Selected auxological aspects of anorexia nervosa – relations of body weight to body height and menstrual cycle

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Abstract

Specific aspects of therapy of eating disorders in pubescent and adolescent girls are related to unfinished biological development in time of severe malnutrition. Namely the issues of 1) exact determination of recommended body weight (target weight, weight for discharge etc.) on the basis of the exact analysis of the weight history, 2) relation between body weight and menstrual cycle (menarche, amenorrhoea and remenorrhoea) and 3) risk of non-realization of the genetic growth potential (status of linear growth and skeletal maturity) are discussed in this article. The article brings the results of the data analysis of 90 inpatients with anorexia nervosa and the tables of the recommended target weight for adolescents with finished linear growth. The authors emphasize the importance of an exact analysis of growth and weight history and of reflection of biological age in girls with eating disorders for successful and reasonable realimentation therapy.

Abbreviations

ED	- eating disorders
AN	- anorexia nervosa
BMI	- body mass index (kg/m^2)
BW	- body weight (kg)
BH	- body height (cm)
SD	- standard deviation
SDS	- standard deviation score

INTRODUCTION

Loss of body weight and altered body composition as results of malnutrition in anorexia nervosa (AN) in pubescent and adolescent girls represent a specific auxological situation (Αυξω = I grow; auxology = multidisciplinary discipline of biomedicine that deals with a complex view of growth and development).

ORIGINAL ARTICLE

Calendar age of paedopsychiatric patient girls with eating disorders (ED) ranges between 9 and 18 years, which up to 15 years in average means girls with unfinished linear skeleton growth. The range contains two biologically different stages: childhood and puberty with substantially different endocrinological characteristics [10,15].

Weight restoration is the backbone of ED therapy [26]. In paedopsychiatry, making a sound weight plan is also complicated because of the unfinished linear skeleton growth; in most of our patients below 15 years of age the target weight is indeed a moving target [26].

Start of puberty comes in contemporary European girls in average at 11 years of age, when growth velocity accelerates and the initial stadia of secondary sexual attributes appear (B2/breast bud, PH2/first pubic hair) [19,25].

Since the start of female puberty (in average since 11 years of age) until the end of growth there are still cca 20 cm (12%) to be grown and cca 20 kg (cca 35%) to be put on weight to reach the average (appropriate) weight. The physiological range of the puberty onset is generally accepted as 11±2 years, i.e. 9 to 13 years of calendar age. Menarche is the final completion of physiological puberty that follows in the fixed algorithm of sexual maturation in average 2 to 2.5 years after the initial pubertal stage of breast B2. Menarche is characterized by already markedly developed breasts with the areola and the nipple elevated above the level of the breast (B4); pubic hair is also in an advanced stage (PH4). According to the results of both recent national anthropological studies (1991 and 2001), the median menarcheal age in the Czech Republic is 13 years. Repeatedly, 50% of responding girls stated their first menstruation before their 13th birthday and 50% after their 13th birthday (95% confidency interval: 12.3 – 13.8 years) [16]. The range of 11–15 years of calendar age is most usually reported as the normal variability of menarche.

The age of menarche most significantly correlates with the year of the highest growth velocity (growth spurt), and with the degree of skeletal maturity (bone age). The growth spurt in contemporary European girls occurs one year before menarche, i.e. in average shortly before their 12th birthday. In the set of relations among the essential milestones of puberty this is one of the strongest known biological correlations and it is concluded that the genetic system that controls skeletal maturity is also the genetic determinant of the age of menarche [17].

A girl in the time of her menarche has only a small residual growth potential, her body height is at 95% of its final value [6]. The maximum increase of all significant bone variables (e.g. bone density, dimensions, mineral concentration) can be observed in the period of 2 years (± 1 year) around the age of menarche [18]. The known relation of chronic malnutrition and risk of osteoporosis follows apparently; less known is the risk of non-realization of genetic growth potential in ED patients with unfinished linear growth [13].

Bone age assessed at menarche has in healthy girls only a very small variability of one year between 12.5 and 13.5 years. It can be assessed very exactly on an X-ray image of the left hand and the distal part of the forearm, optimally using an elaborate method TW3 [33] or with the less exact method of Greulich and Pyle [9]. In the time of menarche, there is a fusion of metaphyses and epiphyses of distal phalangae (Figure 1): according to TW3 classification of stages of the hand skeleton ossification this is the incommutable stadium H, what can be called "perimenarcheal ossification".

From the biological point of view, menarche is further characterized very significantly by body composition: first menstruation is limited by the amount of body fat that plays a significant role in the value of perimenarcheal body weight. Empirically, and in a number of studies, earlier menarche is observed in overweight and obese girls and delayed menarche is observed in slim girls – it is known that BMI correlates better with biological age than with calendar age [5]. Minimum proportion of fat (fatness) at menarche is reported to be cca 17% of body weight [7]. In average, the proportion of fat in the whole body weight necessary to maintain and restore (remenorrhea) the menstrual cycle in post-pubertal girls is cca 22% [2,23].

Despite the decrease of menarcheal age by cca 4 years since the end of 19th century, average body weight at menarche (47.5±0.5 kg) has not significantly changed [21]. The contemporary average perimenarcheal Czech girl (13 years, cf. above) measures 160 cm and weighs 48 kg; median BMI of contemporary 13 years old Czech girls is 18.8 kg/m^2 [4]. Secondary amenorrhea, a significant diagnostic marker of AN, occurs according to our long experience at reduction of body weight under 10th percentile of weight for height (evaluated according to empiric percentiles weight-height of the Czech 1991 standard in girls older than 14.5 years) [4]. It is often reported that secondary amenorrhea comes at the loss of 10–15% of weight [11]. The cut-off point of weight normality is usually marked at 85% of recommended weight [27]; in postmenarcheal girls with finished growth it is BMI below 18 kg/m^2 [29].

According to literature and also to our experience, remenorrhea, or restoration of menstrual cycle, is associated with a higher level of body weight than was that when secondary amenorrhea occurred – by cca 2 kg more [8] and this weight can be derived from the value of body weight at the occurrence of amenorrhea [31]. According to many authors, average weight for remenorrhea is cca 90% of standard weight [8,20].

Patients with primary amenorrhea clearly constitute a different situation: we consider exact assessment of biological age in these circumstances a most important part of a rational therapeutic scheme.

According to the degree of ossification of the hand skeleton, we have to differentiate between girls with physiological primary amenorrhea, e.g. in constitutional delay of growth and puberty (physiological situation when e.g. at 15 years of calendar age a girl's bone/biologi-

cal age amounts only to 13 years and she just reaches her menarche) and patients with primary amenorrhea due to severe malnutrition (pathological situation characteristic e.g. for a postpubertal girl with AN, whose hand X-ray displays already a postmenarcheal ossification).

MATERIALS AND METHODS

In years 2000–2005, on psychiatricians' requests we routinely examined in the anthropological laboratory of the Paediatric Clinic of 2nd Faculty of Medicine, Charles University and Faculty Hospital Motol, 90 patients with AN younger than 15 years (10.7–15.0 years, i.e. within the range of physiological puberty, cf. above). The patients were hospitalized at the Paedopsychiatric Clinic and in all cases the consent of their parents was obtained. Within the auxological examination, growth diagnosis and biological age were assessed in all patients. Based on an exact analysis of weight history, and with respect to current growth status and biological age of the patients, we determined their discharge weight and expected weight for menarche or remenorrhea. In all patients we assessed their body height, body weight, left mid-arm circumference (a common marker of nutritional status) and their frontooccipital circumference. With a calliper we measured the thickness of the four basic skinfolds that correlate with the total amount of body fat (bicipital, tricipital, suprailiacal and subscapular skinfolds). We recorded exact data about menarche, and about the duration of secondary amenorrhoea. According to Tanner's classification, we assessed the degree of sexual maturation and in indicated patients also the degree of their skeletal maturation (bone age) using the TW3 method based on an X-ray image of their left hand [33].

Nutritional status was assessed using the percentiles and standard deviation score (SDS) of body weight for height and using the body mass index (BMI). We note that in individuals with unfinished linear growth, it is not possible to use absolute values of BMI as it is common in adults: in the studied age interval, normal BMI grows by 5 points – between 10th and 18th year of age, median BMI increases from 17 to 22 (Figure 2) [4].

Processing BMI and weight for height (BH/BW) values using our own computer program Growth 2 [12], we used recent Czech reference data from year 1991 [3]. By a consensus of paediatric endocrinologists (Guidelines for preventive check-up, supplement to Postgradual Medicine 2/2005) these reference data are recommended for assessments in current population rather than the more recent reference data from year 2001 (because of the risk of weakening the norm due to increasing obesity in Czech children).

RESULTS

We evaluated the data of 90 patients with AN younger than 15 years (median 13.8, minimum 10.7 years) hospitalized in the Paedopsychiatric Clinic of 2nd Faculty of Medicine, Charles University and Faculty Hospital Motol in years 2000–2005. 34 of the girls were premenarcheal (38%); 56 postmenarcheal (62%). Basic characteristics of the patient groups are included in Table 1–4. Descriptive statistics of basic anthropometric data of the whole set of 90 girls show that they were of average height (SDS BH = –0.1±0.9). Before the onset of the disease, the patients had in average an appropriate body weight, their premorbid SDS BMI was 0.5±1.2, which is the 56th percentile of current Czech BMI norm (average weight for height was at the 51th percentile of the norm).

Exact assessment of the patients' auxological parameters was done in average on the 7th day of their hospital stay (median = 7) when their weight was in average by 1.6 kg higher than at admission. At the examination (cf. Table 1), SDS BMI was in average –1.5 and SDS of mid-arm circumference was in accord with BMI also –1.5. Size of the neurocranium (by head circumference) was totally on average (SDS = –0.1), significant alteration of voluminal brain growth as result of malnutrition was not detected in our group.

Weight gain in their first week of hospitalization was in average 1.6 kg, in two weeks 2.6 kg, in the first month 4.4 kg and over all hospitalization (average 69 days, median 67 days) it was in average 8.1 kg (descriptive statistics cf. Table 2). At discharge, the patients' values of

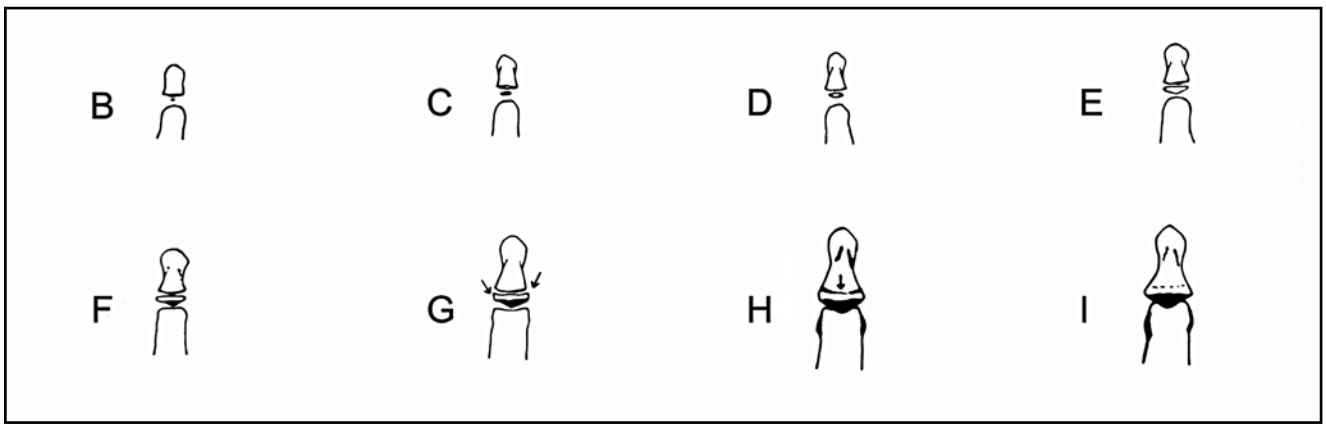

Figure 1. Ossification stadia of distal phalangae (B–I) according to the TW3 method [33]. Transition G - H is the perimenarcheal ossification.

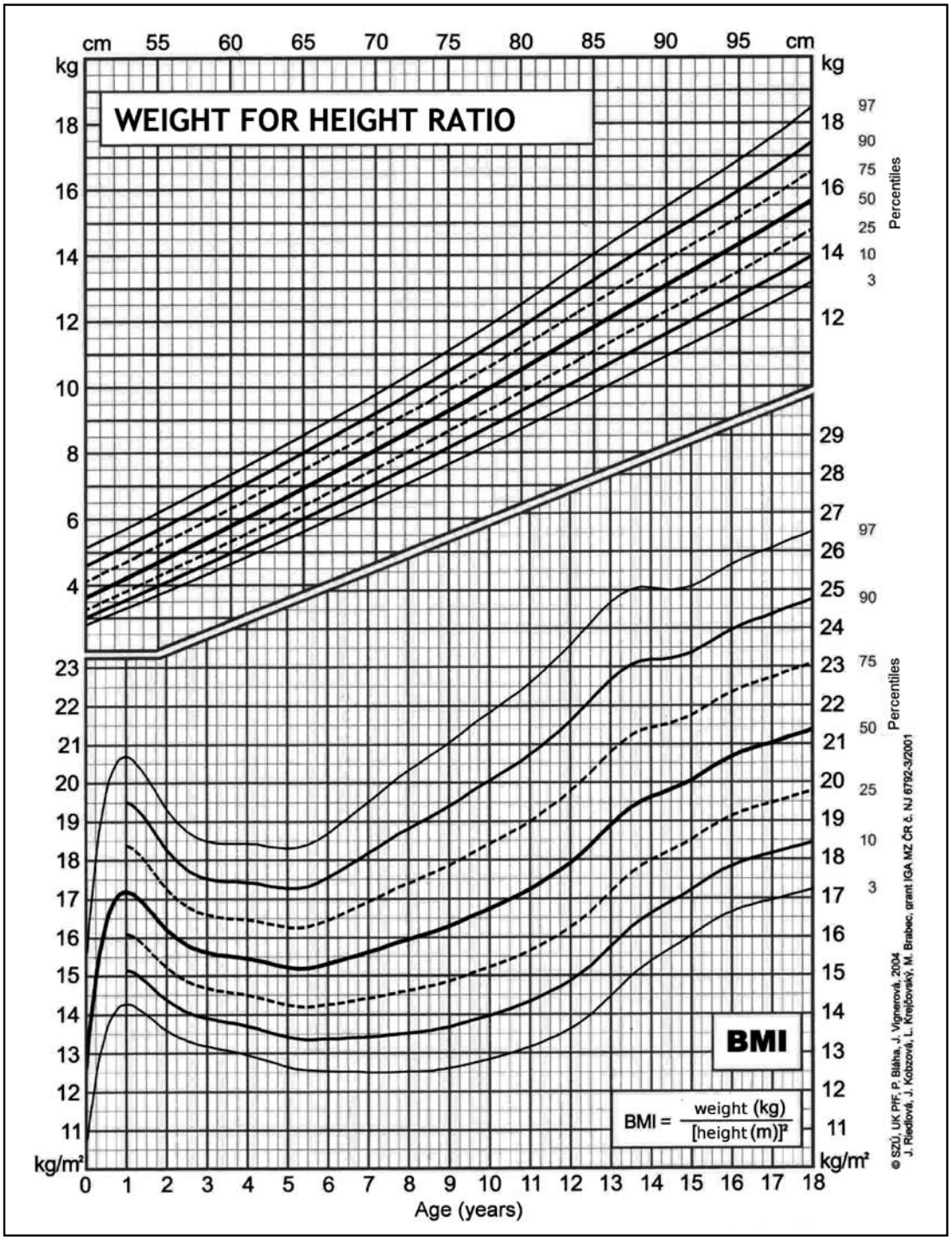

Figure 2. Percentile graph of BMI in Czech girls - Czech reference data 1991 [3].

body weight and of BMI were insignificantly below the norm (SDS BW = –0.6; SDS BMI = –0.7, cf. Table 1)

Premenarcheal girls (cf. Table 3) were in average 13.1 years old (SD = 1.0, 10.7 to 15 years) and they were of average body height (SDS BH = –0.4±0.7). Before the onset of the disease they had a totally average (appropriate) body weight (SDS BMI = 0.1±1.1). The average duration of their body wasting was 10.4 (±6.8) months and their nutritional state at admission according to BMI was very significantly below average (SDS BMI = –1.7±0.6). In realimentation during the hospitalization, the patients reached in average SDS BMI = –0.9 (SD = 0.5), i.e. 21st percentile of weight for height (SD = 16). The length of hospital stay of premenarcheal girls was on average 72 days (±30, min = 23, max = 155 days).

Postmenarcheal girls (cf. Table 4) were in average 14.2 years old (SD = 0.6 years, 12.3 to 15 years) and they were (as well as the premenarcheal girls) of average body

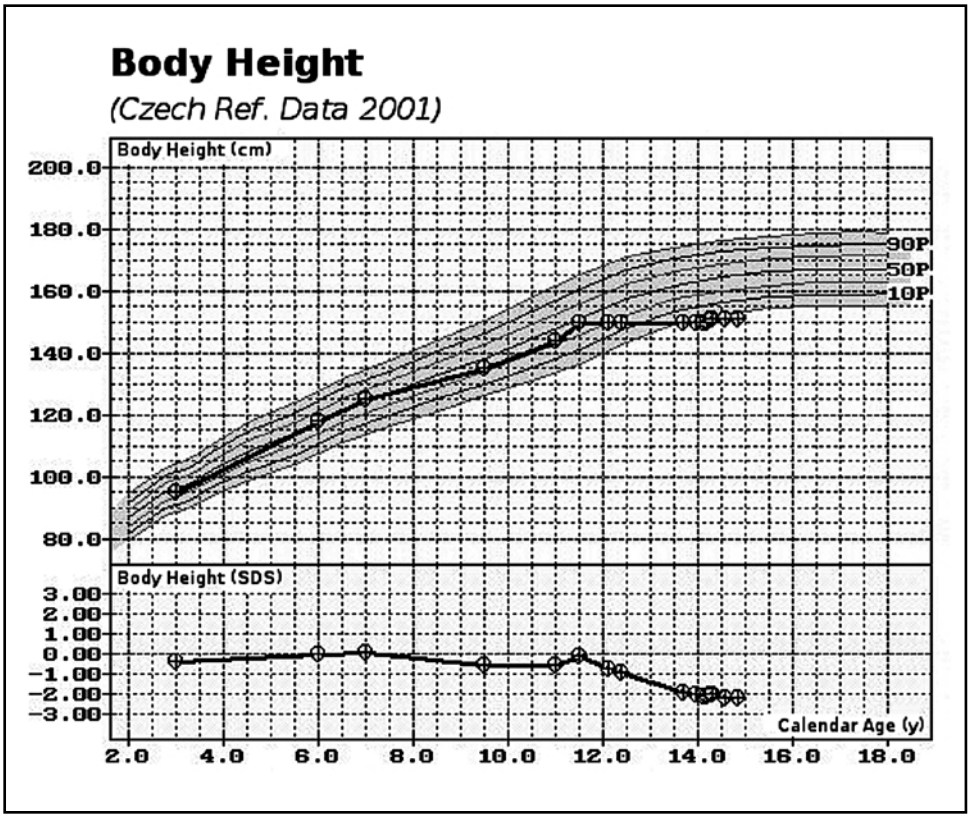

Figure 3. Body height (cm) and SDS of body height – irreversible growth suppression in a patient with an unfavourable course of AN.

Table 1. Selected characteristics of the patients with AN.

n = 90	average	SD	median	min	max
Age (years)	13.8	0.9	13.8	10.7	15.0
Duration of body wasting before hospitalization (months)	11.5	8.0	10.0	1.0	50.0
Premorbid BMI (SDS)	0.5	1.2	0.3	–1.5	4.0
Body height (SDS)	–0.1	0.9	–0.1	–2.7	2.1
Body weight SDS)	–1.3	0.7	–1.3	–3.3	0.2
BMI (SDS)	–1.5	0.6	–1.6	–3.1	–0.1
Mid-arm circumference (SDS)	–1.5	0.9	–1.5	–3.6	0.4
Frontooccipital circumference (SDS)	–0.1	0.9	–0.2	–1.8	2.8
Body weight at discharge (SDS)	–0.6	0.6	–0.6	–2.5	0.8
BMI at discharge (SDS)	–0.7	0.5	–0.7	–2.0	0.4

SD = standard deviation, SDS = standard deviation score (standardized value according to age and sex)
SDS = 0.0 = average value = 50th percentile
SDS = +2.0 = upper limit of norm = 98th percentile
SDS = –2.0 = lower limit of norm = 2nd percentile

Table 2. Increase of body weight (kilograms) during hospitalization (average = 69 days).

n = 90	average	SD	median	min	max
1 week	1.6	1.5	1.6	–2.3	5.0
2 weeks	2.6	1.4	2.6	–1.5	5.7
1 weeks	4.4	1.8	4.5	–1.5	10.1
10 weeks	8.1	3.3	7.8	0.7	16.6

Table 3. SDS BMI in premenarcheal patients.

n = 34	average	SD	median	min	max
SDS BMI (premorbid)	0.1	1.1	–0.3	–1.5	3.0
SDS BMI (at admission)	–1.7	0.6	–1.7	–3.1	–0.1
SDS BMI (at discharge)	–0.9	0.5	–0.9	–2.0	0.2

Table 4. SDS BMI in postmenarcheal patients.

n = 56	average	SD	median	min	max
SDS BMI (premorbid)	0.7	1.2	0.6	–1.3	4.0
SDS BMI (at admission)	–1.5	0.6	–1.5	–2.7	–0.1
SDS BMI (at discharge)	–0.6	0.5	–0.6	–1.7	0.4

height (SDS = 0.2±0.9). Their weight before the onset of disease was insignificantly above the average (SDS BMI = 0.7±1.2). Before admission, in average after 12.2 (±8.7) months of body wasting, their BMI decreased by 2.2 SD, average SDS BMI at admission was –1.5 (±0.6). Average length of stay was 67 days (±23.1, min = 16, max = 130 days) and at discharge, their average SDS BMI was –0.6 (±0.5), i.e. 21st percentile of weight for height (SD = 13).

The weight plan of all our hospitalized patients (discharge and target weight) was set using the algorithms stated below (cf. Conclusion and Table 5–7), with respect to their biological age.

DISCUSSION

The results of the analysis of auxological data of 90 patients with AN under 15 years age (10.7 to 15.0 years) have proven that these are primarily girls with average body height and of average (appropriate) body weight before the onset of the disease, their premorbid relation of weight for height being within limits of stricter standard. We do not confirm the findings of Swenne [32], who finds overweight before the onset of disease in adolescent AN patients. Our AN patients were admitted in hospital in average 11.5 months (SD = 8.0) after the beginning of

Table 5. Body weight (BW) in an ED girl with finished growth.

BH=167 cm (50th P)	BW	BMI	% average BW	BW/BH evaluation
50th percentile BW/BH	58 kg	21.0	100%	Premorbid state (average weight)
25th percentile BW/BH	53 kg	19.0	91%	Clinically insignificantly below the average relation
20th percentile BW/BH	52 kg	18.7	90%	Remenorrhea
10th percentile BW/BH	50 kg	18.0	86%	Clinically significant underweight (secondary amenorrhea)
3rd percentile BW/BH	46 kg	16.5	<80%	Clinically highly significant hypothrophy

(BH = 167 cm = 50th percentile, resp. 0.00 SD, Czech reference data, 2001),

Table 6. Body weight (BW) in an ED girl with finished growth.

BH=173 cm (85th P)	BW	BMI	% average BW	BW/BH evaluation
50th percentile BW/BH	61 kg	20.4	100%	Premorbid state (average weight)
25th percentile BW/BH	57 kg	19.0	93%	Clinically insignificantly below the average relation
20th percentile BW/BH	55 kg	18.5	90%	Remenorrhea
10th percentile BW/BH	53 kg	17.7	87%	Clinically significant underweight (secondary amenorrhea)
3rd percentile BW/BH	50 kg	16.7	<82%	Clinically highly significant hypothrophy

(BH = 173 cm = 85th percentile, resp. +1.00 SD, Czech reference data, 2001).

Table 7. Body weight (BW) in an ED girl with finished growth.

BH=160 cm (15th P)	BW	BMI	% average BW	BW/BH evaluation
50th percentile BW/BH	53 kg	20.7	100%	Premorbid state (average weight)
25th percentile BW/BH	49 kg	19.0	93%	Clinically insignificantly below the average relation
20th percentile BW/BH	48 kg	18.8	90%	Remenorrhea
10th percentile BW/BH	46 kg	18.0	87%	Clinically significant underweight (secondary amenorrhea)
3rd percentile BW/BH	42 kg	16.4	<80%	Clinically highly significant hypothrophy

(BH = 160 cm = 15th percentile, resp. –1.00 SD, Czech reference data, 2001).

body wasting. The difference between their weight before the onset of disease and admission weight was in average 12.2 kg; in average 24% of body weight. The observed degree of underweight (76% of recommended weight) is according to international criteria in the range of severe pathological malnutrition; the cut-off of normal weight is usually (according to diagnostic criteria of ICD-10 and DSM-IV) marked at 85% of recommended weight [1].

Weight gain was in average 1.6 kg in the first week of hospitalization, 2.6 kg in two weeks, 4.4 kg in the first month and until discharge (average 69 days, median 67 days) it was in average 8.1 kg (descriptive statistics cf. Table 2). At discharge, values of patients' body weight and BMI were insignificantly below average (SDS BW = –0.6; SDS BMI = –0.7, cf. Table 1). The observed (empirical) algorithm of weight restoration in hospitalized AN girls can be viewed and recommended as realistic. It is also in accord with published data; weight gain is most often reported between 0.9 and 1.4 kg per week [20,24,27].

The observed age of menarche in our 56 postmenarcheal patients (average = 12.1 years, SD = 1, median = 12) is in accord with published data [28] significantly below standard. Early onset of puberty can be valued as a factor affecting the occurrence of ED [28,30]. It is generally known that rejection of puberty or of attributes of maturity is one of the characteristics of AN patients. Primary or secondary amenorrhea does not obligatorily mean a stress factor for AN patients. According to our long-term experience it is very productive from the therapeutic point of view to inform the patient about the risk of growth suppression, or of non-realization of her residual genetic growth potential. In very severe, protracted anorexias we repeatedly found this condition. For instance, the patient X.Y.'s final height prediction according to her premorbid body height and the height of her parents was 168 cm (cf. Figure 3). Her height prediction (verified by hand X-ray) after three years of AN, however, is only 150 cm. In this patient with a history of AN since 11.5 years of age (treated in our hospital only since 14.5 years age) we found an irreversible growth suppression and non-realization of her hereditary growth potential [cf also 13,22].

CONCLUSION

From our long-term experience with hundreds of paedopsychiatric ED patients it follows that a most important part of the therapeutic scheme in both hospitalized patients and outpatients is besides a precise weight history and an exact weight plan also the assessment of biological age (premenarcheal or postmenarcheal situation) and an exact growth diagnosis. Patients' biological age is tightly connected to their residual genetic growth potential, i.e. to their actual and final height. Therefore, the algorithm for setting the recommended target weight must differentiate between premenarcheal and postmenarcheal girls and must take into account also their biological age and body height. As the weight restoration is indeed the backbone of ED therapy, psychiatrists should work with exact auxological data from paediatricians.

For good diagnosis of puberty, a healthy girl in the time of her menarche is characterized by:

a) sexual maturation score B4, PH4 (on Tanner's scale of breast and pubic hair development, cf. above)
b) age cca 1 year after the growth spurt (95% of final height)
c) bone age of 13±0.5 years (fused epiphyses and diaphyses of distal phalangae of hands, cf. above)
d) at least 25th percentile of weight for height (median BMI of contemporary 13 year old Czech girls is 18.8; a contemporary Czech perimenarcheal girl is 160 cm high and weighs 48 kg).

To premenarcheal hypotrophic girls with primary amenorrhea and with indicators of perimenarcheal situation we recommend to reach at least the 25th percentile of weight for height (average relation at menarche is at the 50th percentile, cf. Introduction) and we set the minimum discharge weight at the 10th percentile of BW/BH.

To postmenarcheal patients with secondary amenorrhea we recommend to reach the 20th percentile of weight for height (relation needed for remenorrhea, corresponds to 90% of appropriate weight or to BMI over 18.5, cf. Table 5–7) and we set their discharge weight at the 15th percentile of BW/BH.

For postmenarcheal girls with finished linear growth we sum our empirical findings in Table 5–7 with differentiated recommendations for short (160 cm), average (167 cm) and tall (173 cm) girls.

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