

SEXUAL MATURATION TYPE AND BODY STRUCTURE OF GIRLS

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Abstract: *The aims of the study were 1) to characterize sexual maturation in pubertal girls, 2) to demonstrate alterations in body composition of athletes and non-athletes by the level of maturation, 3) to examine differences in somatotypes.*

1150 athlete and 1030 non-athlete girls were studied. Breast development was rated according to Tanner's suggestions. Data for menarche were collected by "status-quo" method. Quartiles were used to separate early and late maturers. To obtain body components the Drinkwater-Ross method was applied. Somatotype was determined by the Heath-Carter method.

Athletes ripened later than non-athletes. In both groups late maturers had consistently less relative fat mass and more muscle mass than their early maturing counterparts. Somatotype of early maturing athletes was balanced. Late maturers had meso-ectomorph body build. Non-athletes with early breast development were extremely endomorph. Late maturers were balanced endomorph.

Keywords: *Athletes; Sexual maturation; Body composition; Somatotype.*

Introduction

Puberty is a relatively short, but one of the most interesting periods of life involving rapid changes in morphology and function of human body. This period embraces all the processes leading to sexual and physical maturation: that is the development of secondary sexual characteristics, the maturation of the gonadal functions as well as growth of body dimensions and changes in body composition. Size and shape are gradually manifested during the pubertal years as they obtain their grown up form. These processes have a relatively independent trend line each, but simultaneously they are mutually interrelated.

During adolescence the respective phases of sexual maturation associate with well-defined changes in the size and shape of the body (Pápai and Bodzsár 1989/90, Pápai 1992, 2000, Bodzsár 2001). The common background for them is that both sexual maturation and the rapid growth in body dimensions are governed by the neuro-hormonal activity of the central nervous system acting differentially upon them. Differences in the timing of maturation events may be accompanied by divergent developmental trends in the body structure.

One dilemma in kinanthropometry is whether physical performance is related to a specific body build (Malina 1986, Malina and Bouchard 1991). During the developmental period talented athlete children are exposed to the effect of sport selection. As an extreme group, they differ in many features from the average children. In puberty one of the possible view-point of selection is the maturation type. In the majority of the sport disciplines early maturing boys are preferred because of their larger body dimensions, more muscular physique and advanced mental performance. In other events mainly the late maturing children are chosen. But what are the selection criteria for girls?

Studies on the relationship of menarche with the body dimensions have shown that postmenarcheal girls differ in their body proportions from premenarcheal youngsters (Bodzsár 1975, 1991, Pápai 1992, Zsákai és Bodzsár 2000). The former are also larger than their less mature peers. When studying athletes, late maturing girls are developmentally superior to their early maturing peers (Malina and Bouchard 1991, Claessens et al. 1992, Pápai 2000, 2002).

The research presented in the current work was conceptualized to show the differences in body size and shape of early and late maturing girls. It was another challenge to explore the effect of selection by comparing the body build of physically active and non-active children. We have also examined the question whether sexual maturation type could be a factor in the selection of young skilled athletes or whether it is simply a part of other dynamic co-occurring processes of maturation.

The principal issue under investigation was to compare and contrast the alterations in body composition and somatotype of athlete and non-athlete girls during the maturation. It is an important question whether or not the growing child, in her additional role as an athlete, differs from the non-athlete child in sexual maturation characteristics and body structure.

The aims of the study were:

- To characterize the sexual maturation in athlete and non-athlete girls.
- To demonstrate the alterations in body composition by the level of sexual maturation.
- To compare the body composition of athletes and non-athletes.
- To disclose differences in the somatotype of athletes and non-athletes.

Material and methods

The study was carried out using a cross-sectional design. Athletes were recruited from several sport clubs and sport schools in Hungary. The sample size comprising the athletes' group amounted to 1150 (aged between 8.5 and 16.5 years). The bulk of this group was composed by young girls involved in aerobic sports, fighting disciplines and ball games. All participants have attended a minimum of four training sessions every week in the year preceding the study. Therefore, the participants in this group could be considered as habitually physically active. This group was then further classified as early or late maturing (N=574).

Other group under study consisted of 1030 girls who had been categorized to a non-athlete sample (aged between 7.5 and 15.5 years). All participants in this group took part only in compulsory Physical Education (PE) classes and in some instances in occasional recreational activities. Therefore, the girls in this group could not be considered as regularly physically active. Similar to athletes, this group was also further classified as early and late maturing (N=515).

Body components were calculated by the four-component model of Drinkwater and Ross (1980). In this study only the relative components were analysed (bone, muscle and fat masses). Somatotype was determined by the Heath-Carter method (Carter and Heath 1990), using the regression equations of Szmodis (1977).

Sexual maturation was assessed on the basis of breast development and physiological age (menarche). Developmental phases of breast were rated according to Tanner's (1962) suggestions. Data for determining menarche were collected by "status-quo" method (Malina and Bouchard 1991, Bodzsár and Zsákai 2004). Median ages for breast

developmental stages B2 through B5 were calculated, as well as for the ages at menarche by using the “maximum-likelihood” technique of probit regression (Weber 1969). Early and late maturers were separated by the quartiles of chronological age for every breast stage. Relative body component masses and changes in body shapes were studied along the four developmental stages of the breasts. One way ANOVA was applied to reveal the differences in body components of early and late maturing children. Differences between the means of subgroups were examined by using Scheffé test at the level of $p < 0.05$.

Results and discussion

In the first part of the data-analysis we have tested the differences in the timing of sexual maturation characteristics between athletes and non-athletes. Table 1 presents the maturation indices for the two groups. Non-athletes started to develop their maturation characteristics in an early chronological age. They were ahead of athletes in all stages. The divergence was the largest in the early- and mid-phases. In athletes the late start in breast development was accompanied by belated occurrence of menarche. The lagging was 0.8 years.

Table 1. Maturity characteristics of non-athlete and athlete girls.

Maturity characteristics	Non-athletes	Athletes
	Median ages (yr.)	
Breast stages		
B2	9.6	11.2
B3	11.1	12.3
B4	12.9	13.3
B5	14.3	14.7
Menarche (\pm SD)	12.68 \pm 0.06	13.51 \pm 0.06

The question that merits special consideration relates to the late maturation observed in the young female athletes. From studies examining the sexual maturation of females, emerging data are almost exclusively only available for menarche. Although in Hungary the assessment of menarche dates back to more than a century ago (Bodzsár 2003), such measurements were not taken for athletes, but only for the general population. The earliest examinations (Erdélyi 1962, Farnosi 1982) investigated adult female athletes and revealed a relatively late appearance of menarche. During the last quarter of the 20th century both longitudinal and cross-sectional examinations were carried out to explore the maturation characteristics of young female athletes crossing the maturation border from child to teenager (László 1998, Pápai 1996, 2002). The data from these studies showed that the menarche in athlete girls has occurred later in relation to average Hungarian children. The present research has confirmed the belated menarche in athletes. These findings from Hungary are consistent with those reported in the literature. There is evidence that, menarche occurs at a later age in athletes. For example, the average American girls tend to get their first menstrual period between ages 12 and 13 years. Some inquiries have shown that menarche starts at the age of 13.6 years in track and field athletes (Malina et al. 1973), 14.2 years in Olympic volleyball candidates (Malina et al. 1978), 14 years in elite figure skaters, 12.9 years in elite Alpine racers, 13.4 years in competitive swimmers (Stager et al. 1984), and 15.6 years in elite gymnasts (Claessens et al. 1992).

When focusing on the delayed menarche ages in athletes, the first explanation that comes to mind is the intensive physical training of young athletes from an early chronological age. However, the effect of demanding physical work has no relevance in our sample, because the work load of the athletes reached the optimal level rather than a damaging one.

Although not all the factors that influence the timing of menarche have been identified yet, the effects of several factors have been shown to affect the late menarche in athletes (Malina 1983, 1986, Malina and Bouchard 1991). Malina (1983) reviewed the data on menarcheal age in detail and framed a two-part hypothesis combining the effect of biological and social factors.

Baxter-Jones and associates (1994) have examined the age of menarche in intensively training girls (gymnastics, swimming, tennis). All the children started their sport at an early age and had long and demanding training sessions. Between the three groups, only the gymnasts were late maturers. On the basis of the results the authors supposed that menarche in gymnasts was intrinsically late rather than delayed. These results suggested some form of sport-specific selection.

Age at menarche is closely related to the development of secondary sexual characteristics (Tanner 1962, Malina 1986, Bodzsár 2003). Studies on the relationship between physiological age and indices of sexual maturation are very rare for athletes. In athlete longitudinal samples (László 1998, Balázs and László 2006) a close connection was found between physiological age and the time at entering stages of sexual characteristics (for girls: $r=0.81-0.87$ between breast stages B3–B5 and menarche; for boys: $r=0.77$ between genital stages G3–G5 and spermatarche). Menarche has a fixed position in the sequence of pubertal events. Being a late pubertal maturation index, it occurs at/around stage B4, after the intense somatic changes (Tanner et al. 1976). Such findings suggest that later menarche is associated with later development of the maturity characteristics or reversed. This phenomenon was also confirmed in the current study.

Children's sexual maturation is not bound to the chronological age. In parallel with sexual maturation, there is an increase in the body's maturation and changes take place in both body proportions as well as body composition. As a consequence, changes in body shape also become evident. Early and late maturation does not simply imply a delayed development on the time scale, but rather the period the development of various maturation markers (Bodzsár and Pápai 1989), that may be conceptualised as the rate of rapid changes in body measurements and their magnitude (Pantsiotou et al. 2008). As a consequence of differences in the rate and magnitude of development, body size, body proportions, and body composition also differs between early and late maturing children.

We were interested in the question whether or not the maturation type has impact on the body components. It was also a question whether athletes and non-athletes differ by maturation type. Henceforth, we examined body components of early and late maturing athlete and non-athlete girls. In the analysis three aspects were considered: (1) Comparison of athletes and non-athletes. (2) Changes along the breast stages. (3) Differences between early and late maturing children.

When comparing the body mass of athletes and non-athletes by the time of maturation we could not find significant difference. At the same time there were notable differences in the body composition. Non-athletes – irrespectively of maturation type – had significantly lower muscle mass and higher fat mass than athletes. It is interesting, that the relative bone mass was quite similar in both groups, only the late maturing girls differed in stage B2.

The bone per cent of early maturing non-athlete girls did not decrease significantly in the consecutive stages of breast development (Figure 1). They had higher proportion of bone mass than their late maturing counterparts. For late maturers the decline was steeper along the breast stages. Significant difference was found between stages B3 and B4. Relative bone mass of early and late maturers differed in stages B4 and B5 (Figure 1).

Similarly to the non-athletes, the proportion of bone mass lessened in athletes through the breast stages (Figure 2). The diminution was significant both for early and late maturers during the entire maturation period. The differences between the maturation types were more accentuated in phases B3 and B4.

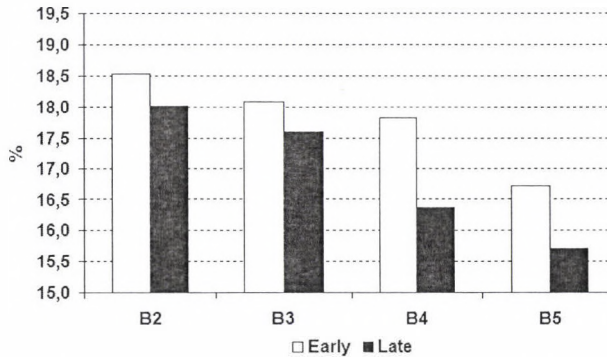


Figure 1: The relative bone mass (mean) of non-athletes.

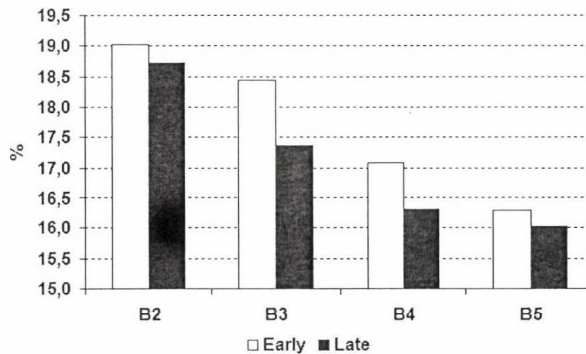


Figure 2: The relative bone mass (mean) of athletes.

The results for bone mass indicate that the later a girl enters the respective phase of her breast development, the less relative bone mass she has. Perhaps, the effect of the late maturation on the bony system manifests in a more fragile skeleton.

When comparing non-athletes to athletes, it was a surprising result that both early- and late maturing girls had similar portion of bone mass. Presumably, the similar body mass demanded similarity in the bone mass of the examined girls. The early growth and stabilization of skeletal mass is fundamental in the course of puberty, because it has to bear the intensely growing body mass in which the amount and the rate of the components changes significantly (Pápai 2000).

Not only the amount of bone mass but also the structure and the function of bones change during sexual maturation. Probably it is not actually the mass, but the structural robustness of the bones that is to keep pace with the growing muscle mass. Data referring to the changes in skeletal system revealed that bone mineral density in non-athlete girls increases significantly during the breast development (Boot et al. 1997). Other studies proved that physical activity, both in childhood and adolescence has a beneficial effect on the skeleton, by aiding in bone mineral acquisition (Courteix et al. 1998, Zanker et al. 2003, El Hage et al. 2009). The data suggest that in general the skeleton of athletes is stronger and better mineralized than that of the non-athletes. Athletes have advantage over non-athletes in skeletal maturation, especially in the weight-bearing sports disciplines.

The active part of the skeleto-muscular system behaved distinctively. Non-athlete girls showing an early maturation had the lowest muscle mass in their body (Figure 3). In stage B4 the proportion of muscle mass increased suddenly denoting a faster gain in muscle mass in relation to body mass. Late maturers had a higher portion of muscle mass, than their early maturing peers. The changes along the breast stages indicate that the gain in muscle mass was proportionate to their body mass. The differences between the maturity groups were significant in the early- and mid-stages (B2–B3).

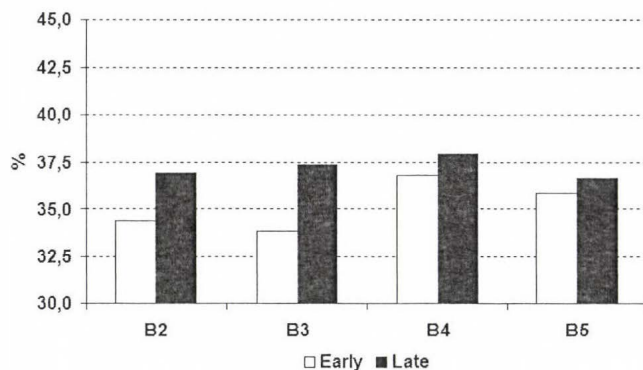


Figure 3: The relative muscle mass (mean) of non-athletes.

Relative muscle mass of athletes did not change during the breast development (Figure 4). This result demonstrated that the growth in muscle mass kept pace with the one in body mass. Similar to non-athletes, late maturers also had higher ratios of muscle mass. The differences between the subgroups were significant, but in the end-phase of breast maturation the differences have levelled off.

Early maturing non-athletes (Figure 5) had a very high portion of body fat in stages B2 and B3. Late maturers did not change their fat proportion during the developmental period. Reaching stage B5 (adult phase), both groups gained considerable rate of fat mass. In stages B4 and B5 the differences disappeared between the maturation groups. In athletes (Figure 6) the fat accumulation was almost linear along the stages. Early maturing girls had significantly greater fat per cent than their late maturing peers. After menarche (B4) the gain was significant for late maturers and the differences have equalized between the two groups.

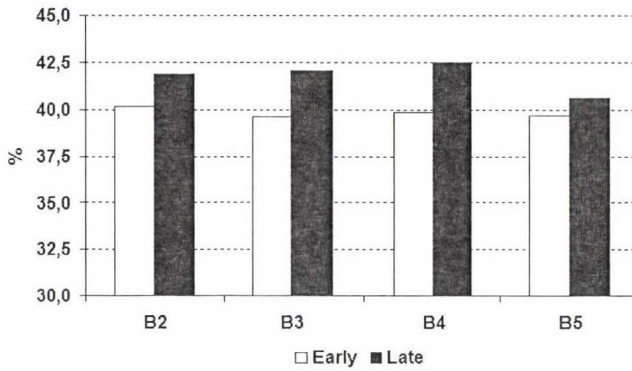


Figure 4: The relative muscle mass (mean) of athletes.

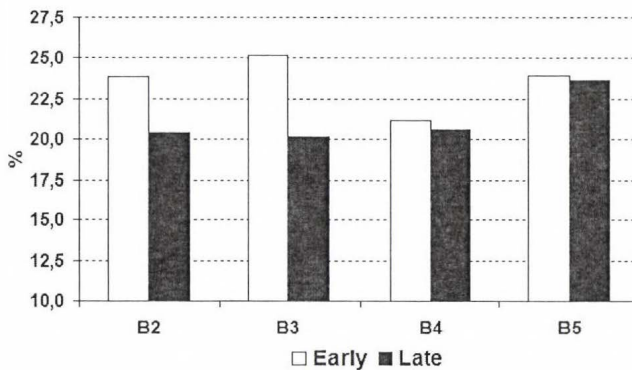


Figure 5: The relative fat mass (mean) of non-athletes.

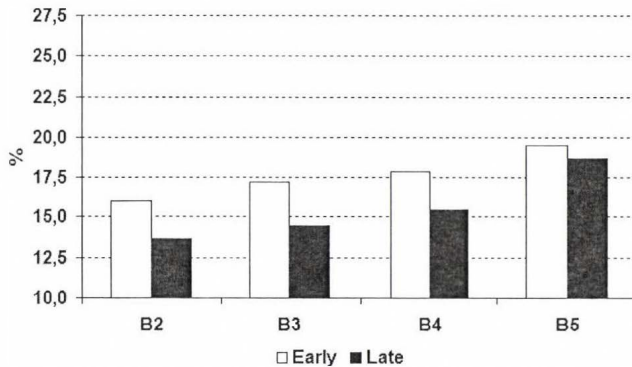


Figure 6: The relative fat mass (mean) of athletes.

Studies have shown that sexual maturation has noticeable influence on fat accumulation and on the onset of maturation (Garn et al. 1986, Van Lenthe et al. 1996). It was also pointed out that the rate of overweight or obese girls is greater among early maturers than among the average or late maturing children (Adair and Gordon-Larsen 2001, Wang 2002).

Non-athletes in the current study had relatively high body fat percentages, which is mainly characteristic of early maturing girls especially at the onset of sexual maturation. In stage B4, when the menarche appears, the differences between early and late maturing girls levelled off. Subsequently the post-menarcheal accumulation of fat started in both groups. A decrease in body fat around the menarche, could not be established in athletes. Early maturing athletes, similarly to non-athletes, possessed larger fat stores, but the absolute values of these were not even close to the fat mass accumulated by the non-athletes.

Summary of data analysis revealed that two body components that clearly distinguished young female athletes from the non-athletes were the relative proportions of body fat mass and muscle mass.

The progression in breast maturation was in relation with significant changes in body shape, too. The dispersion showed clearly that the somatotype of girls in various stages of development differed substantially. Early maturers of non-athlete girls were extremely endomorph (Figure 7). Late maturers have had a more slender physique than their early maturing peers. During the developmental phases (B2–B4) their somatotype remained almost constant. Thereafter, there was a significant wandering toward endomorphy and in stage B5 they reached the balanced endomorph field.

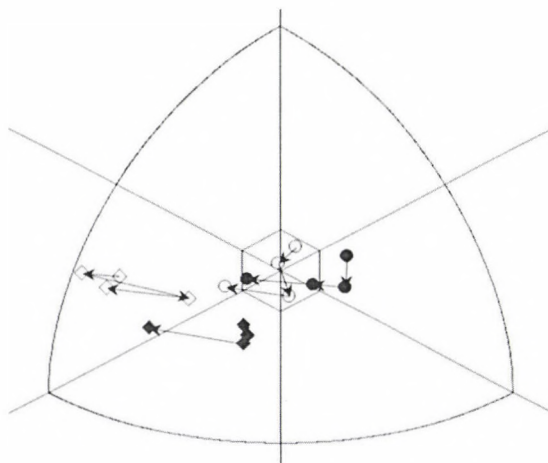


Figure 7: Somatotype of the examined girls by the maturation stages of breast (◇: early maturing non-athletes; ●: late maturing non-athletes; ○: early maturing athletes; ●: late maturing athletes; start arrow: second stage of breast development – B2; end arrow: adult stage of breast development – B5).

The somatoplots of early maturing athletes were in the central hexagon. During the sexual development the mesomorph dominance decreased in their shape. After stage B4 they passed towards the balanced endomorph field. Late maturers started from the mesomorphic ectomorph field and reached the central hexagon. The late maturing girls were more linear in the early phases of breast development and they kept their mesomorphy component stable. These subgroups had much more similar somatotype than it was found for non-athletes (Figure 7).

Although the body composition, examined on the bases of breast development, of early maturing athletes and non-athletes showed a similar trend, the body mass composition of the athletes was substantially different from those of non-athletes. The difference was attributed to the greater – and more advantageous – muscle/fat ratio in athletes as contrasted to non-athletes. A large proportion of early maturing girls quit their athletic career at the time of adolescence. The decision could be explained in part by lesser success in sport that could be attributed to fast fat accumulation and increase in body mass after the menarche, which interferes with skilled motor performance. However, social and psychological factors could also largely contribute to career termination after sexual maturation.

The current data demonstrate that selection in sport plays a crucial role in the girls' body built. Sport selections favour those whose body built resembles that of boys, or whose body shape is more linear, the body mass contains a high muscle to fat ratio. The preponderance of early and late maturers in a given sport largely depends on the biomechanical significance of linearity and robustness in successful performance. Among the participants of the study a large proportion of the early maturing girls took part in ball games and combat sports, while the bulk of late maturers were involved in gymnastics, track and field and modern pentathlon. Nevertheless, some early maturing girls preferred participating in track and field athletics and some late maturers were involved in ball sports and judo.

It appears that in sports where height and body built are important in the selection criteria, the selection aims primarily at body built. Since a given body built is associated with a typical maturation type, the selection of the later may be a consequential process. With regard to the late menarcheal age of athletes, several scholars have discussed the possible consequences of selection. We suggest that the late sexual maturation seen in young athletes is a consequence of selection.

Summary

The present work has examined the body composition and body dimensions of early and late maturing athlete and non-athlete girls in relation to the stages of their breast development. The most prominent findings of the study are summarized below:

- Athletes have experienced the onset of their breast development later than non-athletes and menarche also occurred later in the former group.
- The developmental trend for body components was similar for athletes and non-athletes. The alterations in body composition of athletes were more balanced than it was found in non-athletes.
- Early maturers had higher rate of bone mass, gained more fat and had less proportion of muscle than their late maturing peers.
- Differences in body composition between the early and late maturers were accentuated mainly in the developmental stages (B2–B4). At stage B5 the body builds of the two maturation types became similar, indicating the transient nature of the studied phenomenon.
- Early maturing non-athletes have had a dominant endomorph body built. Late maturing ones were relatively slimmer and they changed their body form conspicuously after stage B4.

- The somatotypes of athlete subgroups were closer to each other than that of the non-athletes. The relative weight of the three components was balanced or in the case of the late maturers slight mesomorph dominance was seen.
- Belated menarche and late breast maturation are linked up; they represent the two aspects of maturation type. Late maturation correlates with specific body structure, i.e. more linear body build and higher muscle to fat ratio. Sport disciplines, in which body build is an important factor, select their talented candidates on the basis of size and shape. That is, why we think, that maturation is a consequential moment in the process of sport selection.

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