FAT DISTRIBUTION PATTERNS IN YOUNG AMENORRHEIC FEMALES

Sylvia Kirchengast and Johannes Huber
University of Vienna

The present study analyzes body fat distribution, a well-known and important indicator of reproductive capability, in young women between 18 and 28 years of age (mean = 23.3 years) suffering from secondary amenorrhea and therefore temporary infertility resulting from self-starvation. Body composition parameters estimated by means of dual energy x-ray absorptiometry and the fat distribution index, indicating body shape, were compared with those of healthy controls. Although members of the infertile, amenorrheic group exhibited dramatically low body weight and total amount of body fat, and therefore a marked negative energy balance in comparison with the healthy controls, the sex-specific fat distribution patterns did not differ between infertile and fertile young women. In contrast, the lower the weight and total fat amount, the more gynoid the fat distribution, even in infertile women. This observation may be interpreted in an evolutionary sense: Our ancestors had to cope with frequent food shortages, even starvation, and therefore lengthy periods of negative energy balance. In addition to pregnancy and lactation, temporary infertility as a result of long-term negative energy balance was not an uncommon phenomenon in female life histories. Nevertheless, after a time of plenty, reproductive function recovered, and therefore the gynoid fat distribution patterns in temporarily infertile young women may be interpreted as signal of reproductive capability, which resumes after a time of surplus.

KEY WORDS: **Anorexia nervosa; Body fat distribution; Evolution of beauty standards; Infertility; Starvation.**

Received: September 30, 1999; accepted March 24, 2000.

Address all correspondence to Dr. Sylvia Kirchengast, Institute for Anthropology, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria. E-mail: sylvia.kirchengast@univie.ac.at

Human Nature, Vol. 12, No. 2, pp. 123–140. 1045-6767/01/$1.00+.10

Several evolution-based theories try to explain the relatively homogeneous, culturally independent standards of female attractiveness. The fundamental assumption of these hypotheses is that female physical attractiveness is an indication of the woman's reproductive potential, which is one of the most important criteria by which males select a mating partner (Anderson et al. 1992; Brown 1991; Brown and Konner 1987). Since ovarian function and therefore the potential fertility of a female is not visible, several morphologic features associated with potential reproductive success are important for sexual selection. Cross-cultural analyses have revealed that female body size, the total amount of body fat, and the distribution of body fat play an important role in standards of female beauty. Nevertheless, marked differences are observable between the individual cultural traditions, especially regarding the total amount of body fat as well as body weight deemed attractive. Several hypotheses were formulated to interpret these markedly different approaches to body fat as an element of female attractiveness (Anderson et al. 1992). Within developed countries only groups with low socioeconomic status associate plumpness and mildly overweight with female attractiveness, whereas in developing countries the majority of traditional societies link female body with health, especially in regions were food is scarce or food shortages are frequent (Brown 1991; Brown and Konner 1987).

There are several hypotheses regarding the relationship between energetics and female reproductive success. Rose Frisch (1978, 1985, 1990) has suggested that female body fat represents an essential caloric resource for successful gestation and lactation and that when the reserves fell below a critical value ovarian function is interrupted to prevent a pregnancy with little chance of success. Although the so-called Frisch hypothesis has been disconfirmed, several other hypotheses have been developed to explain the energetics of human reproduction (Bongaarts 1980; Eaton et al. 1994; Ellison 1990, 1994; Prentice and Whitehead 1987; Short 1994). Notwithstanding the fact that the energy costs of human reproduction are lower than those of any other group of mammals (Prentice and Whitehead 1987), human ovarian function is extremely vulnerable to an energy imbalance (Ellison 1990). Ovarian function shows a graded continuum from fully competent cycles through luteal phase suppression, follicular phase suppression, ovulatory failure, oligomenorrhea, to amenorrhea in response to endogenous and exogenous factors affecting energy balance (Ellison 1990). An especially lengthy negative energy balance may result in anovulation and, in severe cases, in amenorrhea (when menstrual cycling stops and the woman becomes temporarily infertile). The most impressive morphological indicator of a negative energy balance is a low amount of body fat. Therefore a higher amount of body fat may be associated with female attractiveness and potential reproductive success in societies where food supply is uncertain and periods of starvation are frequent. For this reason, no specific transcultural standard of the association between attractiveness, potential reproductive success, and body fat is observable.

In contrast, the results of the studies carried out by Singh (1993, 1994a, 1994b; Singh and Luis 1995) may be interpreted as evidence that the preference for a particular sex-specific fat distribution pattern represents a cross-cultural and historical standard of female attractiveness. According to Singh, a certain body fat distribution (mostly evaluated using the waist-to-hip ratio) was considered attractive, independent of ethnic or socioeconomic background. The preferred fat distribution is gynoid—in other words, the amount of lower body fat (hips, buttocks, thighs) surpasses the amount of upper body fat, especially of the abdominal region. Although Singh's model seems to weaken when population-specific differences in fat distribution patterns are taken into consideration (and although the waist-to-hip ratio actually describes body shape and not the fat distribution per se), there is a marked association between fat distribution and/or body shape and female life history stage: The gynoid body fat distribution is typical for young fertile women, whereas an android fat distribution, with a higher amount of abdominal body fat in relation to lower body fat, is typical of infertile phases such as pregnancy and menopause or is a frequent symptom of severe endocrine disorders resulting in reduced fertility or sterility such as polycystic ovarian syndrome (PCOS) (Bringer et al. 1993; Douchi et al. 1995; Kirchengast et al. 1997a, 1998a; Ley et al. 1992). In healthy female adolescents, soon after puberty body fat is deposited preferentially on the lower body parts mentioned above (DeRidder et al. 1990; Garn et al. 1986; Kirchengast et al. 1998b). The gynoid fat distribution pattern develops at the time when the young female becomes fertile and persists during the entire fertile phase of her life, with the exception of temporary infertile periods such as pregnancy. The lower body fat deposits are important energy stores which can be accumulated during times of plenty and used during food shortages as well as during phases of high energetic costs such as pregnancy or lactation (Rebuffe-Scrive et al. 1985, 1986). In this way a sufficient amount of lower body fat enhances the likelihood of bringing a pregnancy to term successfully, even under worsened environmental conditions. Therefore a gynoid fat distribution was interpreted as a valid indicator of a woman's potential fertility.

According to this interpretation, the gynoid fat distribution—this important signal of potential female reproductive success—should decrease or totally disappear during all phases of persistent anovulation or amenorrhea occurring within what would normally be a woman's fertile phase. The change from gynoid to android fat distribution is well-documented for young women suffering from PCOS, the most common endocrinological fertility disorder (Conway 1996). Even during perimenopause, when anovulation is frequent and potential reproductive success is reduced, there is a shift from gynoid fat distribution through an intermediate stage, when the amount of upper and lower body fat is more or less equal, to the android fat distribution typical of menopause (Kirchengast et al. 1997a). But what happens to the sex-specific fat distribution during long-term food shortages and periods of starvation, when the energy deposits are consumed and the fat percentage falls under a critical value? This energetic situation was not uncommon during our evolutionary history and is an urgent problem in developing countries even today.

The aim of our study is to analyze fat distribution patterns during periods of temporary infertility caused by severe long-term negative energy balance resulting from self-starvation in young women and to test the hypothesis that gynoid fat distribution is in general a marker of reproductive capability.

METHODS

Subjects

Twenty-five women between 18 and 29 years of age (mean = 23.4 ± 2.9) were examined between 1994 and 1997 at the University Clinic for Gynecology and Obstetrics, Department of Endocrinology, in Vienna. Fifteen women ranging from 18 to 28 years of age (mean = 23.3 years) had suffered from secondary amenorrhea for more than nine months as a result of low body weight from anorexia nervosa. Ten young women ranging in age from 19 to 29 (mean = 22.9 years) served as controls. All controls had regular menstrual cycles (26- to 33-day cycles) and normal sex hormone levels. The anorectic patients were extremely underweight, but at the time of the investigation their weight status was not life-threatening. All of them received intensive psychotherapy and gained enough weight over the two years following the examination that they started to menstruate again without hormone treatment.

Hormone Levels

In the anorectic group the examination started with the quantitative determination of 17β-estradiol (E2), follicle stimulating hormone (FSH), luteinizing hormone (LH), testosterone (T), dehydroepiandrostendionsulfate (DHEA-S), and androstendione (A). Blood samples were collected between 7.30 and 9.30 A.M. The quantitative determination was made at the central hormone labratory of the University Clinic for Gynecology and Obstetrics. After coagulation, the samples were centrifuged and the serum was stored at −20°C until further processing. Assays were employed according to NCCLS guidelines as follows (intra- and interassay CV in parentheses): Autodelfia LH (9.3%, 3.9%) and Autodelfia estradiol (5.2%, 8.5%) by Wallac Oy; Enzymun FSH (4.2%, 8.3%) on ES700 by Böhringer Mannheim; DHEA-S (7.4%, 10.5%) radioimmunoassay by Immunotech Inc.; testosterone (6.5%, 11.2%) RIA Coat-A-Coat by Diagnostics Product Corp.; androstendione (6.6%, 9.0%) radioimmunoassay by Alima Inc.

Anthropometrics

Stature (in centimeters) and body weight (in kilograms) were determined for each proband according to the methods described in Knussmann 1988. The body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Weight status was classified using the following BMI categories (World Health Organization 1995):

Underweight:	category 1, 17.00–18.49 (mildly underweight)
	category 2, 16.00–16.99 (moderately underweight)
	category 3, >16.00 (severely underweight)
Normal range:	18.50–24.99
Overweight:	category 1, 25.00–29.99 (mildly overweight)
	category 2, 30.00–39.99 (severely overweight)
	category 3, <40.00 (obese)

Body Composition

Dual-energy x-ray absorptiometry (DEXA) (Hologic 2000) was used to measure bone as well as lean and fat mass (Slosman et al. 1992). Although this method is indirect, its reliability, relatively low cost, and degree of comfort for the probands make it especially useful for determining body composition. The body consists of soft tissue (fat and lean tissue) and bone. DEXA measures bone mineral content and density, fat mass, and lean mass with a precision (coefficient of variation) of 0.9%, 4.7%, and 1.5%, respectively. The precision for abdominal fat mass and overall percentage of fat is 4.3% and 3.4%, respectively (Svendsen et al. 1995). The relatively low radiation dose with 0.1m Sievert and a short scanning time (less than 7 minutes) make this technique especially suitable for such determinations.

Fat Distribution

The fat distribution index (FDI), based on the results of the dual energy x-ray absorptiometry (Kirchengast, Gruber, Sator, et al. 1997b), was calculated as follows:

FDI = Upper body fat mass in kg / Lower body fat mass in kg

The upper body begins immediately below the chin and ends at the articulation of the pelvis and femurs. The hip region is included in the lower body. A fat distribution index below 0.9 indicates a gynoid fat distribution (i.e., the fat mass of the lower body surpasses the fat mass of the upper body). A fat distribution index above 1.1 defines an android fat distribution. An FDI between 0.9 and 1.1 is classified as an intermediate stage of fat distribution (for a detailed description see Kirchengast et al. 1997b).

Statistical Analysis

The statistical analyses were carried out using SPSS Version 7.0 (Microsoft Corp.) following the methods used by Bühl and Zöfel (1996). After descriptive statistics (means, standard deviations, medians, range) were calculated, significance of group differences was evaluated using distribution-free Mann-Whitney tests (z-values). Multiple regression analysis was used to test the impact of weight status, and absolute and relative fat mass, on fat distribution.

RESULTS

Hormonal Parameters

The amenorrheic group exhibited decreased estrogen levels (mean = 16.0 pg/ml ± 7.2), whereas the gonadotropines showed levels well within the age-specific norm (FSH mean = 5.64 mU/ml ± 1.69; LH mean = 1.8 mU/ml ± 2.6). All androgen levels fell within the age-specific norms (T mean = 0.35 ng/ml ± 0.20; A mean = 2.43 ng/ml ± 0.89; DHEA-S mean = 1.68 ng/ml ± 0.66).

Body Size and Weight Class

As can be seen in Table 1, in stature the two proband groups differed insignificantly. In contrast, as expected, highly significant differences occurred in body weight ($p > 0.007$) and body mass index ($p > 0.009$). While the majority of anorectics (79%) corresponded to the definition of underweight (BMI below 18.49), 70% of the controls were classified as normal weight (BMI < 18.49) (Table 2).

Body Composition

The two proband groups differed significantly with regard to body composition. This was especially true of the absolute and relative amount of fat tissue ($p > 0.000$). As expected, the amount of body fat was lower in

Table 1. Body Size of Anorectic and Healthy Probands: Mann-Whitney Test

	Anorectics				*Controls*				
Variable	*Mean*	*s.d.*	*Median*	*Range*	*Mean*	*s.d.*	*Median*	*Range*	*z-value*
Stature (cm)	166.4	4.6	166	159–176	167.6	5.5	168.5	160–178	−0.64, n.s.
Body weight (kg)	49.0	4.3	48.5	42–55	55.5	4.4	53.5	49–63	−3.06, $p > 0.002$
BMI (kg/m^2)	17.6	1.1	17.7	15.2–19.8	19.9	1.62	19.8	17.4–22.4	−2.93, $p > 0.003$
Total bone mass (g)	2100	235.1	2162	1746–2414	2313	237.5	2419	1919–2559	−2.11, $p > 0.04$
Bone density (%)	89.7	9.9	90	72–109	101.2	8.8	103	92–111	−2.71, $p > 0.006$

Table 2. Weight Status: Percent of Anorectic and Control Samples by BMI Class

BMI	*Anorectics*	*Controls*
>16.00	7.1	0
16.00–16.99	14.3	0
17.00–18.49	57.1	30
18.50–24.99	21.4	70
< 25.00	0.0	0

anorectic women than in healthy ones. In contrast, significantly higher values of bone mineral content were found in the healthy controls. No significant differences between the two groups occurred in lean body mass (Table 3).

Fat Distribution and Fat-to-Lean Ratios

Both anorectic patients and healthy controls exhibited a gynoid fat distribution. Therefore no significant differences in FDI values were found. In contrast, the fat-to-lean ratios differed significantly between the two proband groups. The amount of body fat in relation to lean body mass was markedly higher in healthy women. This was true of the whole body as well as of the upper and the lower body regions.

The Impact of Body Composition and Weight Status on Fat Distribution

Multiple regression analyses indicated a decrease in the fat distribution index with decreasing body mass index as well as decreasing absolute and relative fat mass. In other words, the thinner a woman was, the more feminine was her fat distribution. This was true of all probands together as well as for both proband groups separately. However the impact of fat mass and weight status on fat distribution was statistically significant in the anorectic group only (Table 4, Figures 1 and 2).

DISCUSSION

According to the Duchess of Windsor, with regard to attracting potential mating partners, "No woman can be too slim." However, according to cross-cultural and historical analyses this assertion is only true in contemporary, highly industrialized societies. During our evolutionary history and even today in most parts of the world a certain amount of body fat is the only reliable indicator of a positive energy balance and therefore

Table 3. Body Composition, Fat-to-lean Ratios, and Fat Distribution in Anorectic and Healthy Probands: Mann-Whitney Tests

	Anorectics				*Control*				
Variable	*Mean*	*s.d.*	*Median*	*Range*	*Mean*	*s.d.*	*Median*	*Range*	*z-value*
FDI	0.57	0.22	0.50	0.27–0.92	0.56	0.10			−0.47, n.s.
Fat/lean ratio total	0.27	0.09	0.26	0.13–0.45	0.38	0.07	0.37	0.29–0.51	−2.75, p >0.005
Fat/lean upper body	0.15	0.09	0.13	0.05–0.31	0.22	0.05	0.22	0.14–0.29	−1.87, $p > 0.05$
Fat/lean lower body	0.43	0.14	0.43	0.19–0.71	0.67	0.12	0.64	0.50–0.87	−3.28, $p > 0.001$
Total fat mass (kg)	10.0	3.3	10.1	4.5–14.1	14.8	2.5	14.9	10.7–19.2	−2.98, $p > 0.002$
Upper body fat mass	3.0	1.6	2.5	1.0–5.9	4.5	1.1	4.7	2.9–6.9	−2.23, $p > 0.02$
Lower body fat mass	5.1	1.4	5.2	2.01–7.9	7.9	1.2	8.0	5.6–9.9	−3.63, $p > 0.000$
Total fat %	20.1	5.6	18.2	10.8–22.6	26.4	3.5	26.1	21.4–32.3	−2.75, $p > 0.006$
Total lean mass	37.5	2.8	37.7	31.4–42.6	38.7	3.4	38.6	34.5–44.0	−0.88, n.s.
Upper body lean mass	19.6	1.3	20.0	17.2–21.7	20.8	1.5	20.5	18.8–23.4	−1.52, n.s.
Lower body lean mass	11.8	1.2	11.9	8.8–13.6	11.9	1.5	11.8	10.1–14.4	−0.18, n.s.

Table 4. Results of Multiple Regression Analyses

	B	*s.e. of B*	β	t-*value*
ANORECTIC WOMEN				
BMI	0.07	0.04	0.49	2.05, $p > 0.06$
Total fat mass	0.05	0.01	0.66	3.14, $p > 0.007$
Fat %	0.02	0.01	0.62	2.86, $p > 0.01$
HEALTHY CONTROLS				
BMI	0.03	0.01	0.49	1.58, n.s
Total fat mass	0.02	0.01	0.44	1.39, n.s.
Fat %	0.02	0.01	0.56	1.99, $p > 0.08$

female reproductive potential. In this way, body fat is positively associated with female attractiveness (Brown 1991). It has several important physiological functions. Besides insulating the body core, it is—especially in women—essential for successful reproduction (Triosi et al.1995). On the one hand body fat is a source of calories and crucial for successful pregnancy outcome and lactation (Konner and Worthman 1980; Rebuffe-Scrive et al. 1985, 1986); on the other hand the most important extra-ovarian sex hormone synthesis, the aromatization from androgens to estrogens, takes place in the subcutaneous fat (Perel and Killinger 1979). During adolescence a certain amount of body fat (along with skeletal maturation, especially in the pelvis) is necessary for a young female to commence regular and ovulatory menstrual cycles, and even during adulthood the total body fat mass should not fall below a critical value for a lengthy period lest the maintenance of regular menstrual function be compromised (Ellison 1990). Inadequate amounts of fat tissue over a longer period will result in dramatic hormonal disturbances, such as a drastic decrease of endogenous estrogen levels, in severe cases resulting in complete cessation of menstrual cyclicity.

Although the amount of body fat is a valid indicator of energy balance, the sex-specific distribution of body fat is also an important marker for female reproductive capability. A woman's fat distribution changes according to her reproductive status and hormonal profile. With the onset of pubertal hormonal activity the young woman develops additional fat deposits in her lower body region—in other words, in her hips, thighs, and buttocks (DeRidder et al. 1990). Fat in these regions is an excellent energy store even during phases of increased somatic stress such as pregnancy and lactation. This gynoid fat distribution is typical for the entire fertile phase of the female life history and then changes during perimenopause, leading to the android fat distribution which is typical when female reproductive capability is terminated (Ley et al. 1992; Kirchengast et al. 1997a). Android fat distribution patterns are typical not only of menopause but also when

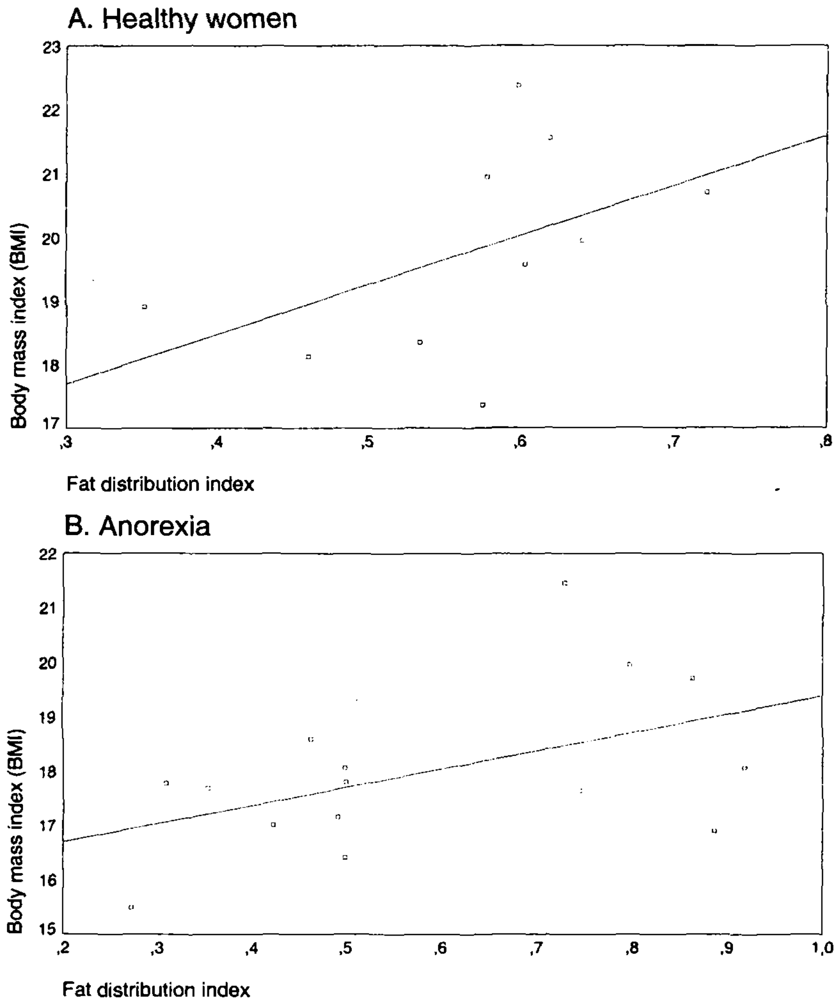

Figure 1. Fat distribution and body mass indices in (A) healthy women and (B) anorexia.

fertility is affected by pathologies such as hormonal disorders, obesity, or during pregnancy when a new conception is impossible.

Unfortunately, fat distribution was estimated by means of the waist-to-hip ratio, which actually reflects body shape more than it does fat distribution. Nevertheless, previous researchers have associated women's waist-to-hip ratio with offspring sex ratio (Manning et al. 1996; Singh and

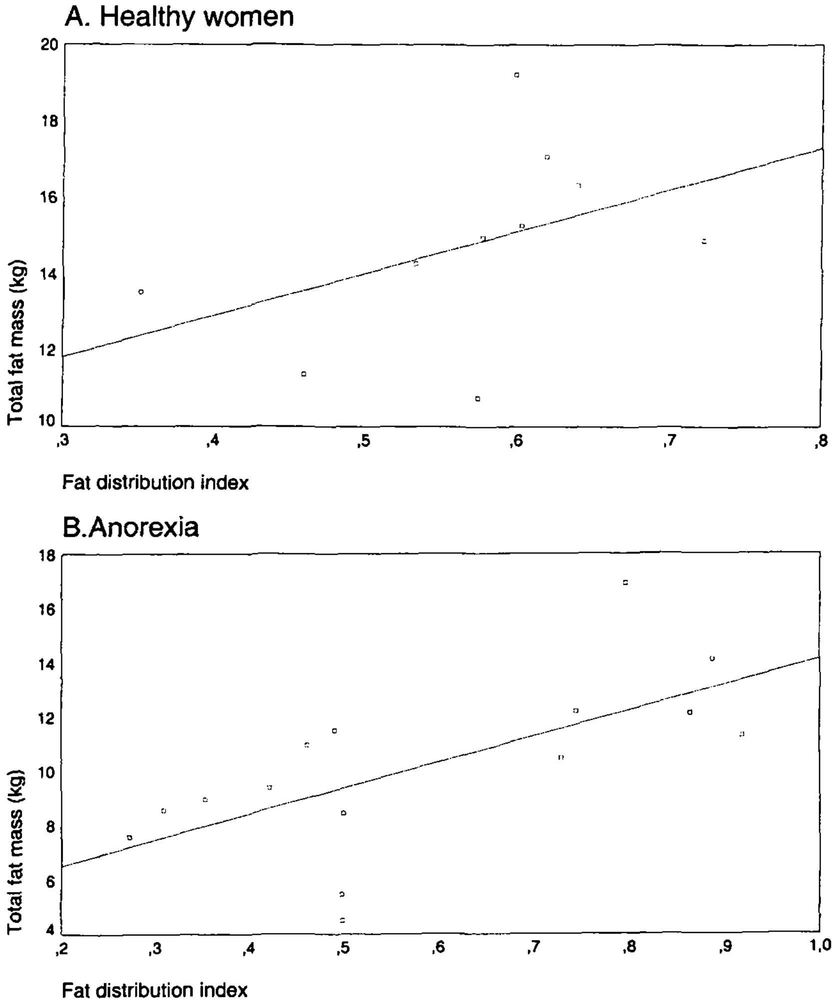

Figure 2. Fat distribution index and total fat mass in (A) healthy women and (B) anorexia.

Zambarano 1997) and conception rates (Zaastra et al. 1993). Another important aspect is the association between fat distribution patterns and disease risk factors. There is some evidence for a close association between android fat distribution and several metabolic disturbances such as diabetes, cardiovascular problems such as hypertension or hypercholesterinemia, the so-called metabolic syndrome (Björntorp 1988, 1997).

If fat distribution is a more valid indicator of female reproductive capa-

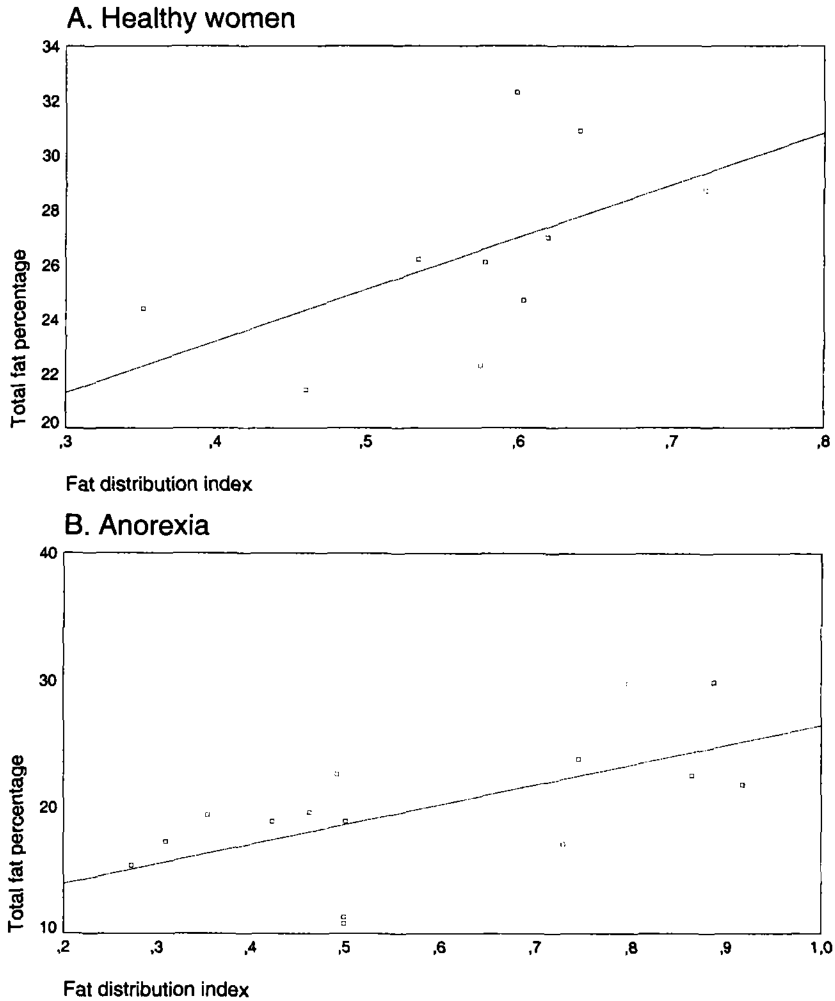

Figure 3. Fat distribution index and total fat percentage in (A) healthy women and (B) anorexia.

bility and general health than the total amount of body fat, what happens to this important marker during lengthy food shortages when energy stores decrease and energy balance becomes negative? During our evolutionary history long-term food shortages caused by ecological and social factors were not uncommon and may have led to severely depleted energy deposits and negative energy balance in the majority of females several times in their lives. Ovarian function shows a continuum from fully competent cycles to the complete interruption of ovarian function according to the observed energetic condition of the female (Ellison 1990). When a successful pregnancy outcome is in doubt as a result of a long-term negative energy balance, ovarian function is interrupted. In the worst case the female becomes temporarily infertile. After a time of surplus, when the energy balance becomes positive, reproductive capability may recover. But what happens to the fat distribution patterns during this infertile phase? Is there an observable change in this important marker for sexual selection?

In our present study we analyzed the fat distribution of young females during a phase of temporary infertility occurring as a result of long-term self-starvation. The phenomenon of anorexia nervosa has been explained in an evolutionary framework using the "adaptive reproductive suppression hypothesis" (Surbey 1987; Voland and Voland 1989). This hypothesis assumes an ancestral adaptation in women enabling them to identify poor conditions for reproduction. A slight change in body weight could trigger a delay in reproductive effort until a more favorable time. Nevertheless this hypothesis is not applicable to our question. It was developed to explain excessive dieting by young girls and women in industrialized societies where food supply is adequate but the social conditions for successful reproduction are temporarily scarce. We are not trying to explain the phenomenon of anorexia nervosa, we are analyzing the effects of starvation and long-term negative energy balance on body fat distribution in young women during their fertile phase of life.

All of our anorectic probands had been amenorrheic for more than nine months. Their weight status was low, and their total fat percentage and bone density were dramatically low. Their reduced bone mass and low estrogen levels indicate the dramatic physiological effects of starvation and a long-term negative energy balance. Nevertheless, all of them exhibited a typical gynoid fat distribution. In fact, with decreasing energy balance and weight as well as total amount of body fat, the fat distribution index decreases and the fat patterning becomes even more gynoid. In the majority of anorectic cases the fat distribution index was even lower than in the healthy control group. Not only does this important sign of reproductive capability persist during a phase of temporary infertility, the fat distribution of the severely undernourished young women could actually be characterized as "hypergynoid."

The observation of gynoid fat distribution patterns in anorectic infertile young women is in accordance with the results of previous studies (Mazes et al. 1990; Orphanidou et al. 1997; Probst et al. 1996). This is also true of the dramatically low bone density observed in the anorectic group (Kooh et al. 1996). Lower body adipocytes showed an increased lipoprotein lipase activity and a blunted lipolytic response during fertile phase (Rebuffe-

Scrive et al. 1986, 1990). This metabolic condition leads to the persistence of those essential energy sources in the lower body region during semistarvation. Our results indicate that even under worse conditions when ovarian function is affected by the long-term negative energy balance, menstrual function is interrupted, and temporary infertility is evident—the gynoid fat distribution persists, as long as there is a realistic chance that reproductive capability can recover.

Our ancestors did not live in the Garden of Eden. They experienced periods of food shortage and starvation resulting from climatic change, drought, and uneven hunting and gathering success. Under these conditions it was nearly impossible for a female to maintain a sufficient amount of body fat to signal potential reproductive capability. But the metabolic activity of their lower body adipocytes enhance the lipoprotein lipase activity and reduce the lipolytic effects even during periods of long-term starvation. Therefore the gynoid fat distribution persists and signals that reproductive success is possible after a time of sufficient energy supply and provides a base for the reestablishment of reproductive function. In this way the cross-cultural and historical constant standards of female attractiveness expressed by gynoid body fat distribution may be explainable.

The authors are gratefully indebted to their probands, without whose cooperation the present study could not have been performed.

Prof. Sylvia Kirchengast has a Ph.D. in physical anthropology and master's degrees in cultural anthropology and psychology. She has taught in the department of anthropology of the University of Vienna since 1994 and was appointed a professor in 1999. Her research interests include the biology of human reproduction, endocrinology, and medical anthropology.

Johannes Huber has a Ph.D. in theology and an M.D. He is a professor and the head of the department of endocrinology and reproductive medicine, obstetrics and gynecology clinic, University of Vienna.

REFERENCES

Anderson, J. L., C. B. Crawford, J. Nadeau, and T. Lindberg

1992 Was the Duchess of Windsor Right? A Cross-Cultural Review of the Socioecology of Ideals of Female Body Shape. *Ethology and Sociobiology* 13:197–227.

Björntorp, P.

1988 The Associations between Obesity, Adipose Tissue and Disease. *Acta Medica Scandinavica* 723:121–134.

1997 Obesity. *Lancet* 350:423–426.

Bongaarts, J.
1980 Does Malnutrition Affect Fecundity? A Summary of Evidence. *Science* 208:564–569.
Bringer, J., P. Lefebvre, F. Boulet, F. Grigorescu, E. Renard, B. Hedon, A. Orsetti, and C. Jaffiol
1993 Body Composition and Regional Fat Distribution in Polycystic Syndrome. *Annals of the New York Academy of Sciences* 687:115–123.
Brown P. J.
1991 Culture and the Evolution of Obesity. *Human Nature* 2:31–57.
Brown, P. J., and M. Konner
1987 An Anthropological Perspective on Obesity. In *Human Obesity*, J. J. Worthman and R. J. Wurthman, eds. Annals of the New York Academy of Sciences 499:29–46.
Bühl, A., and P. Zöfel
1996 SPSS for Windows, version 7.0. Bonn: Addison-Wesley
Conway, G. S.
1996 Polycystic Ovary Syndrome: Clinical Aspects. *Baillere's Clinical Endocrinology and Metabolism* 10:263–279.
DeRidder, C. M., P. F. Bruning, M. L. Zonderland, J. H. H. Thijssen, J. M. G. Bonfrere, M. A. Blankenstein, L. A. Huisfeld, and W. B. M. Erich
1990 Body Fat Mass, Body Fat Distribution and Plasma Hormones in Early Puberty in Females. *Journal of Clinical Endocrinology and Metabolism* 70:888–893.
Douchi T., H. Ijin, S. Nakamura T. Oki S. Yamamoto and Y. Nagata
1995 Body Fat Distribution in Women with Polycystic Ovary Syndrome. *Obstetrics and Gynecology* 86:516–519.
Eaton, S. B., M. C. Pike, R. V. Short, N. C. Lee, J. Trusell, R. A. Hatcher, J. W. Wood, C. M. Worthman, N. G. Blurton Jones, M. J. Konner, K. R. Hill, R. Bailey, and A. M. Hurtado
1994 Women's Reproductive Cancers in Evolutionary Context. *Quarterly Review of Biology* 69:353–367.
Ellison, P. T.
1990 Human Ovarian Function and Reproductive Ecology: New Hypotheses. *American Anthropologist* 2:933–952.
1994 Advances in Human Reproductive Ecology. *Annual Review of Anthropology* 23:255–275.
Frisch, R. E.
1978 Population, Food Intake and Fertility. *Science* 199:22–30.
1985 Fatness, Menarche and Fertility. *Perspectives in Biological Medicine* 28:611–633.
1990 Body Fat, Menarche, Fitness and Fertility. In *Adipose Tissue and Reproduction*, R. E. Frisch, ed. Pp 1–26. Basel: Karger.
Garn, S. M., M. LaVelle, K. P. Rosenberg, and V. M. Hawthorne
1986 Maturational Timing as a Factor in Female Fatness and Obesity. *American Journal of Clinical Nutrition* 43:879–883.
Kirchengast, S., D. Gruber, M. Sator, B. Hartmann, W. Knogler, and J. Huber
1997a Menopause Associated Differences in Female Fat Patterning Estimated by Dual Energy X-ray Absorptiometry. *Annals of Human Biology* 24:45–54.

Kirchengast, S., D. Gruber, M. Sator, W. Knogler, and J. Huber
1997b The Fat Distribution Index—A New Possibility to Quantify Sex Specific Fat Patterning in Females. *Homo* 48:285–295.
1998a The Impact of Nutritional Status on Body Fat Distribution Patterns in Pre- and Postmenopausal Females. *Journal of Biosocial Science* 30:145–154.
Kirchengast, S., D. Gruber, M. Sator, and J. Huber
1998b Impact of the Age at Menarche on Adult Body Composition in Healthy Pre- and Postmenopausal Women. *American Journal of Physical Anthropology* 105:9–20.
Knussmann R.
1988 Somatometrie. In *Anthropologie,* R. Knussmann, ed. Pp. 232–285. Stuttgart: Fischer Verlag.
Konner, S. M., and C. Worthman
1980 Nursing Frequency, Gonadal Function and Birth Spacing among !Kung San Hunter-Gatherers. *Science* 207:788–791.
Kooh, S. W., E. Noriega, K. Leslie, C. Müller, and J. E. Harrison
1996 Bone Mass and Soft Tissue Composition in Adolescents with Anorexia Nervosa. *Bone* 19:181–188.
Ley, C. J., B. Lees, and J. C. Stevenson
1992 Sex- and Menopause-Associated Changes in Body Fat Distribution. *American Journal of Clinical Nutrition* 55:950–954.
Manning, J. T., R. Anderton, and S. M. Washington
1996 Women's Waists and the Sex Ratio of Their Progeny: Evolutionary Aspects of the Ideal Female Body Shape. *Journal of Human Evolution* 31:41–47.
Mazes, R. B., H. S. Barden, and E. S. Ohlrich
1990 Skeletal and Body Composition Effects of Anorexia Nervosa. *American Journal of Clinical Nutrition* 52:438–441.
Orphanidou, C. I., L. J. McCargar, C. L. Birmingham, and A. S. Belzberg
1997 Changes in Body Composition and Fat Distribution after Short-term Weight Gain in Patients with Anorexia Nervosa. *American Journal of Clinical Nutrition* 65:1034–1041.
Perel, E., and D. W. Killinger
1979 The Interconversion and Aromatization of Androgens by Human Adipose Tissue. *Journal of Steroid Biochemistry* 10:623–627.
Prentice A. M., and R. G. Whitehead
1987 The Energetics of Human Reproduction. *Symposium of the Zoological Society of London* 57:275–304.
Probst, M., M. Goris, W. Vandereycken, and H. Van Coppenolle
1996 Body Composition in Female Anorexia Nervosa Patients. *British Journal of Nutrition* 76:639–647.
Rebuffe-Scrive, M., J. Eldh, L. O. Hafström, and P. Björntorp
1986 Metabolism of Mammary, Abdominal and Femoral Adipocytes in Women before and after Menopause. *Metbolism* 35:792–797.
Rebuffe-Scrive, M., L. Enk, and M. Crona
1985 Fat Cell Metabolism in Different Regions in Women: Effects of Menstrual Cycle, Pregnancy and Lactation. *Journal of Clinical Investigation* 75:1973–1976.

Rebuffe-Scrive, M., M. Brönnegard, A. Nilson, J. Eldh, J. A. Gustafson, and P. Björntorp
1990 Steroid Hormone Receptors in Human Adipose Tissue. *Journal of Endocrinology and Metabolism* 71:1215–1219.
Short, R. V.
1994 Human Reproduction in an Evolutionary Context. In *Human Reproductive Ecology*, K. L. Campbell and J. W. Wood, eds. *Annals of the New York Academy of Sciences* 709:416–425.
Singh, D.
1993 Adaptive Significance of Female Physical Attractiveness: Role of Waist-to-Hip Ratio. *Journal of Peronal and Social Psychology* 65:293–307.
1994a Body Fat Distribution and Perception of Desirable Female Body Shape by Young Black Men and Women. *International Journal of Eating Disorders* 16: 289–294.
1994b Is Thin Really Beautiful and Good? Relationship between Physical Attractiveness and the Waist-to-Hip Ratio. *Personality and Individual Differences* 16:123–132.
Singh, D., and S. Luis
1995 Ethnic and Gender Consensus for the Effect of Waist-to-Hip Ratio on Judgment of Women's Attractiveness. *Human Nature* 6:51–65.
Singh, D., and R. J. Zambarano
1997 Offspring Sex Ratio in Women with Android Body Fat Distribution. *Human Biology* 69:545–556.
Slosman, D. O., J. P. Casez, C. Pichard, T. Rochart, F. Fery, R. Rizzoli, J. P. Bonjour, A. Morabia, and A. Donath
1992 Assessment of Whole Body Composition with Dual Energy X-ray Absorptiometry. *Radiology* 185:593–598.
Surbey, M. K.
1987 Anorexia Nervosa, Amenorrhea and Adaptation. *Ethology and Sociobiology* 8:s47–s61.
Svendsen, O. L., C. Hassager, and C. Christiansen
1995 Age at Menopause Associated Variations in Body Composition and Fat Distribution in Healthy Women as Measured by Dual Energy X-ray Absorptiometry. *Metabolism* 44:369–373.
Triosi, R. J., A. M. Wolf, J. E. Mason, K. M. Klingler, and G. A. Colditz
1995 Relation of Body Fat Distribution to Reproductive Factors in Pre- and Postmenopausal Women. *Obesity Research* 3:143–151.
Voland, E., and R. Voland
1989 Evolutionary Biology and Psychiatry: The Case of Anorexia Nervosa. *Ethology and Sociobiology* 10:223–240.
World Health Organization (WHO)
1995 Physical Status: the Use and Interpretation of Anthropometry. *Technical Reports Series* 854. Geneva.
Zaastra, B. M., J. C. Seidell, P. A. H. Van Noord, E. R. DeFelde, J. D. F. Habbema, B. Vrieswijk, and J. Karbaat
1993 Fat and Female Fecundity. A Prospective Study of Effect of Body Fat Distribution on Conception Rates. *British Medical Journal* 306:484–487.