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THE IMPACT OF THE AGE AT MENARCHE ON BODY BUILD AND SEX HORMONE LEVELS IN HEALTHY ADULT WOMEN FROM VIENNA, AUSTRIA

ABSTRACT: The present study focused on the impact of the age at menarche on adult type of body build as well as adult sex hormone levels in 124 healthy adult women aging from 20 to 37 years, originating from Eastern Austria. The investigation yielded significant correlations between the menarcheal age and several metric traits and the estradiol and testosterone levels. Above all the amount of subcutaneous fat tissue and a type of gynoid fat distribution correlated negatively with the age at menarche, while positive correlations between age at menarche and height- and length- dimensions and a more masculine type of body build occurred. Women with an early menarche were smaller in stature but more corpulent and their body types were more feminine than women with a late menarche who were taller, slenderer and more masculine. Beyond that negative correlations between the age at menarche and the sex hormone levels could be observed. A late menarche was associated with lower levels of the steroid hormones, especially estradiol. The results of the present study indicate a strong assotiation between of the hormonal situation in puberty, adult body shape and adult sex hormone levels.

KEY WORDS: Age at menarche – Body build – Sex hormone levels – Adult females.

INTRODUCTION

The relations between body build, bone growth and age at menarche were topics of several studies. Above all stature and body weight have been related with the time of first menstrual bleeding (Stone, Barker 1937, Barker, Stone 1938, Malcolm 1954, Maresh 1959, Hillman et al. 1970, Bai et al. 1973, Rona, Pereira 1974, Cameron 1976, Chan, Soong 1976, Zacharias 1976, Low et al. 1978, Clegg 1980, 1989, Farkas, Takacs 1986, Welpe, Bernhard 1986, 1987, Yoneyama et al. 1988, Tsuzaki 1989, Cameron, Wright 1990, Pönninger 1990, Musaiger 1991, Samsudin 1991). Today the interaction between age at menarche and body growth is explained by two different views: the first and older theory explains the correlations between menarcheal age and skeletal maturation. This theory provided the traditional proximate explanation of the secular trend in menarcheal age as a consequence of the secular acceleration of statural growth (Tanner 1962, 1973). The hypothesis implicit in this view is that premenarcheal girls are growing toward an appropriate structural status to initiate reproduction and that the age at which this status is attained is closely related to the menarcheal age (Ellison 1982). The first menstrual bleeding as a predication for reproduction occurs at the time when the necessary skeletal age is reached

(Shuttleworth 1937, 1938, Simmons, Greulich 1943, Tanner 1962, 1973, Marshall, Tanner 1986, Marshall, DeLimongi 1976).

According to the second view the body weight and the body weight in relation to body height are essential for the timing of menarche (Frisch 1972, 1974, 1976a, 1976b, 1985, Frisch, Revelle 1970, Frisch et al. 1973, Frisch, MacArthur 1974). Frisch postulated that 46 – 48kg are minimum values for the onset of menstruation and the maintenance of regular ovulatory menstrual cycles. This theory of the "critical mass" was criticized by several authors (Johnston et al. 1971, 1975, Billewicz et al. 1976, Cameron 1976, Trusell 1978, 1980, Ellison 1981, 1982, Scott, Johnston 1982), however, other authors agree to the so-called "Frisch-hypothesis" (Friscancho, Flegel 1982, Garn et al. 1986, Fakeye 1988, Stark et al. 1989).

Nearly all studies mentioned above described the relations between age at menarche and traits of body build at the time of menarche. Only a small number of investigations dealt with the connection of menarcheal age and body build of adult women several years after their first menstruation (Malina et al. 1983, Sharma 1988, Wellens et al. 1992, Kirchengast 1993d). Regarding the relationship between adult body dimensions and age at menarche no uniform trend could be observed. According to Frisch and Revelle (1970) after puberty no differences of the body build between early and late menstruating women can be stated. This is also true for the results of Marshall and Tanner (1986) and Yoneyama et al. (1988). Dreizen et al. (1967) and Onat (1975) reported a trend toward increased stature with earlier menarche, however, the majority of investigations yielded a close association between an early menarche and a shorter adult stature and higher body mass indices relative to later maturing females (Barker, Stone 1936, Shuttleworth 1937, Jacobson 1954, Szemik 1980, Vikho, Apter 1984, Stark et al. 1989, Malina 1990, Wellens et al. 1992, Kirchengast 1993d).

The first menstruation is induced by a distinct level of sex hormones (August et al. 1972, Widlom et al. 1974, Lee, Migeon 1975, Lee et al. 1976, Siszenko 1978, Sklar et al. 1980, 1981, Lemarchand-Beraud et al 1982). Furthermore a marked interaction between sex hormone levels and body build and body fat distribution could be proved (Purifoy et al. 1981, Illig et al. 1982, Janson et al. 1983, Cassorla et al. 1984, Parker et al. 1984, Caruso-Nicoletti et al. 1985, Katz et al. 1985, Hediger, Katz 1986, Knussmann et al. 1986, Zemel, Katz 1986, Castro, Castro 1987, Knussmann, Sperwien 1988, Christiansen, Winkler 1990, Winkler, Christiansen 1991, Kirchengast 1993a, b, 1994a). Body build and sex hormones and hormonal induced events such as menarche, menopause, fertility outcome and menstrual cycle show significant relations (Kirchengast 1993c, d, e, 1994b). Therefore in the present study not only the relations between age at menarche and body build but also between age at menarche and the sex hormone levels in adult females several years after their first menstrual bleeding were tested.

MATERIALS AND METHODS

Subjects

The probands (n = 124), ranging in age from 20 to 37 years (x = 26.4) and originating from Vienna or Lower Austria, were examined at the Hormone-outpatient department of the I. Universitäts-Frauenklinik in Vienna from February to October 1990. All probands were healthy, with intact ovaries, uteri and adrenals and showed regular menstrual cycles with a cycle length between 22 and 31 days (x = 28.8). Their menarche occurred at a minimum of four years prior to the time of the present investigation. The probands consulted the hormone-outpatient department for control check-ups exclusively. None of the women were under any hormonal therapy or had taken any hormonal contraceptive within three months prior to the time of investigation. Women with a history of amenorrhoe or very irregular cycles were excluded from the present sample. This was also true for pregnant women.

Age at menarche

Since all probands had started to menstruate more than four years before this study commenced, the age at menarche could only be investigated retrospectively. This technique relies on self-reported age at menarche and is reputed not to be exact because women might experience memory loss, particulary if menarche dated back for a long time (Chan 1967, Bergsten-Bruce fors 1976, Cravioto et al. 1987). Nevertheless this method was used for the present study, since it can be assumed that women remember well such marked events as their first menstruation (Bean et al. 1979, Madrigal 1991). Furthermore several studies yielded a reliability of 75 – 90% for this method (Livson, McNeill 1962, Damon et al. 1969, Damon, Bajema 1974, Bean et al. 1979, Madrigal 1991).

Anthropometric variables

Each proband was measured by one of the authors according to the methods described by Knussmann (1988). 29 head and body measures were determined. Head measures were (numbers according to Knussmann): Maximum head length (1), Maximum head breadth (3), Bizygomatic breadth (6), Bigonial breadth (8), Mouth breadth (14), Morphological facial height (18), Nasion-Stomion height (19), Labial height (25). Body measures were: Stature (1), Chin height (3/1), Acromial height (8), Dactylion height (11), Span (17), Sitting height (23), Biacromial breadth (35), Chest breadth (36), Waist breadth (39), Pelvic breadth (40), Projectivic arm length (45a), Physiognomic leg length (53/4), Bicondylar breadth

(59d), Chest girth (61), Waist girth (62), Hip girth (64/1), Upper arm girth relaxed (65), Upper arm girth flexed (65/1), Hand circumference (67/2), Thigh circumference (68), Body weight (71). Based on the head and body measures mentioned above the following indices were computed: Cephalic index (3/1), Morphological facial index (18/6), Jugomandibular index (8/6), Lip index (25/14), Relative Physiognomic leg length (53.4/1), Scelic index (53.4/23), Acromio-chest index (36/35), Acromio-cristal index (40/35), Biacromial index (35/1), Chest index (36/1), Waist index (39/1), Bicristal index (40/1), Bicondylar index (59d/1), Thoracic circumference index (61/1), Waist circumference index (62/1), Hip circumference index (64.1/1), Thigh circumference index (68/1), Upper arm index (65/1), Upper arm contraction index (65.1/1), Hand circumference index (67.2/1), Quetelet index (71/1), Body mass index (71/1), Index of corpulence (71/1), Chest-hip girth index (61/64.1), Waist-hip girth index (62/64.1), Waist breadth/Pelvic breadth (39/40), Hip index ((64.1 – 62)/62), Thigh circumference/Waist girth (68/62), Thigh circumference/Hip girth (68/64.1), Thigh circumference/Leg length (68/64.1), Muscle index (65.1 – 65).

Hormone assays

Blood samples were collected at the hormone-outpatient department of the I. Universitäts-Frauenklinik in the early morning hours between 7.30 a.m. and 10.30 a.m. In order to warrant the comparability of the hormone levels, blood was drawn at the 10th day of cycle during the follicular phase before ovulation. The quantitative determination of the hormone levels was made at the hormone laboratory of the I. Universitäts-Frauenklinik using the following methods:

Enzymimmun-assay:
(Boehringer Mannheim Enzymun)

- Lutenizing hormone (LH)
- Follicle-stimulating hormone (FSH)
- Prolactin (HPRL)

Radioimmun-assay:

- Estradiol (E2) (Coat-aCoat DPC)
- Progesterone (P) (Coat-aCoat DPC)
- 17-Hydroxyprogesterone (17-OHP) (Coat-aCoat DPC)
- Dehydroepiandrostendione (DHEA-S) (Immunotech)
- Androstendione (A) (DSL 3800)
- Testosterone (T) (Coat-aCoat DPC)
- Sex hormone binding globulin (SHBG) (Serono).

In addition to finding serum levels of individual hormones, eight ratios of the individual hormone values were calculated. Ratios of estradiol to gonadotropines, progesterone and androgens (E2/LH, E2/FSH, E2/P, E2/DHEA-S, E2/A, E2/T) and the ratios of the androgens androstendione and DHEA-S to Testosterone (T/A, T/DHEA-S) were computed.

STATISTICAL ANALYSES

Statistical evaluation of the data was carried out using SPSSX program version according to Schubö and Uehlinger (1986). Since the results of the Kolmogoroff-Smirnov test indicate that no normal distribution could be assumed for all hormonal variables and for nearly all anthropometric variables, all variables were z-scored in order to apply parametric procedures. In order to eliminate the influence of age on the correlation coefficients, partial correlations (age=constant) between anthropometric variables, hormonal variables and age at menarche were computed. Factor analyses (principal components methods) of all 29 metric variables were also carried out. After varimax rotation individual factor scores were determined and then correlated with the age at menarche. Additionally, the subjects were divided into three subgroups: 1. with an extremely low age at menarche (11 years), 2. with a low to moderate age at menarche (12 – 14 years), 3. with a high age at menarche (15 – 18 years). In order to state significant differences of body measures and sex hormone levels between the three groups, analyses of variance (1-way Anovas) were computed.

RESULTS

Age at menarche

The mean age at menarche of the probands amounted to 13.2 years. Thus the age at menarche of the present sample lies within the normal age range of western industrialized countries (12 – 14 years) (Pönninger 1990). With 37 probands (29.1%) the first menstrual bleeding occurred relatively early i.e. before the 12th year, 68 females (58.3%) experienced the menarche between the 12th and 14th year, with 19 probands (15.3%) the menarche occurred after the age of 14.

Anthropometric variables

The sample parameters (means x, standard deviations SD, medians M) of the 29 head and body measures and the 31 anthropometric indices are listed in *Table 1.* In order to describe the amount and the distribution of the subcutaneous body fat, first of all breadth- and circumference measures and their ratios were considered, since these allow conclusions regarding body fat distribution and nutritional status of the proband (Mueller & Malina 1987).

TABLE 1. *Means (x), standard deviations (SD) and medians (M) of the anthropometric variables and indices.*

Variable (No. from Knussmann 1988)	x	SD	M
Maximum head length (1)	185.9	5.4	186
Maximum head breadth (3)	149.6	5.0	150
Bizygomatic breadth (6)	136.4	5.5	136
Bigonial breadth (8)	104.5	5.6	105
Mouth breadth (14)	51.8	3.9	52
Morphological facial height (18)	106.9	5.5	106
Nasion-Stomion height (19)	65.5	3.7	65
Labial height (25)	13.2	2.8	13
Stature (1)	1662.2	64.2	1666
Chin height (3/1)	1449.1	61.1	1453
Acromial height (8)	1358.8	58.4	1359
Dactylion height (11)	652.6	37.1	654
Span (17)	1627.4	66.1	1624
Sitting height (23)	886.3	32.7	885
Biacromial breadth (35)	368.9	17.0	370
Chest breadth (36)	266.3	19.7	264
Waist breadth (39)	220.9	23.5	219
Pelvic breadth (40)	317.9	25.5	317
Projectivic arm length (45a)	706.4	37.3	709
Physiognomic leg length (53/4)	775.9	41.6	776
Bicondylar breadth (59d)	96.9	8.5	95
Chest girth (61)	904.6	79.9	891
Waist girth (62)	708.9	83.5	692
Hip girth (64/1)	974.2	84.6	962
Upper arm circ. relaxed (65)	266.8	29.8	263
Upper arm circ. flexed (65/1)	282.8	29.1	278
Hand circumference (67/2)	187.7	8.7	187
Thigh circumference (68)	549.8	58.4	541
Body weight (71)	60.2	10.2	58
Cephalic Index (3/1)	80.5	3.7	80.0
Morphological facial index (18/6)	78.4	4.5	77.9
Jugomandibular- index (8/6)	76.6	3.3	76.8
Lip index (25/14)	25.7	5.9	25.0
Rel. physiog. leg length (53(4)/1)	46.7	1.2	46.8
Acromio-chest-index (36/35)	72.2	4.4	72.0
Acromio-cristal-index (40/35)	86.2	6.0	85.8
Biacromial index (35/1)	22.2	0.9	22.3
Chest index (36/1)	16.1	1.2	15.9
Waist index (39/1)	13.3	1.4	13.1
Bicristal index (40/1)	19.1	1.5	19.0
Bicondylar index (59d/1)	5.8	0.5	5.8
Thoracic circumference index (61/1)	54.5	5.0	53.4
Waist circumference index (62/1)	42.7	5.0	41.4
Hip circumference index (64(1)/1)	58.7	5.2	57.9
Thigh circumference index (68/1)	33.1	3.7	32.8
Upper arm index (65/1)	16.1	1.9	15.8
Upper arm contraction index (65(1)/1)	106.1	2.5	105.6
Hand circumference index (67(2)/1)	11.3	0.5	11.3
Scelic index (53(4)/23)	87.6	4.2	87.8
Quetelet index (71/1)	3.6	0.6	3.5
Body mass index (71/1)	2.2	0.3	2.1
Index of corpulence (71/1)	1.3	0.2	1.3
Hip index ((64(1) – 62)/62)	0.4	0.1	0.4
Chest-hip girth index (61/64(1))	107.9	5.8	107.9
Waist-hip girth index (62/64(1))	138.1	8.8	137.9
Waist breadth/Pelvic breadth (39/40)	69.6	5.6	70.1
Thigh circ./leg length (68/53(4))	34.5	4.4	34.0
Upper arm circ./arm length (65/45a)	37.9	4.8	37.2
Thigh circ./Waist girth (68/62)	77.9	6.5	78.1
Thigh circ./Hip girth (68/64(1))	56.4	2.8	56.3
Muscle index (65(1) – 65)	15.9	5.9	14.5

TABLE 2. *Factor analysis of the 29 absolute metric traits. Loadings and eigenvalues after varimax rotation.*

Variable	F1	F2	F3	F4	F5	F6
Head length	0.13	0.10	–0.14	0.15	0.85	–0.02
Head breadth	0.21	–0.06	0.68	0.22	–0.11	0.06
Bizygomatic breadth	0.28	0.06	0.74	0.15	–0.29	–0.20
Bigonial breadth	0.46	0.14	0.57	0.04	0.02	–0.13
Morphol. facial height	0.09	0.23	0.19	0.81	0.19	0.07
Nasion-stomion height	0.07	0.19	0.17	0.84	0.13	–0.01
Lip height	–0.06	0.07	–0.24	0.56	–0.37	–0.09
Stature	0.08	0.97	0.04	0.08	0.03	0.13
Chin height	0.07	0.97	0.03	0.04	–0.01	0.11
Acromial height	0.11	0.97	0.04	0.09	0.01	0.13
Dactylion height	0.19	0.70	–0.03	0.03	–0.05	0.51
Span	0.05	0.87	0.06	0.16	0.06	–0.23
Sitting height	0.18	0.76	0.06	0.05	0.03	0.37
Biacromial breadth	0.49	0.44	0.20	0.12	0.15	–0.19
Chest breadth	0.78	0.19	0.17	–0.09	0.15	–0.13
Waist breadth	0.81	0.07	0.18	–0.04	0.04	–0.17
Pelvic breadth	0.79	0.23	0.20	0.04	0.01	0.19
Projectiv. arm length	–0.03	0.81	0.08	0.12	0.06	–0.29
Physiognom. leg length	–0.01	0.90	0.02	0.09	0.02	–0.09
Bicondylar breadth	0.73	0.03	0.12	0.14	0.11	0.28
Chest girth	0.91	0.05	0.09	–0.06	0.09	–0.12
Waist girth	0.89	0.09	0.12	0.04	0.02	–0.05
Hip girth	0.91	0.07	0.09	0.08	0.03	0.24
Upper arm girth rel.	0.92	–0.02	0.04	0.02	–0.06	–0.05
Upper arm girth flex.	0.91	–0.02	0.05	0.01	–0.07	–0.10
Hand circumference	0.33	0.49	0.39	0.01	0.11	–0.08
Thigh circumference	0.86	–0.08	–0.01	0.15	–0.04	0.26
Body weight	0.92	0.26	0.14	0.04	0.03	0.09
Eigenvalue	10.70	6.03	1.90	1.62	1.09	1.06

Factor analysis:

The factor analysis on the basis of all absolute metric variables yielded six factors with an eigenvalue above 1.0. The first factor (eigenvalue 10.70) can be interpreted as a "postcephalic breadth-circumference-weight factor". Higher loadings (0.49 – 0.92) were found for breadth- and circumference dimensions and the body weight. The second factor (eigenvalue 6.03) can be described as a "postcephalic length-height factor" with higher loadings (0.49 – 0.97) for length- and height dimensions of the postcephalic body only. The third factor (eigenvalue 1.90) is a "facial breadth factor" with higher loadings (0.57 – 0.74) for facial breadth dimensions exclusively. The fourth factor (eigenvalue 1.62) is a "facial height factor". Higher loadings (0.56 – 0.84) were found for facial height dimensions only. The fifth factor (eigenvalue 1.09) is a pure "head-length factor" because only the head length showed a higher loading (0.85). The sixth factor (eigenvalue 1.06) showed a higher loading (0.51) for the dactylion height only.

Sex hormone levels

The random sample parameters (means x, standard deviations SD, medians M) of the sex hormone

TABLE 3. *Means (x), standard deviations (SD) and medians (M) of the sex hormone levels and the hormone ratios.*

Hormone	n	x	SD	M
LH (MIE/ml)	115	10.9	13.0	6.7
FSH (MIE/ml)	112	6.50	11.1	4.12
Estradiol (pg/ml)	110	78.9	110.5	43.5
Prolactin (ng/ml)	113	13.5	22.7	9.0
Progesterone (ng/ml)	75	3.48	10.0	0.44
17-OHP (ng/ml)	105	1.43	1.1	1.1
Testosterone (ng/ml)	111	0.81	0.5	0.71
Androstendione (ng/ml)	104	2.37	1.2	2.24
DHEA-S (MCG/ml)	107	2.7	1.6	2.4
Estradiol/LH	104	22.12	76.94	6.8
Estradiol/FSH	102	235.49	213.66	10.1
Estradiol/Progesterone	75	112.60	169.9	84.1
Estradiol/DHEA-S	95	32.86	44.05	18.1
Estradiol/Androstendione	93	43.34	122.16	23.3
Estradiol/Testosterone	98	94.57	102.53	65.5
Testosterone/Androstendione	100	0.44	0.53	0.3
Testosterone/DHEA-S	103	0.40	0.29	0.3

levels and the hormone ratios are listed in *Table 3*. Means and medians of the hormone levels are within the normal range for healthy adult females during their fertile phase of life. No pathological alterations of the sex hormone levels could be observed.

Age at menarche and body build

The relations between age at menarche and anthropometric traits were carried out using partial correlations (age at the time of investigation = constant). It became evident, that the postcephalic length- and height dimensions correlated exclusively positively, the breadth- and circumference dimensions exclusively negatively with the age at menarche. Probands whose menarche occurred later were taller and leaner than females with an early menarche. A comparable trend could not be observed for the head dimensions. Regarding the correlations between age at menarche and anthropometric indices very similar results could be stated: those indices which decribe breadth- and circumference dimensions, i.e. the subcutaneous fat distribution, correlated exclusively negatively with the age at menarche. This means the menarche occurred earlier in females with a greater amount of subcutaneous fat and a more feminine type of body build (*Table 4*).

In a next step the proband group was divided into three subgroups: Group 1 comprised 37 women whose menarche occurred before the 12th year, group 2 included 68 females whose first menstrual bleeding took place between their 12th and 14th year of life and group 3 comprised 19 women whose menarche occurred after their 14th year of life. The differences between the three groups with respect to their body dimensions and body proportions were examined by

TABLE 4. *Partial correlations (rho) between age at menarche and anthropometric variables and indices (age is constant) $P < 0.05$ *; $P < 0.01$ **.*

Variable	rho
Maximum head length	−0.18*
Morphological facial height	−0.17*
Chin height	0.19*
Span	0.21**
Chest girth	−0.16*
Thoracic circumference index	−0.22**
Hip circumference index	−0.16*
Biacromial index	−0.23**
Chest index	−0.17*
Bicristal index	−0.15*
Bicondylar index	−0.16*
Body mass index	−0.15*
Index of corpulence	−0.18*
Thigh circumference/leg length	−0.18*
Upper arm circumference/arm length	−0.19*

means of 1-way Anova (*Table 5*). Although only few statistically significant differences between the three proband groups could be stated a distinct trend was seen: All postcephalic length- and height dimensions showed a marked increase from the first to the third proband group. In contradiction, the breadth- and circumference dimensions decreased markedly from the first to the third proband group. This is also true for the indices: those indices which describe the amount and distribution of body fat decrease from the first to the third proband group. Those probands whose menarche occurred especially early showed a more gynoid kind of body fat distribution than females whose menarche occurred later. An especially late first menstruation is associated with a more masculine type of body build. Regarding the head indices no distinct trend could be observed.

Age at menarche and sex hormone levels

The statistical relation between age at menarche and sex hormone levels was quantified by partial correlations (age at time of investigation = constant) and by 1-way Anova of the three proband groups mentioned above. Only the estradiol (E2) level correlated statistically significantly with the age at menarche. Regarding the hormone ratios significant relations with the menarcheal age could be stated for E2/FSH, E2/DHEA-S and E2/A. All correlations, not only the significant ones, were negative. This means that with an increase in age at menarche a decrease of the sex hormone levels, above all the estradiol level, could be observed (*Table 6*).

Regarding the 1-way Anova only few statistically significant differences between the three proband groups could be stated. Nevertheless, a distinct trend was seen. The levels of the steroid hormones estra-

TABLE 5. *Age at menarche and anthropometric variables. 1-way Anova, (Duncan-test), Levels of significance* ** $P < 0.01$, * $P < 0.05$.

Age at menarche	9 – 11	12 – 14	15 – 18	F-Value
n	37	68	19	
Variables				
Maxium head length	188.1	185.1	185.0	4.5*
Maximum head breadth	150.0	149.6	148.7	0.4
Bizygomatic breadth	136.9	136.1	136.9	0.3
Bigonial breadth	104.3	104.4	105.4	0.3
Mouth breadth	52.5	51.7	51.1	1.1
Morphological facial height	108.1	106.2	106.6	1.6
Nasion-Stomion height	66.4	64.8	66.4	2.8
Labial height	13.8	12.8	13.6	1.6
Stature	1657.2	1659.4	1682.1	1.1
Chin height	1438.9	1448.2	1471.7	1.8
Acromial height	1352.9	1356.9	1376.9	1.2
Dactylion height	650.5	653.5	658.6	0.5
Span	1613.6	1627.9	1652.8	2.4
Sitting height	883.3	887.9	893.9	0.9
Biacromial breadth	371.7	368.1	366.4	0.8
Chest breadth	270.1	265.3	262.8	1.9
Waist breadth	223.0	221.3	215.7	0.7
Pelvic breadth	322.4	317.5	310.9	1.4
Projectivic arm length	699.6	706.9	717.8	1.6
Physiognomic leg length	769.3	776.1	788.2	1.5
Bicondylar breadth	98.3	96.8	94.6	1.5
Chest girth	920.9	903.8	875.4	2.2
Waist girth	715.9	710.9	688.4	0.7
Hip girth	988.7	971.4	955.9	1.1
Up. arm circumference relaxed	269.7	267.3	259.8	0.7
Up. arm circumference flexed	285.3	283.3	276.2	0.8
Hand circumference	188.0	187.4	187.8	0.1
Thigh circumference	556.9	548.1	541.9	0.5
Body weight (kg)	61.4	60.0	58.6	0.5
Cephalic index	79.8	80.9	80.4	1.3
Morphological facial index	78.9	78.1	78.0	0.5
Jugomandibular index	76.3	76.7	77.0	0.6
Lip index	26.4	25.0	26.8	1.1
Rel. physiognomic leg length	46.4	46.8	46.9	1.4
Rel. projectivic arm length	42.6	42.8	43.5	4.3**
Acromio-chest index	72.7	72.1	71.7	0.5
Acromio-cristal index	86.8	86.3	84.8	0.6
Thoracic circumfer. index	55.7	54.5	52.1	3.6*
Waist circumference index	43.3	42.8	40.9	1.7
Hip circumference index	59.8	58.6	56.8	2.2
Thigh circumference index	35.5	34.4	34.0	1.9
Hand circumference index	11.3	11.2	11.1	0.8
Upper arm index	17.8	17.2	17.0	1.5
Upper arm contraction index	105.8	106.1	106.4	0.3
Biacromial index	22.6	22.1	21.6	2.9*
Chest index	16.3	15.9	15.6	2.4*
Bicristal index	19.5	19.0	18.4	2.8*
Bicondylar index	5.9	5.8	5.6	2.2
Scelic index	86.6	87.8	88.2	1.2
Quetelet index	4.1	3.9	3.8	1.6
Body mass index	2.3	2.2	2.1	1.6
Index of corpulence	1.4	1.3	1.2	2.1
Hip index	0.4	0.3	0.4	0.4
Waist breadth/pelvic breadth	69.2	69.7	69.5	0.1
Thigh circumference/leg length	38.5	36.9	36.2	2.8*
Upper arm circ./arm length	41.8	40.3	39.4	2.4*
Chest-hip girth index	105.9	106.5	105.7	0.5
Waist-hip girth index	130.0	131.8	131.5	0.5
Muscle index	13.6	14.9	13.3	1.8

TABLE 6. *Partial correlations (age = constant) between the age at menarche and the sex hormone levels.* $P < 0.05$ *; $P < 0.01$ **.

Hormone	rho
Estradiol (E2)	−0.25**
Estradiol/FSH	−0.21*
Estradiol/DHEA-S	−0.23*
Estradiol/Androstendione	−0.19*

diol, testosterone, androstendione and DHEA-S decrease with increasing menarcheal age. This is also true for the prolactin levels and the individual hormone ratios. In contrast, a marked decrease of gonadotropin and progesterone concentrations with increasing age at menarche could be ascertained.

DISCUSSION

The first menstrual bleeding, the menarche, is induced by the increase of gonadotropin- and estradiol concentrations during puberty (Widholm et al. 1974, Le et al. 1976, Sizonenko 1978). The increase of gonadotropin- and estradiol levels is initiated by the androgen secretion of the adrenal gland in two different ways: The adrenal androgens influence the hypothalamus directly and induce the secretion of gonadotropin-releasing hormones, which stimulate the release of the gonadotropines LH and FSH in the pituitary gland. The gonadotropines initiate the secretion of the steroid hormones, first of all of estradiol, in the ovaries (Parker, Mahesh 1977, Kuhlmann, Straub 1986). The second kind of influence is the aromatization of the androgens androstendione and testosterone to the estrogen estron in the subcutaneous fat tissue (Nimrod, Ryan 1975, Perel, Killinger 1979, Kirschner et al. 1982, Hediger, Katz 1986). Therefore the subcutaneous fat tissue can be designated as a secondary hormonal gland.

Regarding the factors which determine the time of these hormonal alterations no uniform opinion previously existed. On the one hand exogenous influences such as living conditions, family composition, socioeconomic factors, physical exercise and psychosocial stress, on the other hand genetic disposition, nutritional status and body build are discussed as the reasons for the hormonal changes (Rona, Pereira 1974, Ness 1991).

In the present study the complex interactions between body build, sex hormone levels and menarcheal age in healthy adult females several years after the first menstrual bleeding were tested. A direct comparison between the results of the present study with those of Frisch and Revelle (1970, 1972, 1973, 1974, 1976a, b, 1985) and those of Greulich and Simmons (1943), Johnston et al. (1975), Trusell (1978, 1980) is not possible because in the present study the probands' body build and sex hormone levels were not determined at the time of menarche, but several years later. Despite the time interval between age at men-

TABLE 7. *Age at menarche and sex hormone levels, 1-way Anova levels of significance : * p < 0.05; ** P < 0.01.*

Sex hormones	Age at menarche 9 – 11	12 – 14	15 – 18	F-Value
LH	8.8	12.7	8.7	1.3
FSH	6.43	6.73	5.84	0.1
Estradiol	94.4	77.8	52.5	1.8
Prolactin	16.1	13.1	9.9	1.0
Testosterone	1.1	0.7	0.6	3.7*
DHEA-S	3.1	2.6	2.3	1.4
Progesterone	3.2	3.9	1.7	0.9
17-OHP	1.5	1.4	1.3	0.3
LH/FSH	3.3	2.3	2.5	0.9
E2/LH	44.5	13.8	10.7	1.9
E2/FSH	32.7	17.4	21.7	1.4
E2/DHEA-S	43.6	29.3	23.9	1.6
E2/A	35.2	52.2	31.4	0.4
E2/T	106.0	93.1	78.9	0.6
T/A	0.5	0.4	0.4	0.1
T/DHEA-S	0.5	0.4	0.4	2.3

arche and time of investigation statistically significant correlations between the age at menarche and various anthropometric traits as well as sex hormone levels could be stated. Though several correlations were significant at the 1% level, the absolute values of the correlation coefficients mostly fell short of 0.25. These relatively low correlation coefficients are to be expected, since body build and sex hormone levels in adult women are multifactorially conditioned and menarcheal age represents only one factor among several others. Nevertheless the present study yielded a distinct trend: females whose first menstrual bleeding occurred later were taller and leaner than females whose menarche occurred earlier. In adult females an early time of menarche is associated with higher breadth- and circumference dimensions, i.e. with greater amount of subcutaneous fat and a general more feminine type of body build. The results of the present study resembled therefore the findings of several authors (Barker, Stone 1936, Shuttleworth 1937, Jacobson 1954, Szemik 1980, Vikho, Apter 1984, Garn et al. 1986, Stark et al. 1989, Malina 1990, Ness 1991, Wellens et al. 1992, Kirchengast 1993d), who found a negative connection between age at menarche and body mass index and the amount of subcutaneous fat tissue in general. As mentioned above, for a sufficient estrogen secretion a distinct minimum amount of subcutaneous fat tissue is essential and therefore the menarche occurred in more corpulent girls earlier than in very slender ones. This is in accordance with the theories of Frisch (1972, 1974, 1976a, b, 1985), Frisch and McArthur (1974) as well as Frisch and Revelle (1970). The early sufficient supply with androgens and estrogens in more corpulent girls leads to an earlier start of the pubertaly growth spurt and an earlier first menstrual bleeding. In leaner girls not only the growth spurt during adolescense but also the sexual maturation and the development of extra-genital sexual traits are delayed (Cameron, Wright 1990). A sufficient level of estrogen supports the development and growth but it leads to an early closure of the epiphyses (Ganong 1979). The epiphyses of leaner girls with lower estrogen levels close later, and the pubertal growth spurt is extended. Therefore females whose menarche occurred later were taller and surpassed females with an early menarche in all length and height dimensions. Regarding the correlations between age at menarche and sex hormone levels the following trend could be stated: the later the first menstrual bleeding occurred, the lower were the sex hormone concentrations. Females who started to menstruate later had a lower amount of subcutaneous fat tissue and the amount of body fat is also an indicator for the hormonal situation of the women. Therefore leaner females who had started to menstruate later showed lower estrogen levels than corpulent females who had started to menstruate early. Since the time of menarche is also an indicator for the hormonal situation during puberty and body build as well as the sex hormone levels during adulthood correlated significantly with the age at menarche, it can be assumed that the supply of sex hormones during puberty influences body build as well as the hormonal situation long after the termination of puberty. This hypothesis is supported by the results of those investigations which yielded a significant connection between body build and sex hormone levels in adult males and females a long time after puberty (Knussmann et al. 1986, Knussmann, Sperwien 1988, Christiansen, Winkler 1990, Winkler, Christiansen 1991, Kirchengast 1993a, b, 1994a). The kind of body type and the sex specific distribution of adipose tissue during adulthood is determined by the hormonal situation during puberty. Therefore the menarcheal age may be an indicator for the expression of sex specific body build several years after termination of puberty.

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