3	12·8–42·4
Duration (years)	5·6	4·8	0·4–25·0
Weight (kg)	40·3	5·7	23·4–55·4
Height (m)	1·64	0·07	1·40–1·80
BMI (kg/m²)	14·9	1·7	10·2–18·4
Densitometry*			
Density (g/ml)	1·0680	0·0091	1·0426–1·0895
FFM (kg)	34·89	3·9	22·2–44·4
Fat mass (kg)	5·63	2·3	1·2–11·4
Body fat (%)	13·51	4·3	4·3–24·8
Anthropometry*			
Density (g/ml)	1·0684	0·0110	1·0443–1·0967
FFM (kg)	34·75	4·1	22·7–45·7
Fat mass (kg)	5·55	2·4	0·5–11·6
Body fat (%)	13·36	4·8	1·3–24·0
Skinfold sum (mm)	73·64	29·1	11·69–164·9

FFM, fat-free mass.
* For details of procedures, see pp. 640–641.

Table 2. *Percentage body fat for each BMI point in female anorexia nervosa patients* (n 200)*

(Mean values and standard deviations, with ranges)

			Percentage body fat			
BMI	*n*	Tech	Mean	SD	Range	Cum %
10	1	A	10·7	0	0	—
	2	B	7·0	2·3	5·3–8·5	1·0
11	4	A	6·0	0·7	5·3–6·9	—
	5	B	4·4	2·0	2·8–7·8	3·5
12	26	A	9·4	3·0	4·3–15·4	—
	28	B	8·7	3·9	1·3–18·3	17·5
13	31	A	10·8	2·7	7·2–17·9	—
	33	B	10·4	2·8	5·3–17·2	34·0
14	29	A	12·4	2·5	7·7–16·6	—
	29	B	12·1	2·4	6·4–17·6	48·5
15	35	A	14·8	3·4	7·8–20·7	—
	37	B	14·8	3·8	5·1–21·5	67·0
16	41	A	16·6	3·2	11·3–24·8	—
	45	B	16·9	2·9	10·1–24·0	89·5
17	17	A	17·8	3·6	9·6–23·8	—
	17	B	17·9	3·4	10·6–23·8	98·0
18	2	A	20·3	2·2	18·8–21·9	—
	4	B	20·5	1·6	18·8–22·5	100·0

Tech, technique; A, underwater weighing; B, skinfold measures; Cum %, cumulative percentage of cases (*n* 200).
* For details of subjects and procedures, see Table 1 and pp. 640–641.

Table 3. *Clinical features and body composition in subgroups of anorexia nervosa (AN) patients (restricters v. bingers and/or purgers)*†

(Mean values and standard deviations)

	AN restricters		AN bingers and/or purgers		Statistical analysis of difference (Student's *t* test): *t*
	Mean	SD	Mean	SD	
n	131		69		
Age (years)	21·5	6·3	25·1	5·8	3·98
Duration (years)	4·7	4·3	6·9	5·2	3·16**
Weight (kg)	38·7	5·4	43·3	5·1	5·86
Height (m)	1·64	0·07	1·66	0·05	2·58*
BMI (kg/m²)	14·5	1·6	15·7	1·5	5·32
Densitometry					
Density (g/ml)	1·0694	0·0094	1·0652	0·0104	2·75**
FFM (kg)	33·9	3·8	36·8	3·5	5·16
Fat mass (kg)	5·2	2·1	6·5	2·5	3·85
Body fat (%)	12·9	4·1	14·7	4·5	2·76**
Anthropometry					
Density (g/ml)	1·0705	0·0091	1·0644	0·0110	3·89
FFM (kg)	33·7	3·8	36·7	3·5	5·05
Fat mass (kg)	4·9	2·2	6·7	2·5	5·10
Body fat (%)	12·4	4·5	15·1	4·8	3·92
Skinfold sum (mm)	68·2	26·3	84·1	31·3	3·79
Skinfold (mm)					
Biceps	3·52	1·55	4·16	1·70	2·67**
Triceps	5·61	2·53	6·88	2·79	3·26
Subscapula	5·18	1·49	6·21	1·89	4·21
Suprailiac	3·90	1·37	4·50	1·70	2·73**
Side	4·24	1·38	5·17	1·94	3·89
Waist	6·17	2·90	7·35	3·57	2·53*
Abdomen	5·42	2·33	6·03	2·40	1·74 NS
Chin	4·64	1·81	5·84	2·26	4·08
Thigh: Anterior	8·53	4·84	11·08	5·79	3·29
Posterior	9·52	5·03	12·74	6·39	3·92
Calf: Lateral	6·09	3·48	7·13	3·21	2·06*
Medial	5·49	2·86	7·37	3·52	4·07

FFM, fat-free mass.

Mean values for the AN restricters were significantly different from those for the AN bingers and/or purgers (two-tailed *t* tests): $P < 0{\cdot}000$, except * $P < 0{\cdot}05$, ** $P < 0{\cdot}01$.

† For details of subjects and procedures, see Table 1 and pp. 640–641.

DISCUSSION

Body composition studies in AN are rare. One of the reasons for this may be the complexity of the semi-starvation state. Most human studies of weight loss have involved obese subjects who are not comparable with AN patients. In anorectics physical exercise, dieting, vomiting and laxative use could affect the body composition (Mitchell & Truswell, 1987). In addition to this complexity we have to take into account several methodological problems.

A serious problem is the lack of comparability between body composition studies in AN patients concerning, for instance, protein (Russell *et al.* 1983; Dempsey *et al.* 1984; Forbes *et al.* 1984; Pirke *et al.* 1986), water (Ljunggren *et al.* 1957; Dempsey *et al.* 1984; Vaisman *et al.* 1988; Hannan *et al.* 1990; Casper *et al.* 1991) and bone density (Forbes *et al.* 1984; Rigotti *et al.* 1984; Andersen *et al.* 1995; Shetty, 1995) due to the use of different techniques. For example, in comparison with a normal control group, the hydration coefficient has been found to be similar (Hannan *et al.* 1990), lower (Casper *et al.* 1991) or higher (Vaisman *et al.* 1988).

A possible error is that the two-compartment model assumes constant densities for FM and FFM. This assumption is generally accepted for FM. In contrast, FFM is composed of several major chemical components such as water, protein, glycogen and various minerals. These components differ in density from each other. Consequently, relative changes in the chemical composition of FFM may change the density of FFM from the assumed value of 1·10 g/ml.

With a decrease in bone-mineral density the use of the Siri (1956) equation results in a possible overestimation of PBF. No method gives an adequate value for the changes of the FFM. Even the most recent dual-energy X-ray absorptiometry (DEXA) method (Heymsfield *et al.* 1995) does not escape this problem. The data of Roubenoff *et al.* (1993) support the concern that in subjects with acute or chronic alterations in body water, DEXA could suffer from important errors in measurements of soft tissue mass (Kohrt, 1995). The result is that errors in fat estimates may occur when using the conversion of D by the application of the Siri (1956) equation in subjects whose density of FFM is not 1·10 g/ml (Heymsfield *et al.* 1995). For want of a good alternative and a specific equation for AN, we have decided to use the much-cited Siri (1956) equation. Of course, an interpretation of PBF data has to take into account the possible influences of considerable variation in the body composition of AN patients. In the future, more specific and homogeneous population studies have to address this problem.

The relationship we found between PBF estimated by SFT and by UWW is in agreement with those given in the literature for normal samples (Womersley *et al.* 1972; Goris, 1984). UWW was surprisingly well accepted and tolerated by our patients, but it remains a rather unpractical method. SFT measurements give a very good indication of FM and PBF. This method is very useful in clinical practice and field research because it is non-invasive, cheap and easy to apply. A disadvantage is that it has a larger SEE and still requires some training and experience (Lohman, 1981). We conclude, however, that in AN patients the estimation of body fat with SFT can be recommended as a standard procedure. Beside the prediction formula we propose to use the sum of the twelve skinfolds. With this the problems with the different equation formulas can be largely avoided.

There is no general consensus in the literature about the 'normal' PBF for the general female population. PBF averages range between 24 (Jackson & Pollock, 1985) and 28 % (Mitchell & Truswell, 1987). Similarly, the values given for 'minimal' PBF for women may vary from 7 to 14 (Behnke & Wilmore, 1974; Katch *et al.* 1980; Williams *et al.* 1984). According to Steinbaugh (1984), a PBF of less than 5 is medically dangerous. Great variations in PBF have been reported in ballet dancers: from 16–17 (Calabrese *et al.* 1983; Kirkendall & Calabrese, 1983; Clarkson *et al.* 1985) to 20–22 (Dolgener *et al.* 1980; Hergenroeder *et al.* 1991*a*). These results have particular relevance for AN because dancers are considered at risk of developing an eating disorder. The low to very-low PBF values in our sample are similar to those reported in other studies using the same methods (e.g., Davies *et al.* 1978; Russell *et al.* 1983; Charest-Lilly *et al.* 1987; Vaisman *et al.* 1988; Mayo-Smith *et al.* 1989; Casper *et al.* 1991; Krahn *et al.* 1993). The reasons for the great range of PBF are unclear, but may be determined by premorbid body composition (childhood obesity), excessive physical activity during weight loss, or inadequate food intake (severity and/or duration of restriction, quantity and quality of diet; Mitchell & Truswell, 1987; Garfinkel & Garner, 1982).

Our findings in relation to the magnitude of the correlation between BMI and PBF from UWW are in agreement with those of Smalley *et al.* (1990), Haarbo *et al.* (1991) and Michielutte *et al.* (1984), but are higher than those of Brodie & Slade (1988) and Wang *et al.* (1984), whereas Cochran *et al.* (1988) and Heymsfield *et al.* (1990) found a higher correlation. The relationship between BMI and PBF from SFT was similar to that reported by Brodie & Slade (1988), Kushner & Schoeller (1986), Hergenroeder *et al.* (1991*b*) and Heymsfield *et al.* (1990), but higher than that from the studies by Van Loan & Mayclin (1987), and Volz & Ostrove (1984).

BMI reflects real changes in weight: height, but in spite of the high correlation with PBF it is not a direct index or predictor of relative body fatness (Mitchell & Truswell, 1987). Hannan *et al.* (1995) came to similar conclusions in a population of adolescent schoolgirl volunteers and adult female patients. The BMI has only limited significance in the diagnosis of AN. Hannan *et al.* (1993*a*) state that target values for FFM may be more appropriate than BMI for assessing the severity of the disorder and its response to treatment. In the light of our results, one may question some recent attempts to define AN in terms of BMI: below 17·5 (American Psychiatric Association, 1994), 16 (Beumont *et al.* 1988) or 15 (Llewellyn-Jones & Abraham, 1984).

Our study shows that one should always take clinical variables into account. Unexpectedly, we did not find a difference in PBF between adolescents (postpubertal development) and young adults. Older adults (> 30 years) had a higher PBF. This is not due to a difference in the duration of the illness which, contrary to our expectations, does not influence PBF. An important factor is the subtype of AN; we were the first clearly to differentiate results in pure restricters from those in patients who alternate food restriction and binge eating with vomiting and/or purging. It confirms the subclassification defended by Vandereycken & Pierloot (1983) many years ago on the basis of clinical features and which is now proposed in DSM-IV (American Psychiatric Association, 1994).

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