

## Fat pattern of athlete and non-athlete girls during puberty

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**ABSTRACT:** The study focused on the peculiarities of fat accumulation during maturation. The main purpose of the study was trifold: to detect the alterations in fat gain during breast maturation; to examine fat accumulation after physiological maturation and the influence of breast maturation and sport activity on fatness. The subjects were athlete (N=1428) and non-athlete (N=1030) girls. They were grouped by the stages of breast development. Fat accumulation was followed up until four years after menarche. Regional fat distribution was examined on the basis of skinfolds taken at triceps, scapula, abdomen and thigh. Progressing with breast development, body fat percent increased in both groups, though in non-athletes a decrease was found in stage B4. During sexual maturation the thickness of subcutaneous adipose tissue decreased on the extremities and increased on the trunk. Non-athletes stored more fat on their upper trunk, while athletes did it on their lower trunk. After menarche the differences between athlete and non-athlete girls were preserved. In conclusion it may be stated that during sexual maturation the regional apposition trend of body fat was similar for athletes and non-athletes. The differences emerged in the relative distributions. Athlete girls accumulated proportionally more fat on their lower body, representing better the female-type distribution of body fat than non-athlete girls.

**KEY WORDS:** breast maturation, menarche, regional fat distribution, athlete girls

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The adult pattern of fat distribution manifests gradually until the late twenties. Adolescence is an important period in this process. At this time there is a significant rearrangement in regional fat distribution. Children appear to deposit fat centrally and lose fat peripherally as they mature.

Lenthe and colleagues (1996) established that girls with a relatively early menarche showed a more central pattern of body fat compared to girls with a relatively late menarche in adolescence and

adulthood. Several studies have shown that the incidence of being overweight or obese is greater among early maturers than among the average or late maturing children (Slyper 1998; Adair and Gordon-Larsen 2001; Wang 2002). Controversially, the Frisch (1972) hypothesis postulated that body adiposity influences the initiation of sexual maturation. Ridder and associates (1992) concluded that neither body fat mass nor body fat distribution seems to trigger the onset of puberty in healthy girls.

Although the casual connection is disputed, there is a growing body of evidence that sexual maturation has noticeable influence on fat accumulation and on the onset of maturation (Garn et al. 1986; Lenthe et al. 1996; Guo et al. 1998; Ribeiro et al. 2006).

Body fat distribution is also an important metabolic and cardiovascular risk factor (Daniels et al. 1999; Katzmarzyk et al. 1999; Shalitin and Phillip 2003). The more central the subcutaneous fatness is, the higher the risks are. Fat distribution appears to be a more important influence on cardiovascular risk factors in young subjects than overall adiposity (Daniels et al. 1999). The data indicate that this phase is one of the critical periods for becoming overweight or obese (Dietz 1994; Lawlor and Chaturvedi 2006).

In athletic performance fat is an essential factor. Different sport disciplines demand different fat storage. Tróznai and Pápai (2008) found that young talented athletes with excellent performance had less overall fat than their less efficient peers.

It is an important question whether or not the growing child athletes differ by sport disciplines and from non-athletes in body fatness and subcutaneous adiposity. Moore et al. (2003) gave supporting data to the hypothesis that higher level of physical activity during childhood contributes to the acquisition of less body fat by the time of early adolescence. Other authors found that proportionate regional fat distribution of athletes and non-athletes is quite similar (Pařízková 1977; Eisenmann and Malina 2002). On the other hand, some studies have shown that athlete girls of various sports disciplines accumulate more relative fat on their extremities than non-athletes (Pápai 2000; Tróznai and Pápai 2005).

The topic of our work was to follow the changes in body fatness during sexual maturation.

The aims were trifold: to observe alterations in fat deposition in athlete and non-athlete girls during breast development, to examine the pattern of fat accumulation after physiological maturation and the influence of breast maturation and sports activity in the measures of fatness.

## Materials and methods

The cross sectional athlete study was carried out in the sport clubs and sport schools of Budapest and the large cities of Hungary. The case number was 1428. Their age varied between 8.5 and 17 years. The representatives of aerobic sports, fighting disciplines, ball games and gymnastics were mainly involved in this subsample. All of them had attended a minimum of four training sessions a week in the year before the study. Thus, they were regarded as a sample with an athletic level of habitual physical activity.

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.

Body measurements were taken according to the description of Martin and Saller (1957–1966) and the recommendations of IBP (Tanner et al. 1969). Body components were calculated by the four-component model of Drinkwater and Ross (1980). To characterize the regional body fat distribution the following

skinfolds were chosen: triceps, subscapular, abdominal and thigh. To obtain relative measures they were proportionated to the sum of skinfolds.

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 a "status-quo" method.

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. The groups were compared by multivariate GLM. This procedure allowed us to assess the effect of breast maturation and sports activity on the regional fat indices.

## Results

First the indices of sexual maturation were examined. Table 1 shows the differences found in the timing of sexual maturation variables.

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 the belated occurrence of menarche.

Maturation events run parallel with significant changes in body build. The most intense growth in body dimensions emerges in the early- and the mid-phases of sexual development. In point of dimensional growth menarche is a late pubertal event. Both in athletes and non-athletes it occurs at/around stage B4.

Our study focused on the measures of fatness. To evaluate body adiposity, per-

Table 1. Median ages for breast maturation and menarche in the study population

Breast stages	Non athletes	Athletes
	Median ages (yr.)	
B2	9.6	11.2
B3	11.1	12.3
B4	12.9	13.3
B5	14.3	14.7
Menarche	12.68±0.06	13.51±0.06

cent body fat was used. The data were arranged by the successive stages of breast development.

Progressing with breast maturation, body fat percent increases in athlete girls (Fig. 1). Two breakpoints could be detected in figure, one is at the beginning and the other is at the end of maturation. The total accretion was about 6%. Half of it was collected during the developmental phases of breast maturation, while the other half was gained in stage B5, in the final stage. The data indicated accelerated fat gain at the end of sexual maturation.

The rapid fat accumulation after menarche is often said to be a significant factor in sports career termination in athlete girls. Did fat stores increase as rapidly and at a high rate as the figure shows?

To reply to this question, we examined what happened in the postmenarcheal period (B5) after physiological maturation. The girls in this stage were grouped by the time elapsed after their menarche. Figure 2 shows that body fat percent had increased significantly for two years after physiological maturation. The data certified the rapid fat storage in a short time interval in athlete girls.

As was expected, non-athletes were fatter than athletes (Fig. 1). They gained less body fat during breast maturation (about 4%) than their athlete counter-

parts. Similar to the athletes, half of this increment was stored in the final phase (B5). After physiological maturation body fat did not change in non-athletes (Fig. 2).

It is also a very important question whether there is a similarity in the apposition of subcutaneous fat on different anatomical sites of the body. The next analysis refers to the body adiposity in different body regions.

Studying the relative measure of fat over the triceps (Fig. 3), a decline was observed in both groups with the progressing of breast maturation. The decrease was conspicuous in the early phases. After menarche (Fig. 4) the yearly increments were small in this measurement. Athlete children had a remarkably thin-

ner subcutaneous fat layer on their upper extremities than did non-athletes.

From among the anatomical sites the proportionally thickest fat was found on the thigh (Fig. 5). Proceeding with breast maturation, the relative fat decreased in both groups. From stage B3 non-athletes had significantly less proportionate adipose tissue on their thigh than did athletes. After menarche (Fig. 6), a small but further drop was found in both groups.

On the other hand, trunk fat had increased in both groups. In the early developmental phases athletes had a significantly thicker proportionate fat layer on their upper trunk (Fig. 7) but by the end of the maturation the trend reversed and non-athletes stored more fat in this region than athletes. After menarche (Fig.

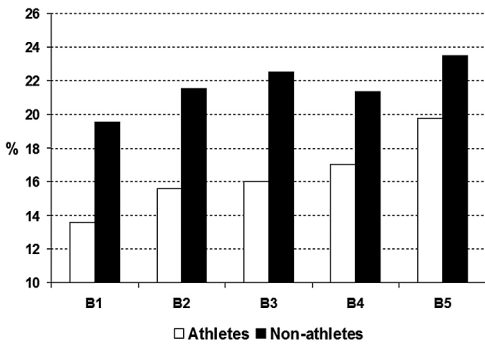


Fig. 1. Relative fat mass by the breast development

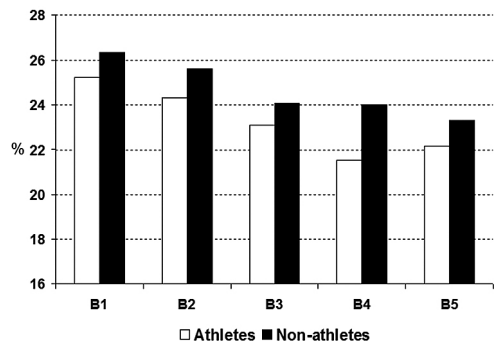


Fig. 3. Relative fat over triceps by the breast development

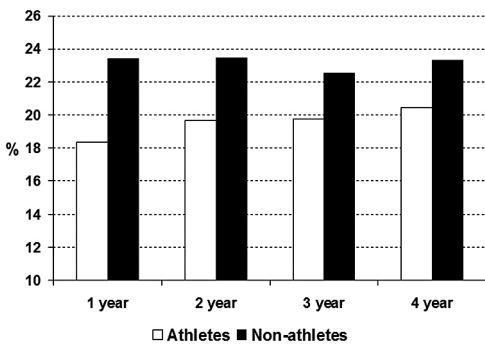


Fig. 2. Relative fat mass after menarche

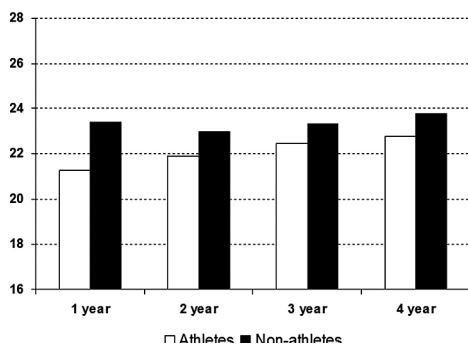


Figure 4. Relative fat over triceps after menarche

8) a small decrease was found in both groups with the subsequent years.

In the abdominal area (Fig. 9) a reversed pattern was detected. Fat stores of athletes on the lower trunk surpassed the ones in the non-athletes. After menarche (Fig. 10) the trend of fat accumulation was switched for the groups: athletes decreased, non-athletes increased their fat store. However, at the end of the investigated period the differences levelled off.

For testing the influence of maturation and sports activity a multivariate analysis of variance (MANOVA) model has been applied for all fatness variables (Malhotra 2008) and controlled by multivariate covariates (Pillai's Trace, Wilks Lambda) in two groups under study. The MANOVA model well fits the data. The

assumption of equal group variances was not supported by the Levene-test. Taking into account that the Levene test is highly sensitive to large cell numbers, we investigated the spread versus level plots and group variances. Both the plots and variances revealed that the assumption of variance homogeneity was not violated.

The linear model proved to be significant (Table 2). The partial eta values proved that both breast maturation and sport activity exerted influence on the measures of fatness, but the proportion of the explained variance was moderate. The strongest impact was found on the overall fatness and the abdominal skinfold.

The independent variables (breast maturation and sports activity) contributed to the measures of fatness to a vary-

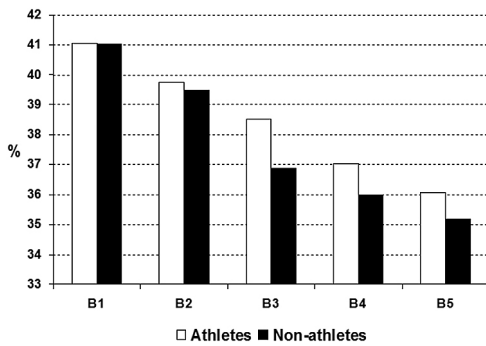


Figure 5. Relative fat on the thigh by the breast development

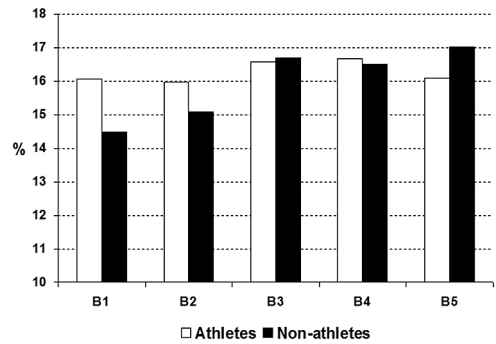


Figure 7. Relative fat over the scapula by the breast development

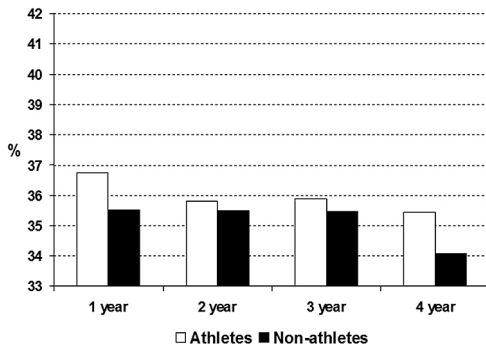


Fig. 6. Relative fat on the thigh after menarche

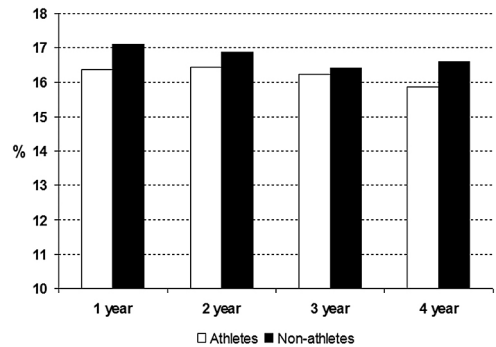


Fig. 8. Relative fat over the scapula after menarche

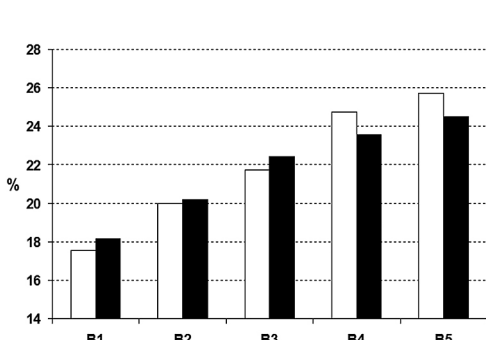


Fig. 9. Relative fat at the abdomen by the breast development

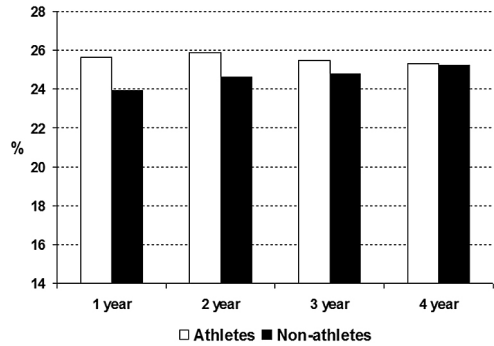


Fig. 10. Relative fat at the abdomen after menarche

Table 2. Contribution of breast maturation and sport activity to the measures of fatness. Results of multivariate linear regression model

Source	Dependent Variable (%)	Type III Sum of Squares	F	Sig.	Partial Eta Squared
Corrected Model	Triceps	7008.057 <sup>a</sup>	58.240	.000	.155
	Scapula	1860.325 <sup>c</sup>	19.701	.000	.059
	Abdomen	24082.654 <sup>d</sup>	131.624	.000	.294
	Thigh	12508.627 <sup>e</sup>	54.475	.000	.147
	Total fat	26002.493 <sup>f</sup>	177.291	.000	.359
Breast maturation	Triceps	4633.739	86.644	.000	.108
	Scapula	990.140	23.593	.000	.032
	Abdomen	21572.890	265.291	.000	.271
	Thigh	11914.510	116.748	.000	.141
	Total fat	9169.769	116.748	.000	.165
Sport activity	Triceps	1220.204	91.264	.000	.031
	Scapula	64.509	6.148	.013	.002
	Abdomen	163.068	8.021	.005	.003
	Thigh	199.654	7.825	.005	.003
	Total fat	18419.514	1130.298	.000	.284
Breast*Sport	Triceps	182.467	3.412	.009	.005
	Scapula	624.805	14.888	.000	.020
	Abdomen	867.979	10.674	.000	.015
	Thigh	277.906	2,723	.028	.004
	Total fat	815.655	12.513	.000	.017

a. R Squared = .155 (Adjusted R Squared = .153)  
 b. Computed using alpha = .05  
 c. R Squared .059 (Adjusted R Squared = .056)  
 d. R Squared = .294 (Adjusted R Squared = .292)  
 e. R Squared = .147 (Adjusted R Squared = .144)  
 f. R Squared = .359 (Adjusted R Squared = .357)

ing extent. Maturation had the most intense effect on abdominal relative fatness and overall fatness of the subjects.

Sports activity has only a minimal but significant impact on the regional fat distribution. By contrast, it revealed a stronger effect on the overall fatness of the examined girls. There was an interaction between the independent variables that was also significant, but small.

## Discussion

This study provides information on the development of body fatness during puberty. The first point to discuss is that athlete and non-athlete girls exhibited different patterns of fat apposition during breast maturation. The peculiarity of this trend was exemplified by a sudden drop in stage B4 for non-athletes.

In the reviewed literature, data rarely exist on the fat changes in the context of breast maturation. A couple of studies (Malina and Bouchard 1991; Ridder et al. 1992) examined fat gain only in the early stages of breast maturation. We could find some supporting data on the existence of this phenomenon. In a longitudinal study for normal girls a decrease was observed in skinfold thicknesses at the time of menarche (Pápai and Bodzsár 1989/90). Bodzsár (2003) got similar results to ours when grouping non-athlete girls by the stages of breast maturation. Studying body fat changes by maturation type (Pápai et al. 2009), late maturing non-athletes exhibited a pattern similar to our athletes, while the early and average maturing girls showed a significant decrease in stage B4. In the above mentioned studies the relative body fat was higher than 20% per cent.

Analyzing the present athlete sample by sport disciplines, only the ball players

exhibited an irregular pattern, similar to the non-athletes. We have to note that they had the highest body fat amongst the representatives of the examined sports disciplines.

This irregular pattern of fat accumulation appears as high body fat content. Our data suggest that high body fat at the beginning of puberty may influence and perhaps alter the apposition trend of accumulation. Otherwise, we have no explanation for this phenomenon.

During puberty the changes in regional fat distribution are partly due to the changes in hormonal levels and to the altered responsiveness of fat organ to hormonal effects.

Studies, dealing with age-related changes in the distribution of subcutaneous adipose tissue, have pointed out the tendency of fat centralization (Malina and Bouchard 1991; Ridder et al. 1992; Len-the et al. 1996; Malina 1996; Hajnis et al. 2003; Taylor et al. 2010). It has also been suggested that adolescence is a sensitive period for the development of a central pattern of fat (Ramirez and Mueller 1980; Mueller 1982). Though this centralization pattern is characteristic for both sexes, Mueller (1982) named it a masculinising process because of its more rapid manifestation in males than in females.

Our data, arranged by breast maturation, confirmed the masculinising trend both for athlete and non-athlete girls. The decrease in the subcutaneous adipose tissue was well detected on the extremities. But there were significant differences in the proportions between the groups. Non-athletes had relatively thicker fat on their upper extremity, while athletes had it on their lower extremity.

Truncal fat increased in both group. Non-athletes tended to pile up more pro-

portionate adipose tissue on their chest region, and at the end of the maturation process they significantly exceeded athlete girls in this respect. On the pelvic region a reversed pattern was noticed.

Examining the body regions together, athletes from mid-puberty accumulated more relative fat mass on the lower part of their body, while non-athletes did it on their upper body. The difference was about 2 per cent. At the end of breast maturation fat distribution was predominantly extremity type yet.

Pubertal girls – as it was also seen in this study – gain significant amount and rate of fat after menarche. Characteristic for females, they pile up more fat on their thigh, buttock and pelvic sites (Malina and Bouchard 1991; Elbers et al. 1999; Manolopoulos et al. 2010; Wells 2010). This stored energy serves reproductive functions and the female organism exerts to preserve it in all circumstances. In this context it was a very interesting result of ours that after some years of menarche abdominal skinfold differences leveled off between the groups (Fig. 10). It is also important that in our model sexual maturation had the highest impact on the abdominal skinfold (Table 2).

The studied athletes have less overall body fat and thinner subcutaneous adipose tissue on the examined anatomical sites than non-athletes. The relative measurements demonstrated that they accumulated more body fat on their lower parts of the body and so represented better the female-type distribution of body fat than non-athletes.

## Conclusions

During breast maturation the line of relative fat accumulation was different for athletes and non-athletes. The explana-

tion for this phenomenon is obscure. It may be in connection with the different body fat content of the two groups.

The regional apposition trend of body fat was similar for athletes and non-athletes. In relation to extremities and trunk, the tendency of centralization was discernible in both groups. The differences between the two groups emerged in the relative distributions. At the end of breast maturation athlete girls accumulated proportionally more fat on their lower body.

In terms of reproductiveness and health expectations, athletes represented better the female-type distribution of body fat than non-athletes.

Both breast maturation and sport activity influenced overall fatness and subcutaneous adiposity. The effects were significant, but moderate.

The changes in body fat distribution after menarche gave additional indication as to the termination of sexual maturation.

## Authors' contribution

JP was the principal investigator, designed and performed the study, conceived and designed the manuscript; ZT arranged and analyzed the data, wrote the result part of the manuscript; TSz wrote the discussion part of the manuscript; ASz performed statistical analyzes and was a proofreader. All authors read and approved the final manuscript.

## Conflicting interests

The authors declare that they have no conflicts of interest in the research.

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