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Body proportions, body composition and pubertal development of children in competitive sports

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The aim of this study was primarily to investigate anthropometric variables, body composition and pubertal development in children aged 9–13 participating in competitive sports. Secondly, the influence of age, sport, training hours and pubertal development/maternal menarcheal age on body composition and pubertal development was explored. A total of 183 (96 girls, 87 boys) children performing swimming (Sw), tennis (Te), European team handball (TH), and gymnastics (Gy) took part in the study. Anthropometric measurements and pubertal development were determined. The participants completed a questionnaire regarding hours of training per week and maternal menarcheal age. Significant differences in stature (z-scores) were found in both boys (Sw=0.06; Te=0.04; TH=0.05; Gy=−0.66, $P<0.004$) and girls (Sw=0.12; Te=0.19; TH=0.25; Gy=−0.96, $P<0.004$). In girls, sum of skinfolds in millimetres (Sw=33.4; Te=33.3; TH=41.0; Gy=27.2, $P<0.02$) and body mass index z-scores (SW=0.00; Te=−0.27; TH=0.35; Gy=−0.25, $P<0.001$) were different between the sports. A regression analysis revealed that in girls, age and maternal menarcheal age were significantly associated with pubertal development ($P<0.005$ and $P<0.01$), respectively, and sport was associated with the sum of skinfolds ($P<0.05$). In boys, only age was significantly associated with pubertal development ($P<0.005$). In conclusion, anthropometric and body composition differences exist in athletes of both sexes from different sports but are more evident in females. Most importantly, we did not find any effect of training on body composition or pubertal development, confirming previous data that children in competitive sports are selected due to constitutional factors.

Participating in competitive sport at a young age has been associated with specific body composition and body proportions (Claessens et al., 1991). Studies of female gymnasts at elite level and of ballet dancers have consistently demonstrated a reduced stature (Baxter-Jones & Helms, 1996; Benardot & Czerwinski, 1991; Caldarone, Leglise, Giampietro, Berlutti, 1986; Claessens et al., 1991), a leaner body composition estimated from skinfold measurements (Benardot & Czerwinski 1991; Caldarone et al., 1986; Pigeon, Oliver, Charlet, Rochiccioli, 1997) and reduced body mass index (BMI) in girls (Caldarone et al., 1986; Pigeon et al., 1997) compared with a normal population and with individuals in other sports. In contrast, girl swimmers seemed to be taller and more advanced in their puberty (Baxter-Jones & Helms, 1996; Theintz, Howald, Weiss, Sizonenko, 1993). Male soccer players who played in primary teams have also been found to follow the growth of an early maturer with advanced stature and testis size (Cacciari et al., 1990). A recent 3-year follow-up study of 231 males and 222 female athletes, 8–16 years of age, in swimming, tennis, soccer and gymnastics has confirmed that differences in stature and pubertal development may exist (Baxter-Jones & Helms, 1996). The reasons for these differences are not clear. We have previously suggested that constitutional factors are important for the choice of sport in children (Damsgaard, Bencke, Matthiesen, Petersen, Müller, 1999). Further investigations are needed, however, to confirm the hypothesis of selection of children into different sports due to their physical appearance.

The aim of the present cross-sectional study was twofold: First, to investigate anthropometric variables, body composition and pubertal development of 183 boys and girls aged 9–13 participating in swimming, tennis, European team handball (team handball) and gymnastics. Second, to elucidate whether age, sport, training hours and maternal menarcheal age could account for any possible differences in body composition and pubertal development between the sports.

Subjects and methods

Subjects

The Danish Sports Association was asked to select Danish sport clubs at national level that have well-developed training programmes for children in swimming, tennis, team handball, and gymnastics. From a total of 11 clubs, the respective coaches selected all girls and boys aged 9–13 years who were active at a competitive level (participating in regional and/or national competitions); these children were then invited to participate in the study. A total of 183 (96 girls, 87 boys) agreed to participate.

The study was performed in accordance with the Helsinki II declaration and approved by the local ethics committee of Copenhagen, Denmark (approval no. (KF) 01–153/97). Oral as well as written information was given. Written informed consent was obtained from each participant and one of the parents. The study was part of a larger collaborative research project performed by the "Copenhagen Study Group of Children in Sports".

Methods

Standing height and sitting height were measured on a stadiometer (Holtain Ltd., Crymych, UK) to the nearest 0.1 cm, and the weight was recorded on a portable scale (Seca^{delta}, Model 707) to the nearest 0.1 kg. Armspan was measured as the distance between the tips of the longest digits on each hand with the arms stretched out horizontally. Sum of skinfolds was measured on the left side of the body using a Harpenden Skinfold Caliber adding four sites: biceps, triceps, subscapular and suprailiac according to previous validated tests (Durnin & Womersley, 1974). Based on double measurements of sum of skinfolds on 11 athletes, we found a standard error of 1.5 mm. This means that 95% of the repeated measurements on an individual would be at most 3 mm from the true value.

Mid-upper-arm circumference was measured midway between olecranon and acromion of both arms. To reduce measurement variation, the same investigator examined all children. In girls, breast stage of puberty was assessed according to Marshall & Tanner (1969). In boys, testicular volume was measured by a Prader orchidometer (Prader, 1966). The same female and male paediatricians assessed sexual maturity in the girls and boys, respectively. All measurements were performed on location in the sport clubs with portable equipment. The participants completed a questionnaire regarding training hours per week and maternal menarcheal age.

Sitting height ratio was calculated as sitting height divided by standing height. Armspan-standing height ratio was calculated as armspan divided by standing height. BMI was calculated as weight (kg) divided by height (m) squared. Left mid-upper-arm muscle circumference was calculated as left mid-upper-arm circumference from which the left triceps skinfold was subtracted (Malina & Bouchard, 1991).

Height, BMI and sitting height ratio were transformed into standard deviation scores (SDS) according to the following equation: SDS=(actual value−mean)/SD (Hertel et al., 1995; Laursen, 1998).

Statistical analyses

Statistical analyses were performed using a statistical package (SPSS). The Mann-Whitney test, Kruskal-Wallis analysis of variance and Chi^2-test were used to test for possible differences between sports. A linear regression model (GLM) was used to analyse the association between age, sport, training hours, pubertal development (breast stage/testicular volume) and skinfolds. A similar GLM was used to analyse the association between age, sport, training hours per week, maternal menarcheal

Table 1. Age distribution and anthropometric characteristics of children participating in four sports

Gender and sport	Age[1] (years)	Height[1] (SDS)[2]	Armspan standing height ratio[1]	Sitting height ratio[1] (SDS)[2]	Body mass index[1] (SDS)[2]	Sum of skinfolds[1] (mm)	Mid-upper-arm muscle circumference (cm)
Boys							
Swimming (*n*=23)	11.59 (9.17–12.99)	0.62 (−2.03 to 2.97)	1.00 (0.97–1.05)	0.09 (−1.24 to 1.40)	0.04 (−1.38 to 1.66)	31.0 (20.2–81.2)	22.7 (18.6–25.3)
Tennis (*n*=25)	11.62 (10.04–12.68)	0.04 (−1.39 to 1.79)	1.00 (0.96–1.04)	−0.10 (−1.41 to 1.92)	−0.01 (−1.30 to 1.69)	32.8 (18.8–74.8)	20.9 (18.3–28.4)
Team handball (*n*=22)	12.09 (11.48–12.72)	0.46 (−1.34 to 2.14)	1.00 (0.97–1.03)	−0.55 (−2.31 to 1.02)	−0.19 (−1.04 to 4.00)	29.5 (16.8–94.2)	21.6 (19.3–28.7)
Gymnastics (*n*=17)	10.81 (9.31–13.81)	−0.66 (−2.76 to 0.33)	1.01 (0.96–1.05)	0.23 (−1.31 to 1.25)	−0.39 (−0.76 to 1.35)	24.8 (18.8–54.8)	20.7 (19.4–25.7)
Kruskal-Wallis[3]	*P*=0.03	*P*=0.001	ns	ns	ns	ns	*P*=0.04
Girls							
Swimming (*n*=28)	11.58 (10.22–13.89)	0.12 (−1.78 to 1.62)	1.01 (0.95–1.04)	−0.11 (−1.69 to 1.85)	0.00 (−1.76 to 1.52)	33.4 (18.4–64.4)	22.6 (17.5–26.2)
Tennis (*n*=12)	11.86 (9.42–12.69)	0.19 (−1.07 to 2.06)	1.00 (0.96–1.03)	−0.37 (−1.67 to 0.65)	−0.27 (−0.75 to 1.81)	33.3 (27.2–61.2)	20.6 (18.8–26.4)
Team handball (*n*=24)	12.28 (11.05–12.92)	0.25 (−0.89 to 1.73)	1.00 (0.97–1.04)	−0.31 (−2.79 to 1.46)	0.35 (−1.11 to 2.38)	41.0 (22.6–79.2)	22.6 (19.2–26.9)
Gymnastics (*n*=32)	11.79 (9.36–13.50)	−0.96 (−2.49 to 1.49)	1.01 (0.97–1.04)	−0.14 (−1.65 to 1.37)	−0.25 (−1.96 to 0.77)	27.2 (18.4–82.2)	21.5 (17.5–23.9)
Kruskal-Wallis[3]	ns	*P*<0.0004	ns	ns	*P*=0.02	*P*=0.001	*P*=0.007

[1]Median (range), [2]Standard Deviation Score, [3]Kruskal-Wallis analysis of variance; ns: not significant.

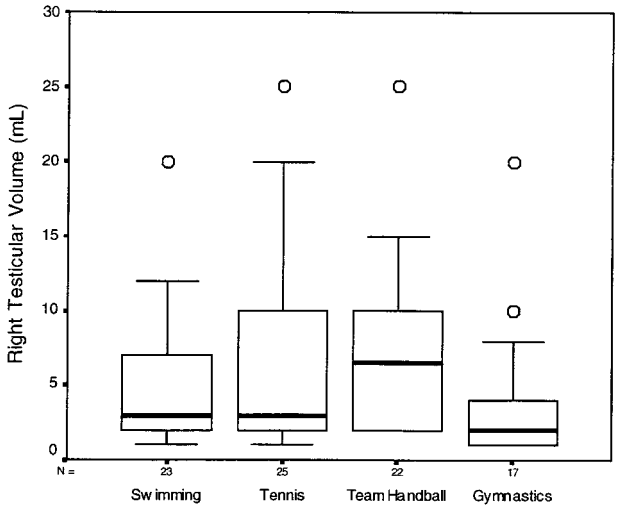

Fig. 1. Box plot of right testicular volume of 87 boys in swimming, tennis, team handball and gymnastics. The box indicates the 25th and 75th quartiles and the central line is the median. The ends of the whiskers are the 2.5% and 97.5% values. Values outside the range of the whiskers are extreme values (Kruskal-Wallis: not significant).

age and testicular volume. In girls, the GLM was approximated to suit pubertal development established as breast stage.

The validity of the regression model was checked using standard tests. These included assessing the distribution of the residuals and testing for normality, testing whether the residual variations in the four groups defined by the sport variable were the same, and checking the linearity assumptions in the model by means of standard scatter plots.

The level of significance used was $P<0.05$.

Results

Age distributions and anthropometric characteristics are given in Table 1. Standing height SDS was significantly different between the four sports in both sexes. As the single exception among the four sports, the median height SDS of gymnasts was below average (Danish standards). Sitting height ratio SDS and armspan-standing height ratio showed no differences between the groups (Table 1).

In girls, BMI and sum of skinfolds were both significantly different among the four sports. In both sexes, there was a significant difference between mid-upper-arm muscle circumference in the four sports (Table 1). Testis size (Fig. 1) and breast stage (Table 2) showed no difference between the sports despite the difference in age distribution in boys. Mothers of female tennis players were significantly older at menarche ($P=0.04$) (Fig. 2). Significant differences in training hours were found for both sexes (Fig. 3). Male gymnasts trained more than in the other sports whereas both female gymnasts and swimmers trained more hours per week than did tennis players and team handball players. Eight girls had reached men-

Table 2. Number of female participants in each breast stage according to Marshall & Tanner in percentage of the total number of participants in each of the four sports

	Breast stage				
	I	II	III	IV	V
Swimming	21.4%	39.3%	14.3%	21.4%	3.6%
	6	11	4	6	1
Tennis	33.3%	25.0%	33.3%	8.3%	
	4	3	4	1	
Team handball	8.3%	58.3%	29.2%	4.2%	
	2	14	7	1	
Gymnastics	43.8%	31.3%	18.8%	3.1%	3.1%
	14	10	6	1	1

(Kruskal-Wallis: Not significant).

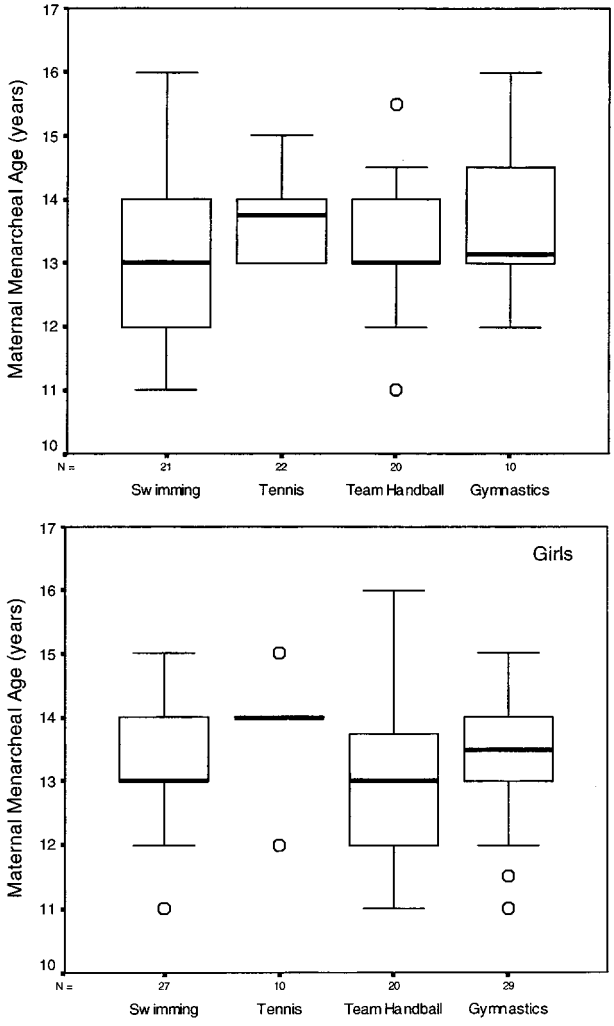

Fig. 2. Box plot of the maternal menarcheal age of 73 boys and 86 girls in swimming, tennis, team handball and gymnastics. The box indicates the 25th and 75th quartiles and the central line is the median. The ends of the whiskers are the 2.5% and 97.5% values. Values outside the range of the whiskers are extreme values (Kruskal-Wallis; Boys: not significant; girls: $P<0.05$).

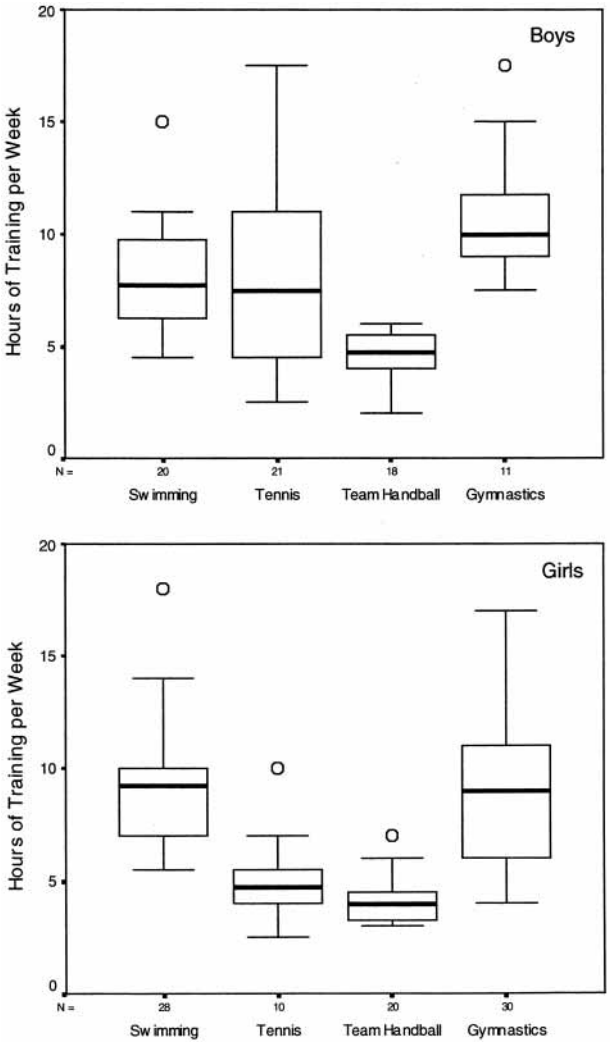

Fig. 3. Box plot for training hours per week of 70 boys and 88 girls in swimming, tennis, team handball and gymnastics. The box indicates the 25th and 75th quartiles and the central line is the median. The ends of the whiskers are the 2.5% and 97.5% values. Values outside the range of the whiskers are extreme values (Kruskal-Wallis; Both sexes: $P<0.0004$).

arche at the time of the study and no differences were found between the sports ($P=0.13$).

A GLM-model was constructed to test the variables for associated covariates. When adjusted for pubertal stage, training hours per week, and age, the height of both male and female gymnasts was smaller than the heights of the participants in the other sports ($P<0.03$ and $P<0.001$, respectively). In boys, BMI, sum of skinfolds (Table 3), and mid-upper-arm circumference did not show any difference between the sports when adjusted for pubertal stage, training hours per week, and age. In girls, however, team handball players had significantly greater BMI ($P=0.001$), sum of skinfolds ($P=0.001$) (Table 3), and mid-upper-arm circumference ($P<0.05$) than did the gymnasts when adjusted for the covariates.

Likewise, stage of puberty was tested for possible associated covariates and, in boys, age was significantly associated with testicular volume (Table 4). When testicular volume was adjusted for age, the parameter estimates of the different sports did not show any significant differences (Table 4). In girls, both age and maternal menarcheal age were significantly associated with breast stage. When breast stage was adjusted for these two covariates, the parameter estimates of the different sports showed that gymnasts had a significant lower breast stage compared to the swimmers ($P=0.02$) and tennis players ($P=0.04$) (Table 4).

Discussion

Stature

In accordance with previous studies (Baxter-Jones & Helms, 1996; Benardot & Czerwinski, 1991; Claessens et al., 1991; Peltenburg et al., 1984a), we have demonstrated considerable differences in standing height in a large sample of prepubertal and pubertal children participating in four different sports at a competitive level. In agreement with the study of Baxter-Jones & Helms (1996), we also found that male and female swimmers were significantly taller than gymnasts were and when compared with a Danish standard population, male swimmers were well above average whereas both male and female gymnasts were well below average. The explanation for this finding has proven to be complex. We have previously shown that in 183 athletes from four different sports standing height and BMI at 2 to 4 years of age and at the beginning of puberty did not shift percentile, suggesting that only constitutional factors are important for the choice of sports (Damsgaard et al., 1999). Several authors have implied that the difference in stature in swimmers and gymnasts might simply reflect the growth and development of an early maturer and a late maturer, respectively (Baxter-Jones & Helms, 1996; Claessens et al., 1991; Malina, 1994a; Peltenburg et al., 1984b). The lack of differences in pubertal development in our data suggests that other factors may be of importance in attained stature such as prepubertal growth, maternal menarcheal age, familial stature and nutrition. However, the children in our sample were relatively young, and pubertal development at this early age may not be advanced enough to detect possible differences. Only a few studies imply that strenuous physical training could affect normal growth (Lindholm, Hagenfeldt, Ringertz, 1994; Pigeon et al., 1997; Theintz et al., 1993). In the present cross-sectional study we have included physical training as a covariate in the GLM-model and found that training hours per week could not explain any of the differences in height attained among the four sports.

Table 3. Parameter estimates (95% confidence interval) for sum of skinfolds in the GLM-model when corrected for age, training, pubertal development, and sports in children participating in competitive sports

	Boys		Girls	
	Parameter estimates	*P*-value	Parameter estimates	*P*-value
Age (years)	−1.20 (−6.17 to 3.79)	0.63	0.86 (−3.19 to 4.92)	0.67
Training (hours/week)	−1.14 (−2.44 to 0.164)	0.09	0.07 (−1.24 to 1.09)	0.90
Testicular volume (mL)	0.48 (−0.26 to 1.22)	0.20		
Breast stage			2.10 (−0.39 to 4.58)	0.10
Swimming	4.52 (−7.99 to 17.02)	0.47	5.10 (−1.24 to 11.43)	0.11
Tennis	2.82 (−9.59 to 15.23)	0.65	4.70 (−3.41 to 12.81)	0.25
Team handball	3.66 (−11.86 to 19.18)	0.64	11.77 (5.25 to 18.29)	0.001
Gymnastics	0[a]		0[a]	

[a]The parameter estimate for gymnastics is set as reference value.

Table 4. Parameter estimates (95% confidence interval) in the GLM-model for right testicular volume in boys and breast stage in girls when corrected for age, training hours per week, maternal menarcheal age, and sport in children participating in competitive sports

	Boys		Girls	
	Parameter estimates	*P*-value	Parameter estimates	*P*-value
Age (years)	4.01 (2.56 to 5.46)	0.00	0.70 (0.47 to 0.93)	0.00
Training (hours/week)	0.01 (−0.45 to 0.48)	0.96	0.02 (−0.05 to 0.09)	0.53
Maternal menarcheal age	0.36 (−0.95 to 1.66)	0.59	−0.26 (−0.44 to −0.07)	0.01
Swimming	−0.78 (−5.28 to 3.74)	0.73	0.55 (0.09 to 1.00)	0.02
Tennis	0.83 (−3.54 to 5.20)	0.71	0.71 (0.04 to 1.38)	0.04
Team handball	−0.82 (−6.30 to 4.67)	0.77	0.25 (−0.39 to 0.89)	0.44
Gymnastics	0[a]		0[a]	

[a]The parameter estimate for gymnastics is set as reference value.

Body composition

Body composition as judged by BMI and sum of skinfolds was only different in girls, the data showing that gymnasts were leaner than the others. It has previously been shown, however, that differences in stature and BMI (girls only) among the participating children already existed at age 2–4, even when controlled for sport and hours of training per week (Damsgaard et al., 1999).

The mid-upper-arm circumference and sum of skinfolds were only different in the girls. When considering the left mid-upper-arm muscle circumference, both sexes showed significant differences between the sports. Interestingly, gymnasts and tennis players had a smaller mid-upper-arm muscle circumference than swimmers and team handball players. In children with little subcutaneous fat, the mid-upper-arm circumference tends to correlate with the muscle mass (Gibson, 1990). This indicates that male swimmers and team handball players may have a greater muscle mass than the other sports. It could be argued that the reduced muscle circumference in tennis players might be explained by measuring the left arm, which is most likely to be the non-dominating arm. Yet a Mann-Whitney test performed between the left and the right mid-upper-arm muscle circumference did not show any differences among the tennis players.

Interestingly, we found that only sport was associated with the sum of skinfolds in girls. Concern about the detrimental effect of training on growth and maturation has previously been raised (Lindholm et al., 1994; Mansfield & Emans, 1993; Theintz et al., 1993). Frisch et al. (1980) have suggested that menarche is dependent on a critical fat-mass. Our data cannot contribute to the concern because neither training hours nor pubertal development had any association with the sum of skinfolds in the GLM-analysis.

Body proportions

Data on the body proportions are few and inconsistent. Claessens et al. (1991) found that elite male gymnasts had significantly shorter legs than in a control group of normal children but our data could not confirm these findings. In accordance with our data, Claessens et al. (1991) detected no differences in leg length or arm length in girls. Though data from the present study did show significantly differences in armspan between the sports, these differences disap-

peared when related to stature. These findings are surprising considering that different sports most likely require different skills, thus favouring specific body proportions.

Pubertal development

A possible delay of puberty in athletes because of intensive physical exercise and/or diminished energy has previously been suggested (Lindholm et al., 1994; Mansfield & Emans, 1993; Theintz et al., 1993). Other studies have merely claimed that the delayed growth in some sports resembled that of late maturers which could be explained by constitutional factors, as discussed earlier (Baxter-Jones & Helms, 1996; Claessens et al., 1991; Malina, 1994a; Peltenburg et al., 1984b). We found no differences in testicular volume or breast stage among the four sports. When corrected for covariates in the GLM-analysis, in boys not surprisingly age was associated with testicular volume. In girls, age and maternal menarcheal age were significantly associated with breast development. The parameter estimates showed that early menarche in mothers was significantly associated with a more advanced puberty in their daughters. A selection of the girls who are most physically advanced seems to be relevant for girls in swimming whereas girls in gymnastics are less advanced. Our data suggest that the selection may to some extent be based on a genetic potential passed on by their mothers.

In conclusion, differences in anthropometric data and body composition between athletes in swimming, tennis, team handball and gymnasts existed in both sexes but were more evident in females. Most importantly, we did not find any association of training on height, body composition and pubertal development, which suggests that training had no effect on these parameters, indicating that children in competitive sports may be selected due to constitutional factors.

Perspectives

During the last two decades there has been increasing attention on a possible negative effect of training on growth and maturation of children engaged in competitive sports (Lindholm et al., 1994; Mansfield & Emans, 1993). However, there is still no consensus among paediatric exercise scientists whether training has an adverse effect on the growing child. Although the presented cross-sectional data show significant differences in children engaged in four different sports, it is not possible to control for all the factors that might affect growth and maturation throughout the prepubertal and pubertal period. Longitudinal data are few (Malina, 1994b; Malina & Bielicki, 1996; Peltenburg et al., 1984b; Theintz et al., 1993) but important in the attempt to separate the effect of training on growth, body composition, and body proportions from the hypothesis that children with a specific physical appearance are selected into certain sports.

Key words: anthropometry; growth; maturation; physical training.

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