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Menarcheal Onset Is Associated with Body Composition Parameters but Not with Socioeconomic Status

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A B S T R A C T

In the present study the menarcheal status (pre-or postmenarcheal), body composition, weight status, and socioeconomic parameters such as type of school and parental educational level as of 1752 female adolescents ageing between 12 and 18 years (x=14.6) from rural areas of Eastern Austria were documented. Furthermore the association patterns between body composition, socioeconomic parameters and menarcheal status were analyzed. It turned out, that body composition parameters such as BMI, lean body mass and absolute and relative fat mass were significantly associated with menarcheal status. Postmenarcheal girls were taller and exhibited a higher weight status, a higher absolute and relative amount of fat mass and a higher amount of lean body mass than their premenarcheal counterparts of the same age. In contrast to the significant association between body composition and menarcheal status, no significant impact of educational level on menarcheal status, indicating socioeconomic status could be documented.

***Key words**: menarche, body composition, weight status, socioeconomic parameters*

Introduction

Sexual maturation, the transition from prereproductive to reproductive phase, is a dynamic biological process, characterized by visible changes in stature, body composition and body proportions[1–3]. On the other hand, pubertal maturation is beside growth the most reliable indicator of health status among adolescents[4]. This is especially true of female pubertal maturation, in particular of the age at menarche. According to Bielicki et al.[5] menarcheal age serves as a reliable instrument with which the effectiveness of social policies practiced may by measured. Although a major part of the enormous interindividual variation found in the age at menarche, is due to genetic factors, social factors seem to be also of special importance of the timing of pubertal maturation in the female sex. During the late 19th and the whole 20th century age at menarche has decreased gradually. This trend was observed for Europe but also for many other parts of the world, where an improvement of the socioeconomic situation, leading to improved nutrition and hygiene resulted in the well described secular trend[4–9]. The association between improved nutritional status and decreasing age at menarche resulted in the introduction of the so called Frisch hypothesis or hypothesis of critical body weight by Rose Frisch during the early seventies[10,11]. The original hypothesis – that menarcheal onset was associated with the attainment of a »critical weight« – was plagued by faulty statistical analyses and extended critique in the literature. Today the Frisch hypothesis is obsolete and ovarian function seems to be associated with the energy balance[12]. However, up to now the strong association between body composition parameters and pubertal onset is reported in many studies[6,13,14]. Puberty seems not only to induce typical changes in body composition, a typical kind of body compositions seems to be essential for pubertal onset. However, body composition and weight status during prepuberty and puberty are also associated strongly with socioeconomic factors[2,8]. So socioeconomic and biological factors are interlinked and influence female pubertal transition independent and in interaction. The aim of the present paper was to analyze the impact of biological factors (body composition), socioeconomic factors (educational level of girls and parents) and behavioral factors (eating behavior) on the timing of menarche.

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Materials and Methods

Probands

Data collection took place between April 2001 and October 2002 in 16 schools of the so called »Weinviertel«, the north eastern part of Lower Austria. This exceptionally rural area is located between Vienna in the south and the international border to Slovakia and the Czech Republic in the north and the east. 1752 adolescent females ageing between 11 and 18 years (x=14.6±2.1) were enrolled in the present study. Absolute and relative age distribution is shown in Table 1.

TABLE 1
ABSOLUTE AND RELATIVE AGE DISTRIBUTION OF THE SUBJECTS ENROLLED IN THE PRESENT STUDY

Age group	Absolute (n)	percentage
12 years	310	17.7%
13 years	276	15.8%
14 years	332	18.9%
15 years	231	13.2%
16 years	255	14.6%
17 years	196	11.2%
18 years	152	8.7%

Socioeconomic status

Since it is forbidden to collect any personal data regarding family income from schoolchildren in Austria, we decided us to use the educational level of the parents and the school type as parameters of socioeconomic status. According to the type of school we distinguished between the grammar school (Gymnasium), indicating a higher level of education and a higher social status, especially in Austrian rural areas and the public comprehensive school (Hauptschule), indicating a lower educational level for the probands ageing between 11 and 14 years. The proband group older than 14 years were divided in second level grammar school or high school (Gymnasium) and technical colleges. 749 subjects (42.8%)were visiting comprehensive schools or technical colleges, 1003 subjects (57.2%) were visiting grammar schools and high schools. Parental educational level was documented for mother and father separately. We classified parental education as follows: in only comprehensive school without further education, comprehensive school with additional 3 year professional training, technical college, high school level, college level, university degree.

Age at menarche

Data regarding menarche were collected by means of status quo method. All girls were interviewed and asked if their menarche had already taken place at the time of interview. Within the postmenarcheal group age at menarche was determined by retrospective method. Furthermore the regularity of the cycle and use of hormonal medication or hormonal contraception were documented.

Eating behavior

Eating behavior was estimated by an structured interview based on the eating behavior and body image questionnaire developed by Buddeberg-Fischer[15] for adolescents in Switzerland.

Weight status and somatometrics

Stature was measured with a Martin anthropometer to the nearest millimeter according to the technique described by Knussmann[16]. Weight was recorded with a scale precise to ±100 g. The probands wore only under wear. Weight status was determined using the body mass index (BMI) kg/m^2. BMI is increasingly used for the diagnosis of underweight, overweight and obesity during childhood and adolescence[17]. In the present study the percentiles of the body mass index published by Kromeyer-Hauschild et al.[18] for Central Europe were used. According to Kromeyer-Hauschild et al.[18] and the recommendations of the European Childhood obesity group[19] we used the 10 percentile to define underweight, Percentile 10 to percentile 90 to define normal weight, percentile 90 to percentile 97 to define overweight and a BMI above 97 percentile to define obesity.

Body composition

Body composition was determined using a TBF 310 Body composition analyzer (Tanita Corp.) according to bioelectrical impedance method (BIA). In this BIA system two foot-pad electrodes are incorporated into a precise electronic scale. Impedance of the lower limbs and body weight are measured simultaneously. While the proband is standing on the scale. The electrodes are in contact with soles and heels of both feet. Bioelectrical impedance was measured with 4 terminals and uses a standard of 50 kHz – 0.8 mA sine wave constant current. The voltage drop was compared with the heel electrodes. The computer software in the machine then used the measured resistance, the programmed probands gender, group (child, adult, athlete) and stature height and the measured weight to calculate the body density based on previously derived equations obtained from regression with under water weighing. This was then applied automatically to the standard densiometric formula according to Brozek to calculate the fat percentage. The following parameters were determined: Absolute lean body mass in kg (LBM), absolute fat mass in kg (FM) and total fat percentage (fat%). The coefficient of variation for within day impedance measurement was 0.9% and between days coefficient of variations was 2.1%[20,21]. Nunez et al.[20] described the leg to leg pressure contact electrode BIA system as comparable to conventional arm to leg electrode BIA. Furthermore this technique of body composition analysis offers the advantage of increased speed and easy transportation. In the present study this method was especially useful because data collection took place in schools and the probands had only to step on the scale.

Statistical analyses

Statistical analyses were carried out by means of SPPS program version 11.0. After computing descriptive statistics (means, Standard deviations, relative frequencies), the statistical significance of group differences was tested by means of student t-tests and Chi-square analyses. Additionally binary logistic regression analyses were carried out.

Results

Menarcheal age and menstrual cycle

The mean age of menarche was 12.4 years ranging from 9 to 16 years. The absolute and relative amount of pre- and postmenarcheal girls according to age group is presented in Table 2. As to be seen in Table 2 and Figure 1 at the age of 13 more than 65% of the probands were already postmenarcheal. At the age of 16 nearly all probands had reached postmenarcheal status. 55.5% of the postmenarcheal girls reported regular cycles, 14.7% of the probands used hormonal contraceptives at the time of investigation.

TABLE 2
ABSOLUTE AND RELATIVE AMOUNT OF PRE- AND POSTMENARCHEAL GIRLS ACCORDING TO AGE GROUP

Age group	Premenarcheal	Postmenarcheal
12 years	223 (73.9%)	87 (28.1%)
13 years	81 (29.5%)	194 (70.5%)
14 years	37 (11.2%)	294 (88.8%)
15 years	5 (2.2%)	226 (97.8%)
16 years	1 (0.4%)	254 (99.6%)
17 years	1 (0.5%)	195 (99.5%)
18 years	0 (0%)	152 (100%)

Menarche and body build

Postmenarcheal girls were significantly taller and heavier than their premenarcheal counterparts. This was true of all girls ageing between 11 and 14 years. At the age of 15 years postmenarcheal girls were also taller and heavier than premenarcheal ones, however, these differences were not of statistical significance. Regarding body mass index significantly higher values were found for all age groups with the exception 11 year old girls. The comparison of body composition parameters yielded also significant differences between premenarcheal and postmenarcheal girls. Postmenarcheal girls surpassed their premenarcheal counterparts in lean body mass, absolute fat mass and fat percentage (Tables 3 and 4).

These findings were corroborated by the results of the binary regression analyses. (Table 5) Body mass index, fat percentage and lean body mass were significantly pos-

TABLE 3
COMPARISON OF SOMATOMETRIC FEATURES BETWEEN PRE- AND POSTMENARCHEAL GIRLS

	Premenarcheal	Postmenarcheal	t value
	X (SD)	X (SD)	
11 years			
Stature (cm)	149.6 (6.2)	157.1 (5.9)	3.16 p<0.003
Body weight (kg)	39.8 (10.3)	50.2 (10.4)	2.64 p<0.01
BMI (kg/m^2)	17.59 (3.59)	20.23 (3.58)	1.91 n.s.
12 years			
Stature (cm)	154.5 (6.9)	158.9 (6.6)	4.82 p<0.001
Body weight (kg)	45.9 (10.8)	53.8 (12.8)	5.13 p<0.001
BMI (kg/m^2)	19.12 (3.96)	21.17 (4.05)	3.81 p<0.001
13 years			
Stature (cm)	158.4 (6.3)	161.9 (6.5)	4.06 p<0.001
Body weight (kg)	46.5 (9.4)	54.2 (10.9)	5.52 p<0.001
BMI (kg/m^2)	18.48 (3.10)	20.60 (3.41)	4.83 p<0.001
14 years			
Stature (cm)	158.5 (5.4)	163.2 (5.3)	5.06 p<0.001
Body weight (kg)	48.3 (9.4)	55.6 (10.9)	3.89 p<0.001
BMI (kg/m^2)	19.16 (3.41)	20.84 (3.77)	2.58 p<0.01
15 years			
Stature (cm)	164.0 (6.4)	164.1 (5.9)	0.21 n.s.
Body weight (kg)	48.7 (4.7)	56.9 (10.1)	1.81 n.s.
BMI (kg/m^2)	18.11 (1.23)	21.12 (3.21)	5.10 p<0.003

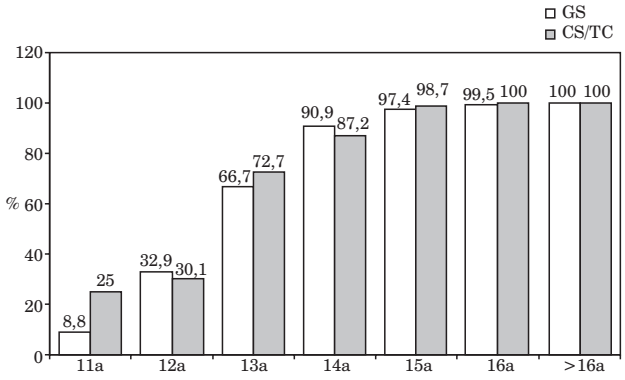

Fig. 1. Percentage of postmenarcheal girls according to age group and school type. GS – Grammar school, CS/CT=Comprehensive school/Technical collage.

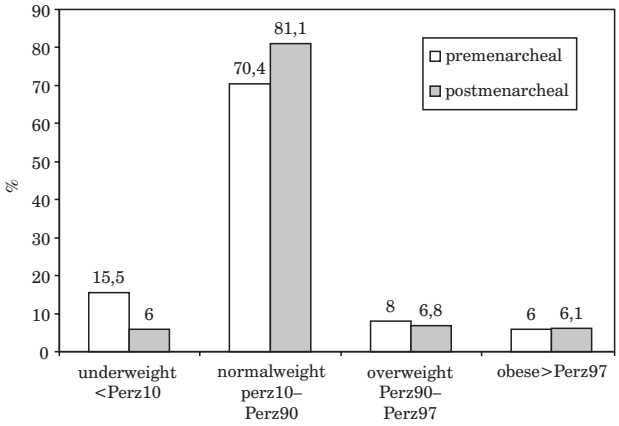

Fig. 2. Weight status distribution according to menarcheal status.

TABLE 4
COMPARISON OF BODY COMPOSITION PARAMETERS BETWEEN PRE- AND POSTMENARCHEAL GIRLS

	Premenarcheal	Postmenarcheal	t value
	X (SD)	X (SD)	
11 years			
Lean body mass (kg)	31.7 (4.3)	36.9 (4.5)	3.18 p<0.002
Fatmass (kg)	8.0 (6.7)	13.2 (6.1)	2.05 p<0.05
Fat%	17.9 (10.1)	25.1 (7.0)	2.50 p<0.02
12 years			
Lean body mass (kg)	35.9 (4.8)	39.4 (4.9)	5.17 p< 0.001
Fatmass (kg)	9.9 (6.6)	14.4 (8.2)	4.7 p <0.001
Fat%	19.8 (8.6)	25.3 (7.6)	4.91 p<0.001
13 years			
Lean body mass (kg)	37.2 (4.2)	40.2 (4.4)	5.31 p<0.001
Fatmass (kg)	9.4 (5.9)	14.0 (7.5)	4.94 p<0.001
Fat%	18.8 (7.9)	24.5 (8.0)	5.36 p <0.001
14 years			
Lean body mass (kg)	38.4 (3.5)	40.9 (4.4)	3.41 p<0.001
Fatmass (kg)	9.9 (6.7)	14.6 (7.6)	3.61 p<0.001
Fat%	18.7 (9.7)	25.1 (7.7)	4.58 p<0.001
15 years			
Lean body mass (kg)	39.4 (3.1)	42.2 (4.2)	1.46 n.s.
Fatmass (kg)	9.3 (2.7)	14.7 (6.9)	1.79 n.s.
Fat%	18.9 (4.3)	24.9 (6.6)	3.06 p<0.05

itively associated with postmenarcheal status. Furthermore menarcheal status was significantly associated with the weight status (χ^2=36.7, p<0.0001). The percentage of underweight was extremely high (15.5%) among premenarcheal girls. In contrast, the percentage of normal weight among premenarcheal girls was significantly lower than among postmenarcheal girls. Regarding overweight and obesity no marked differences between pre- and postmenarcheal girls were observable. (Figure 2)

Menarche and eating behavior

The analyses of the interaction between menarcheal status and eating behavior yielded a significant association between daily counting of calories as well as dieting and caloric restriction and menarcheal status (p<0.001). Premenarcheal girls reported a higher frequency of dieting, caloric restriction and daily counting of calories than their postmenarcheal counterparts of the same age. (Fig-

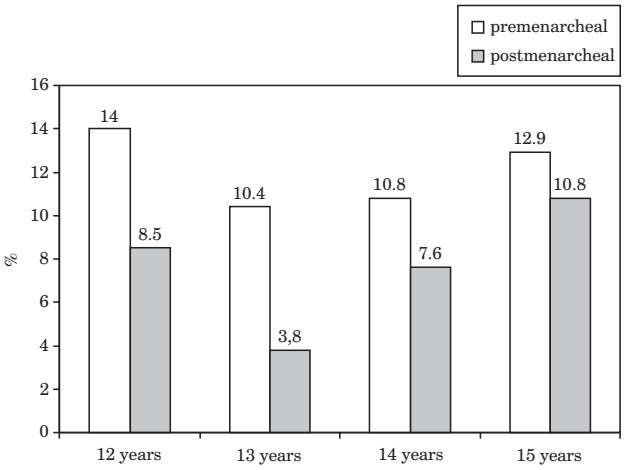

Fig 3. Menarcheal status and diet for weight reduction during the year prior to the investigation.

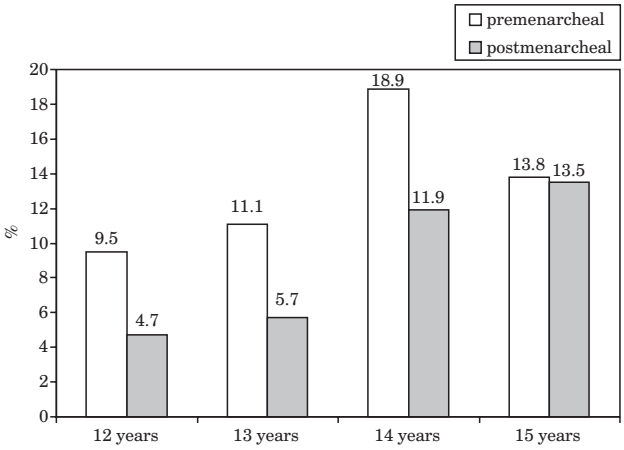

Fig. 4. Menarcheal status and daily calorie counting according to age group.

ures 3 and 4). Weight controlling practices such as frequent stepping on scale, were not significantly related with menarcheal status.

Menarche and socioeconomic parameters

No significant associations between menarcheal status and parental educational level and school type were observable. As to be seen in Figure 1, only at the age of eleven years a marked difference in the percentage of postmenarcheal girls according to school type was observable: the percentage of postmenarcheal girls in comprehensive schools was nearly three times higher than in grammar schools. With increasing age however, these differences diminished dramatically, resulting only in an insignificant association. Regarding the association between mean menarcheal age and socioeconomic parameters no significant differences were observed. Girls visiting comprehensive school experienced their first menstrual bleeding slightly earlier than their counterparts visiting grammar schools or high schools (x=12.3 years versus x=12.5 years). menarche These findings were also corroborated by the results of the binary logistic regression analyses. According to the results of these analyses neither maternal or paternal educational level nor school type were significantly related to menarcheal status. (Table 5)

Discussion

Timing and tempo of sexual maturation are regulated by the functional maturation of the adrenal glands and the hypothalamic–pituitary-gonadal (HPG) axis resulting in an increased secretion of sex hormones during pubertal period. In particular the reactivation of pulsatile secretion of pulsatile gonadotropin releasing hormone leads to the secretion of gonadotropines by the anterior pituitary gland and the increased production of sex steroids in the ovaries and in ovarian follicular development. These hormonal activation induces the development of secondary sexual characteristics, peak height velocity, widening of the pelvis and the changes in body composition and finally in the menarche and the establishment of cyclic ovarian function[22,23]. The timing of sexual maturation is influenced by both genes and environment. An improvement of the socioeconomic environment during the last 150 years had led to a marked de-

TABLE 5
THE IMPACT OF MENARCHEAL STATUS ON BODY COMPOSITION PARAMETERS ESTIMATED BY LOGISTIC REGRESSION ANALYSIS (PREMENARCHEAL VERSUS POSTMENARCHEAL)

Variable	Coefficient	Significance	Confidence interval
BMI (kg/m^2)	0.190	p<0.009	0.717–0.953
Fat %	0.186	p<0.001	1.120–1.295
Lean body mass (kg)	0.214	p<0.001	1.155–1.329
Fat mass (kg)	0.119	p<0.05	0.789–0.998
Age	1.214	p<0.001	2.804–4.043
Maternal educational level	0.020	n.s.	0.827–1.214
Paternal educational level	0.071	n.s.	0.880–1.310
utoEducation (type of school)	–0.119	n.s.	0.591–1.333

cline in the timing of sexual maturation[4,5]. So the mean age of menarche in westernized industrial countries is 12.5–13.5 years now and the majority of girls experience menarche between 12 and 14 years. This value is slightly higher than the mean age of menarche observed in the present study, which was 12.4 years. The majority of girls in the present study experienced menarche between 11 and 13 years. The analysis of the association between menarcheal onset and body build and body composition yielded the expected results. Postmenarcheal girls were taller, heavier and exhibited a higher absolute and relative amount of fat mass than their premenarcheal counterparts of same age. However these results are not the corroboration of the Frisch Hypothesis. Body composition is not the predictor sexual maturation it is associated with it. The hormonal transition during puberty leads to an enormous increase of body fat mass, but also in fat free body mass in both sexes. Fat increases especially in the female sex, because body fat represents an important energy store in the human body and a sufficient energy deposit is absolute necessary to fulfill the energetic demands of female reproductive function[12,24]. Numerous studies have shown, the negative effects of negative energy balance and too small energy stores on female reproductive function, especially among female athletes or patients suffering from eating disorders such as anorexia nervosa[25–27]. In the present study frequent dieting, indicating a negative energy balance had also negative effect on menarcheal age. This association is rather dramatic, since during the last years a new trend in eating habits and weight control practices among adolescents has been observed[28,29]. Beside the well known eating disorders such as anorexia nervosa and bulimia nervosa, defined in the DSM IV, an increasing frequency of altered eating behavior is observable among otherwise healthy subjects[28]. A high prevalence of problematic eating behavior and eating disorder symptoms is described for many western industrialized countries such as the United States or Canada, where 80% of normal weight adolescent females reported that they would like to weigh less[30]. Promoted by mass media, especially fashion magazines, the culture typical ideal body shape has become unrealistically thin[31,32]. An increasing number of girls of decreasing age practices weight controlling and so exhibit a negative energy balance. This behavior seems to influence menarcheal timing. This assumption is corroborated by the results of the present study. In contrast the impact of socioeconomic parameters on menarcheal age could not be proved in the present study. While other studies significant associations between education and pubertal timing[33], neither educational level of the parents nor the kind of school attending by the girls had any significant effect on the timing of menarcheal age in the present investigation. Unfortunately no others than educational data were available to define socioeconomic status. This is due to the very strict school policy in Austria, which forbids the collection of more detail socioeconomic data among schoolchildren. But nevertheless, educational level is an appropriate measure of socioeconomic status in Austria. Furthermore only girls from a distinct rural area were included in the present study and all girls were of Austrian origin. The fact that we found no association between socioeconomic situation and age at menarche among this sample may be explained by the well observed trend, that socioeconomic differences in body build and physique have diminished during the last decades as a result of changes in social stratification[34]. The results of the present study plead for a marked interaction between body build, especially body composition as well as energy balance indicated by eating behavior and menarcheal age. In contrast no influence of socioeconomic parameters on sexual maturation were found.

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POJAVA MENARHE POVEZANA JE S PARAMETRIMA TJELESNOG SASTAVA, ALI NE I SA SOCIOEKONOMSKIM STATUSOM

S A Ž E T A K

U ovom istraživanju dokumentiran je menarhalni status (pre- ili postmenarhalni), tjelesni sastav, težina, i socioekonomski parametri kao što su vrsta pohađane škole i stupanj obrazovanja roditelja, na uzorku od 1752 adolescentice starosti između 12 i 18 godina (x=14,6) iz ruralnih predjela istočne Austrije. Nadalje, analizirani su oblici povezanosti između sastava tijela, socioekonomskih parametara i menarhalnog statusa. Pokazalo se da su parametri tjelesnog sastava poput BMI-a, nemasne tjelesne mase te apsolutne i relativne količine tjelesne masnoće značajno povezani s menarhalnim statusom. Postmenarhalne djevojke bile su više i teže, sa većom apsolutnom i relativnom količinom tjelesne masti te većom količinom nemasne tjelesne mase od premenarhalnih djevojaka iste dobi. Nasuprot tome, nije zapažen značajan utjecaj stupnja obrazovanja, kao pokazatelja socioekonomskog statusa, na menarhalni status.