GROWTH, MATURITY AND FUNCTIONAL CHARACTERISTICS OF FEMALE ATHLETES 11–15 YEARS OF AGE

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ABSTRACT
Objective. To evaluate the growth, maturity and functional characteristics of female sport school participants 11–15 years of age.
Material and methods. The sample included 200 girls aged from 10.55 to 15.42 years. The majority (173) trained in track and field. Height, weight, three skinfolds and % Fat (NIR) were measured. Grip strength, standing long jump, 2 kg medicine ball throw and 20 m sprint were tested. Athletes were compared by menarcheal status and track and field discipline with MANCOVA. Multiple linear regression analysis was used to estimate the relative contributions of age, height, weight and adiposity to the four functional indicators in two age groups, 11–13 years and 14–15 years.
Results. Median age at menarche was 12.99 ± 1.11 years. None of the functional tests differed between pre- and post-menarcheal athletes 13 years, while only grip strength differed between late and early maturing athletes 14–15 years. Height, weight and % Fat, but no performance items differed among track and field athletes by discipline. Team and individual sport athletes were heavier, fatter and stronger than track and field athletes but the latter performed better in the sprint and jump. Height, weight and adiposity accounted for significant portions of variation in the four functional indicators in each age group. Conclusions. Trends in body size of female athletes attending sport schools were generally consistent with observations for female athletes in several sports. Percentages of variance explained in functional indicators were greater in athletes 11–13 than 14–15 years of age.

Key words: menarche, power, strength, speed, youth sports

Introduction

The heights and weights of young female athletes in a variety of sports or disciplines within a sport are reasonably well documented [1–3]. Athletes in the majority of sports have mean statures that equal or exceed reference medians for the general population of females. Artistic gymnastics is the only sport that consistently presents a profile of short stature. Figure skaters also present shorter statures, on average, though data are less extensive. Body weight presents a generally similar pattern. Female athletes in most sports also tend to have body weights that, on average, equal or exceed reference medians. Artistic gymnasts, figure skaters and distance runners tend to have lighter weights. Gymnasts and figure skaters, however, have appropriate weights for their statures. Female distance runners, though average in height, tend to have low weight-for-stature. In contrast to height and weight, data dealing with maturity status (except for age at menarche), body composition and functional capacities of young female athletes in different sports are less extensive [1–3].

Sport programs for youth vary in structure and operation throughout the world [4, 5]. In many countries, sport federations have national governing bodies with a top-down approach from the elite or national teams to the local level. Major sport clubs also have programs that span the local through professional levels and many have academy or developmental programs for the major sports. Sport schools also offer instruction and competition in specific sports, but schools vary by level of emphasis. Some focus on the elite while others offer opportunities for the general population of youth. In between the extremes, there is a mid-level which focuses on youth who are in the mid-range of athletic abilities and/or who are not necessarily interested in pursuing elite status. The characteristics of young athletes in sport schools of different levels may thus be of interest.

This paper considers the growth, maturity and functional characteristics of female sport school participants...
11 – 15 years of age. It has four purposes: (1) to evaluate the growth, maturity and functional status of sport school participants, (2) to compare the growth and functional status of track and field athletes by discipline, (3) to compare the growth and functional status of athletes in track and field with athletes in other sports, and (4) to estimate the contributions of age, body size and adiposity to variation in functional capacities.

**Materials and methods**

**Subjects**

The sample included 200 girls 10.55 to 15.42 years of age from sport schools in the Lower Silesia region (Wroclaw, Jelenia Góra, Wałbrzych, Bogatynia, Zgorzelec) in 2004. Most were involved in track and field ($n = 173$) while the remainder ($n = 27$) were distributed among four team ($n = 22$, basketball 9, volleyball 6, softball 5, handball 1, football 1) and two individual ($n = 5$, swimming 3, karate 2) sports. Track and field disciplines included general athletics ($n = 58$), sprinters ($n = 35$), middle distance runners ($n = 34$), distance runners ($n = 23$), jumpers ($n = 22$) and throwers ($n = 1$).

The youth had been training for one to two years prior to the study for about 1.5 hours per session, two times per week. The younger athletes (< 13 years) can be viewed as beginners in their respective sport specializations, while the older athletes (14 – 15 years) are further along in sport training. The project was approved by the local Ethics Committee. Parents of the youth provided informed consent while each athlete provided assent. All athletes were notified that the project was voluntary and that they could withdraw at any time. Identities of individual athletes were anonymous for the analyses.

**Variables considered**

Each athlete was interviewed about menarcheal status (pre- or post-menarche); if post-menarcheal, the athlete was asked to recall the age at which menarche occurred. Duration of involvement in sport (years) and hours of training per week were reported by each athlete. Anthropometric dimensions included height, weight and triceps, subscapular and abdominal skinfolds measured following the protocol of Martin and Saller [6]. Subjects wore shorts and a T-shirt. Measurements were taken at the same time each day and in a standardized sequence. Height was measured to 0.1 cm with an anthropometer. Weight was measured to 0.1 kg with a medical scale. Skinfolds were measured to 0.1 mm with a Harpenden caliper (pressure of 10 g × mm⁻²). The BMI was calculated and the three skinfolds were summed to provide an indicator of subcutaneous adiposity.

Relative fatness (%Fat) was estimated with the near-infrared interactance (NIR) method using a Futrex analyzer apparatus calibrated for youth (model 5000A/ZL). The instrument measures optical density at the biceps; age, sex, weight and height are included in the algorithm with optical density to predict percentage fat [7]. The device provides a non-invasive method for assessing body composition.

Four indicators of functional capacity were measured. Two trials were administered for each indicator and the better of the two was retained for analysis.

Right and left grip strength was measured with a Jamar hydraulic dynamometer (Sammons Preston, Inc.) to the nearest 1 kg. Subjects were standing and were encouraged to give a maximal effort. Right and left grips were summed to provide an indicator of static muscular strength.

The standing long jump was the indicator of muscular power of the lower extremities. The subject stood behind the take-off line with the feet slightly apart and was encouraged to jump as far as possible. The distance from the take-off line to the point of contact of the heels at landing was measured to the nearest 1 cm.

The two kilogram medicine ball throw was the indicator of muscular power of the upper extremities. The subject stood behind a line with the feet slightly apart and facing the direction to which the ball was to be thrown. The ball was grasped with both hands and the subject was instructed to throw the ball as far as possible in an overhead manner (similar in motion to the football [soccer] throw-in). The distance from the throw line to the point of landing was measured to the nearest 10 cm.

A 20 meter sprint with a running start (5 m) was used as an indicator of speed. The subject was instructed to run as fast as possible. After a preliminary warm-up, two sprints were performed with a rest interval of 2 – 3 minutes between attempts. The sprint was measured to the 0.01 second.

**Analysis**

Descriptive statistics (means, standard deviations) were calculated by age group for the total sample. Age-specific means for height, weight, BMI, better grip and standing long jump were compared to corresponding means from the 1999 national survey of growth and physical fitness of Polish youth [8]. The national survey...
used the Eurofit test battery; grip strength of the preferred hand was used [9]. For comparison, it was assumed that the better grip strength between right and left hands was that of the preferred hand.

Median ages at menarche and 95% confidence intervals for the total sample and for the sample of track and field participants were estimated with probit analysis. Menarcheal status and recalled ages at menarche of athletes 13–15 years were used to evaluate differences in growth and function by maturity status. Among girls 13 years of age, characteristics of pre- (n = 17) and post-menarcheal (n = 27) athletes were compared. A different approach to classification was used for athletes 14–15 years. All but 11 of the 101 athletes 14–15 years had attained menarche. Using the median age at menarche of 12.8 years in the national physical fitness survey [8] and a standard deviation of one year, the athletes 14–15 years were classified into three maturity groups: average (age at menarche between 11.8 and 13.8 years, n = 70), early (age at menarche < 11.8 years, n = 8), and late (age at menarche > 13.8 years, n = 12). The 11 pre-menarcheal athletes ranged in age from 13.8 to 15.3 years; attaining menarche at these ages would classify them as late maturing. Two maturity groups thus were formed: (a) pre-menarcheal and late maturing girls (n = 23) and (b) on time and early maturing girls (n = 78).

Multiple analysis of covariance (MANCOVA) with age and age squared as covariates, i.e., to hold age effects constant, was used to compare maturity groups in body size, adiposity and functional capacity. The same statistic was used to compare track and field athletes by discipline and also to compare track and field athletes as a group with the combined sample of team and individual sport athletes.

Multiple linear regression analysis was used to estimate the relative contributions of age, height, weight, the interaction of height and weight, and adiposity to functional test in athletes in two age groups, 11–13 years and 14–15 years. The younger group approximates the interval of rapid growth associated with the adolescent spurt in girls. Menarche occurs, on average, about one year after peak height velocity [3] and 69 of 99 athletes 11–13 years were pre-menarcheal. The older group approximates late adolescence in girls as most have likely experienced peak height velocity (PHV) and were post-menarcheal (only 11 of 101 had not attained menarche). Mean ages at PHV among Polish girls regularly active in sport were 12.3 ± 0.8 years in 13 girls from the Wroclaw Growth Study and Wroclaw Longitudinal Twin Study [10] and 12.0 ± 0.8 years in 23 girls from Warsaw sport schools [11].

Separate regressions were done with either the sum of three skinfolds or % Fat included among independent variables. Though related (partial correlation controlling for age, r = 0.74), the two estimates of adiposity are not identical. The former indicates subcutaneous adiposity, while % Fat is a global estimate of adipose tissue as a percentage of body weight. The height × weight interaction term was derived from centered scores [(height – mean height) × (weight – mean weight)]. The regression analysis permitted all variables to enter into the equation, and then the variables that met the criterion for elimination (backward elimination) were sequentially removed. In this protocol, the variable with the smallest partial correlation with the dependent variable was considered first for removal; if it met the criterion for removal (p > 0.10), it was removed. The procedure was repeated for the other variables until those that did not meet the removal criterion remained

| Variable                  | 11 (n = 24) | 12 (n = 30–31) | 13 (n = 41–44) | 14 (n = 55) | 15 (n = 46) |
|---------------------------|-------------|----------------|----------------|-------------|-------------|
| Age, yrs                  | 11.1        | 12.0           | 13.0           | 14.0        | 15.0        |
| Training, yrs             | 1.2         | 1.9            | 2.0            | 2.3         | 2.5         |
| Training, hrs/wk          | 1.7         | 1.8            | 1.7            | 1.8         | 1.8         |
| Height, cm                | 149.4       | 154.7          | 161.1          | 163.8       | 164.4       |
| Weight, kg                | 37.7        | 42.9           | 48.4           | 50.5        | 52.0        |
| BMI, kg/m²                | 16.8        | 18.6           | 18.8           | 18.8        | 19.2        |
| Sum skinfolds, mm         | 23.4        | 25.9           | 30.4           | 29.8        | 29.1        |
| Fat, %                    | 15.9        | 25.2           | 25.2           | 23.7        | 23.5        |
| Sum R+L grip, kg          | 39.0        | 44.6           | 53.6           | 59.3        | 63.9        |
| Standing long jump, cm    | 151.7       | 164.0          | 167.3          | 175.2       | 175.3       |
| 2 kg ball throw, m        | 4.2         | 5.1            | 5.4            | 6.3         | 6.7         |
| 20 m sprint, sec          | 3.43        | 3.28           | 3.29           | 3.26        | 3.19        |

1 n = 25 at 12 yrs and n = 37 at 13 yrs
in the equation. The standardized regression coefficients (β) allow comparison of the estimated contributions of each independent variable to the explained variance. Coefficients are not related to the scale of the raw data and are interpreted without scale. Positive and negative coefficients indicate, respectively, an increase and decrease in function associated with change in the specific independent variables.

The Statistical Package for the Social Sciences (SPSS) version 14.0 was used for all analyses.

Results

Descriptive statistics for each age group between 11 and 15 years are summarized in Table 1. Years of training increase with age, while training time per week is rather constant across age groups. Body size increases and three of the functional indicators improve, on average, from 11 through 15 years of age. The sum of skinfolds and % Fat increase from 11 to 13 years and then are rather constant. Performance in the 20 meter dash improves (lower time) between 11 and 12 years, is stable between 12 and 14 years, and then declines at 15 years.

Compared to the national sample of Polish youth in the 1999 fitness survey, the athletes, on average, are taller age for age (Fig. 1), have identical weights (Fig. 2), and thus a lower BMI (Fig. 3). The athletes are also stronger in grip strength (Fig. 4) and more powerful in the standing long jump (Fig. 5).

Median age at menarche for the total sample is 12.99 ± 1.11 years (95% CI 11.51–13.85 years) and slightly later, though not significantly, for track and field athletes, 13.08 ± 1.14 years (95% CI 12.00–13.84 years).

Characteristics of athletes by maturity status are summarized in Tables 2 and 3. Post-menarcheal 13-year-old athletes are, on average, taller and heavier with a larger BMI, sum of skinfolds and % Fat. Only the difference for the sum of skinfolds is significant (p < 0.05), while those for body weight and % Fat are of borderline significance. None of the four functional tests differ between pre- and post-menarcheal 13-year-old athletes.
Figure 4. Mean grip strength of the dominant hand of female athletes plotted relative to mean grip strength of the dominant hand of girls in the 1999 national survey of growth and physical fitness of Polish youth [8]

Figure 5. Mean standing long jump of female athletes plotted relative to mean standing long jump of girls in the 1999 national survey of growth and physical fitness of Polish youth [8]

Table 2. Characteristics (means and standard deviations) of pre- and post-menarcheal 13 year old athletes, results of MANCOVA controlling for age, and age-adjusted means and standard errors

| Menarcheal status | \( F \) | \( p \) | Menarcheal status: age-adjusted |
|-------------------|-------|-------|-------------------------------|
| Pre (\( n = 16-17 \)) Post (\( n = 26-27 \)) | | | Pre- | Post- |
| Age, yrs\(^1\) | Mean | SD | Mean | SD | Mean | SE | Mean | SE |
| 12.9 | 0.3 | 13.1 | 0.3 |
| Height, cm | 158.9 | 5.0 | 162.5 | 6.4 | 2.49 | ns* | 159.2 | 1.5 | 162.3 | 1.2 |
| Weight, kg | 44.8 | 6.6 | 50.7 | 7.8 | 3.67 | = 0.06 | 45.6 | 1.9 | 50.2 | 1.5 |
| BMI, kg/m\(^2\) | 17.7 | 1.8 | 19.1 | 2.3 | 2.39 | ns | 17.9 | 0.5 | 19.0 | 0.4 |
| Sum of skinfolds, mm | 28.0 | 9.2 | 34.2 | 11.8 | 6.73 | < 0.05 | 24.8 | 2.7 | 33.9 | 2.1 |
| Fat, % | 24.4 | 7.5 | 27.2 | 4.2 | 3.05 | = 0.08 | 22.5 | 1.4 | 26.9 | 1.1 |
| Sum R+L grip, kg | 50.3 | 11.1 | 55.6 | 13.3 | 0.31 | ns | 52.2 | 3.0 | 54.4 | 2.3 |
| Standing long jump, cm | 170.6 | 17.3 | 165.2 | 17.9 | 1.57 | ns | 172.0 | 4.7 | 164.4 | 3.6 |
| 2 kg ball throw, kg | 5.3 | 1.2 | 5.5 | 1.2 | 0.09 | ns | 5.5 | 0.3 | 5.4 | 0.2 |
| 20 m sprint, sec | 3.26 | 0.22 | 3.30 | 0.22 | 0.52 | ns | 3.25 | 0.06 | 3.31 | 0.04 |

\(^1\) ANOVA, \( F = 4.26, p < 0.05, \) * ns = not significant

Table 3. Characteristics (means and standard deviations) of 14 and 15 year old athletes classified by maturity status, results of MANCOVA controlling for age, and age-adjusted means and standard errors

| Maturity groups | \( F \) | \( p \) | Maturity groups: age-adjusted |
|-----------------|-------|-------|-------------------------------|
| Late (\( n = 23 \)) Average + Early (\( n = 78 \)) | | | Late | Average + Early |
| Mean | SD | Mean | SD | Mean | SE | Mean | SE |
| Age, yrs\(^1\) | 14.6 | 0.5 | 14.4 | 0.6 | 1.91 | ns* | 162.6 | 1.2 | 164.5 | 0.6 |
| Height, cm | 162.8 | 6.7 | 164.4 | 5.2 | 4.47 | < 0.05 | 48.6 | 1.3 | 51.9 | 0.7 |
| Weight, kg | 49.1 | 7.9 | 51.8 | 6.0 | 3.23 | 0.08 | 18.3 | 0.4 | 19.2 | 0.2 |
| BMI, kg/m\(^2\) | 18.4 | 2.2 | 19.1 | 1.9 | 1.07 | ns | 27.9 | 1.8 | 30.0 | 1.0 |
| Sum of skinfolds, mm | 28.0 | 9.2 | 29.9 | 8.1 | 3.05 | 0.08 | 22.2 | 1.0 | 24.1 | 0.5 |
| Fat, % | 22.3 | 5.0 | 24.0 | 4.3 | 5.15 | < 0.05 | 57.5 | 1.9 | 62.6 | 1.0 |
| Sum R+L grip, kg | 58.2 | 8.5 | 62.3 | 9.8 | 2.07 | ns | 180.0 | 3.8 | 173.8 | 2.0 |
| Standing long jump, cm | 180.1 | 16.6 | 173.8 | 17.9 | 2.23 | ns | 6.2 | 0.2 | 6.6 | 0.1 |
| 2 kg ball throw, kg | 6.2 | 1.0 | 6.5 | 1.1 | 1.53 | ns | 3.13 | 0.09 | 3.26 | 0.05 |

\(^1\) ANOVA, \( F = 2.91, p = 0.09, \) * ns = not significant
athletes while the standing long jump is, on average, greater in pre-menarcheal athletes. Standard deviations in the two tests are quite large. Mean performances for the 2 kg ball throw and 20 m sprint are similar in the two maturity groups.

Results are generally similar in comparisons of size and function in contrasting maturity groups of 14- to 15-year-old athletes. Athletes who are average and early in maturation are, on average, taller and heavier with a larger BMI, sum of skinfolds, % Fat and grip strength compared to athletes who are late maturing. Only the differences for weight and grip strength are significant ($p < 0.05$), while the differences for the BMI and % Fat are of borderline significance ($p = 0.08$). The standing long jump is, on average, greater in late maturing girls, but the standard deviations are large and the difference is not significant. As in younger athletes, mean performances for the ball throw and sprint are quite similar in the two contrasting maturity groups.

Age-adjusted means and standard errors for track and field athletes by discipline are summarized in Table 4. Height, weight and % Fat differ significantly ($p < 0.05$) by discipline. Although height differs significantly, none of the post hoc pairwise comparisons is significant. Girls in general athletics are taller than middle distance and distance runners, but the differences are of borderline significance ($p < 0.11$). Girls in general athletics, on the other hand, are significantly heavier and fatter than distance runners ($p < 0.05$). All other pairwise comparisons for height, weight and % Fat are not significant. In contrast to body size, none of the functional capacity measures differs significantly among track and field athletes by discipline.

Age-adjusted means and standard errors for track and field athletes and the combined sample of athletes in team and individual sports are summarized in Table 5. Height and the 2 kg ball throw do not differ. Athletes in team and individual sports are heavier and have a larger BMI, more subcutaneous adiposity and a greater % Fat ($p < 0.001$). The team and individual sport athletes are also stronger in grip strength ($p < 0.05$) whereas track and field athletes are faster in the 20 m sprint ($p < 0.05$). Track and field athletes also perform better in the standing long jump but the difference is of borderline significance ($p = 0.07$). Given the small sample size for athletes in team and individual sports, the risk of type II error is increased.

Results of the regression analyses are given in Tables 6 and 7. Among athletes 11–13 years of age, more variance is explained by the predictors for grip strength (56% and 64%) and 2 kg ball throw (51% and 55%), while explained variance is less for the standing long jump (21% and 20%) and 20 m sprint (11% and 4%). The explained variance is greater for grip strength and throw and lesser for the sprint when % Fat is among the independent variables (Tab. 6). The sum of skinfolds is a significant predictor only for the sprint and % Fat is a significant predictor only for grip strength.

With the sum of skinfolds among predictors, primary explanatory variables are as follows: grip strength – age and weight (both positive), standing long jump – age (positive) and height × weight interaction (negative), 2 kg ball throw – weight (positive), and 20 m sprint – age (positive) and skinfolds (negative). With % Fat among predictors, significant explanatory variables are as follows: grip strength – height, weight and % Fat (all

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Table 4. Characteristics of female track and field athletes by discipline. Means and standard deviations for age and training history and age-adjusted means and standard errors based on MANCOVA with age at the covariate

|                        | Sprints  | Middle distance | Distance | Athletics | Jumps$^1$ |
|------------------------|----------|-----------------|----------|-----------|-----------|
|                        | $(n = 35)$ | $(n = 33 – 34)$ | $(n = 21 – 23)$ | $(n = 57 – 58)$ | $(n = 23)$ |
| Age, yrs               | Mean     | SD              | Mean     | SD        | Mean     | SD        | Mean     | SD        | Mean     | SD        |
| Training, yrs          | 13.5     | 1.4             | 13.9     | 1.3       | 13.6     | 1.4       | 13.0     | 1.1       | 12.9     | 1.5       |
| Training, hrs/week     | 2.0      | 1.4             | 2.2      | 1.3       | 2.4      | 1.4       | 1.9      | 1.4       | 2.2      | 1.3       |
|                        | 1.8      | 0.7             | 1.7      | 0.4       | 1.9      | 0.3       | 1.8      | 0.5       | 1.6      | 0.3       |
| Height, cm             | 160.1    | 1.0             | 158.5    | 1.0       | 158.1    | 1.2       | 161.9    | 0.8       | 160.5    | 1.2       |
| Weight, kg             | 47.3     | 1.0             | 45.9     | 1.1       | 44.2     | 1.3       | 48.8     | 0.8       | 46.7     | 1.3       |
| BMI, kg/m$^2$          | 18.3     | 0.3             | 18.2     | 0.3       | 17.6     | 0.4       | 18.5     | 0.3       | 18.0     | 0.4       |
| Sum skinfolds, mm      | 28.5     | 0.7             | 26.2     | 1.3       | 25.0     | 1.5       | 27.9     | 1.0       | 26.7     | 1.6       |
| Fat, %*                | 21.7     | 0.7             | 21.2     | 0.7       | 19.2     | 0.9       | 22.6     | 0.6       | 21.7     | 0.9       |
| Sum R+L grip, kg       | 54.7     | 1.6             | 53.9     | 1.7       | 50.0     | 2.1       | 55.1     | 1.3       | 53.2     | 2.0       |
| Standing long jump, cm | 166.7    | 2.9             | 169.2    | 3.1       | 165.6    | 3.7       | 170.7    | 2.4       | 175.0    | 3.6       |
| 2 kg ball throw, m     | 5.7      | 0.2             | 5.4      | 0.2       | 5.6      | 0.2       | 5.9      | 0.1       | 5.8      | 0.2       |
| 20 m sprint, sec       | 3.21     | 0.05            | 3.33     | 0.06      | 3.23     | 0.07      | 3.27     | 0.05      | 3.19     | 0.07      |

$^1$The sample includes one thrower; remainder were jumpers, * $n = 45$ for the sample in athletics, ** ns = not significant
Table 5. Characteristics of female athletes in track and field and in other sports. Means and standard deviations for age and training history and age-adjusted means and standard errors based on MANCOVA with age at the covariate

|                     | Track & field \((n = 169–173)\) | Other sports \((n = 27)\) | \(F\) | \(p\) |
|---------------------|----------------------------------|--------------------------|------|------|
| **Age, yrs**        | Mean 13.4 SD 1.3                | Mean 13.3 SD 1.1         | 0.03 | ns** |
| **Training, yrs**   | Mean 2.1 SD 1.4                 | Mean 2.2 SD 1.1          | 0.84 | ns   |
| **Training, hrs/week** | Mean 1.8 SD 0.5            | Mean 1.7 SD 0.3          | 0.92 | ns   |
| **Height, cm**      | Mean 160.3 SD 0.5              | Mean 159.8 SD 1.2        | 0.16 | ns   |
| **Weight, kg**      | Mean 47.1 SD 0.5               | Mean 51.6 SD 1.2         | 11.34 | < 0.001 |}

1 The sample includes sport school participants in basketball (9), volleyball (6), softball (5), handball (1), football (1), swimming (3), karate (2).

\* n = 160 for the sample in track and field, ** ns = not significant

Table 6. Significant predictors of functional capacities and estimated \(R^2\) in 11–13 year old athletes based on multiple regression analyses including either sum of skinfolds \((n = 95–97, \text{left})\) or percentage fat \((n = 82–84, \text{right})\) among the predictors as an indicator of adiposity

| Variable           | Predictors          | \(\beta\) | \(p\) | \(R^2\) | Adj \(R^2\) | \(p\) | Predictors          | \(\beta\) | \(p\) | \(R^2\) | Adj \(R^2\) | \(p\) |
|--------------------|---------------------|----------|-------|--------|------------|------|---------------------|----------|-------|--------|------------|------|
| **Grip strength**  | age                 | 0.170    | < 0.05 | 0.57   | 0.56       | < 0.001 | weight              | 0.213    | = 0.09 | 0.62   | 0.61       | < 0.001 |
|                    | height              | 0.646    | < 0.001 |        |            |        | height              | 0.315    | = 0.07 |        |            |        |
|                    | weight              |          |        |        |            |        | % Fat               | 0.322    | < 0.05 |        |            |        |
| **Standing long jump** | age                | 0.204    | < 0.05 | 0.22   | 0.21       | < 0.001 | age                 | 0.288    | = 0.01 | 0.22   | 0.20       | < 0.001 |
|                    | Ht × Wt             | -0.346   | = 0.001 |        |            |        | Ht × Wt             | -0.267   | < 0.05 |        |            |        |
| **2 kg ball throw** | weight              | 0.716    | < 0.001 | 0.51   | 0.51       | < 0.001 | age                 | 0.156    | < 0.01 | 0.56   | 0.55       | < 0.001 |
|                    | skinfolds           | -0.240   | < 0.05 |        |            |        | weight              | 0.644    | < 0.001 |        |            |        |
| **20 m sprint**    | age                 | 0.339    | < 0.01 | 0.12   | 0.10       | < 0.01 | age                 | 0.225    | < 0.01 | 0.05   | 0.04       | < 0.01 |
|                    | skinfolds           | -0.240   | < 0.05 |        |            |        | height              | 0.450    | < 0.001 |        |            |        |

* Signs of the coefficients were reversed because a lower time was a better performance.

Table 7. Significant predictors of functional capacities and estimated \(R^2\) in 14–15 year old athletes based on multiple regression analyses including either sum of skinfolds \((n = 101, \text{left})\) or percentage fat \((n = 101, \text{right})\) among the predictors as an indicator of adiposity

| Variable           | Predictors          | \(\beta\) | \(p\) | \(R^2\) | Adj \(R^2\) | \(p\) | Predictors          | \(\beta\) | \(p\) | \(R^2\) | Adj \(R^2\) | \(p\) |
|--------------------|---------------------|----------|-------|--------|------------|------|---------------------|----------|-------|--------|------------|------|
| **Grip strength**  | height              | -0.238   | < 0.05 | 0.45   | 0.44       | < 0.001 | age                 | 0.141    | = 0.09 | 0.35   | 0.34       | < 0.001 |
|                    | weight              | 1.007    | < 0.001 |        |            |        | weight              | 0.552    | < 0.001 |        |            |        |
|                    | skinfolds           | -0.486   | < 0.001 |        |            |        | % Fat               | -0.359   | < 0.001 |        |            |        |
| **Standing long jump** | weight             | 0.211    | < 0.05 | 0.04   | 0.03       | < 0.05 | weight              | 0.211    | < 0.05 | 0.04   | 0.03       | < 0.05 |
|                    | skinfolds           | -0.220   | < 0.05 |        |            |        | height              | -0.252   | < 0.01 | 0.29   | 0.27       | < 0.001 |
|                    | % Fat               |          |        |        |            |        | weight              | 0.920    | < 0.001 |        |            |        |
|                    |                     |          |        |        |            |        | % Fat               | -0.372   | < 0.05 |        |            |        |
| **20 m sprint**    | height              | 0.263    | < 0.05 | 0.17   | 0.15       | < 0.01 | no significant     |          |        |        |            |        |
|                    | weight              | -0.564   | = 0.001 |        |            |        | predictors          |          |        |        |            |        |
|                    | skinfolds           | 0.575    | < 0.001 |        |            |        | height              | 0.575    | < 0.001 |        |            |        |

* Signs of the coefficients were reversed because a lower time was a better performance.
positive), standing long jump – age (positive) and height × weight interaction (negative), ball throw – age and weight (both positive), and sprint – age (positive).

Among athletes 14–15 years of age, greater percentages of variance are explained in grip strength and sprint with the sum of skinfolds among predictors, whereas the explained variance in the standing long jump and throw do not differ when skinfolds or % Fat are included among the predictors (Tab. 7). The sum of skinfolds is a significant negative predictor for grip strength and ball throw, but a positive indicator for the 20 m sprint, while % Fat is a significant negative predictor for the throw. Body weight is the only predictor of the standing long jump but the explained variance, though significant, is very low. Results for the 20 m sprint are different. With the sum of skinfolds among predictors, 15% of the variance is explained. Height and weight have, respectively, a positive and negative influence, while the sum of skinfolds has a positive influence on the sprint. In contrast, there are no significant predictors of the 20 m sprint when % Fat is included among predictors.

Discussion

Trends in body size of female athletes attending sport schools were generally consistent with observations for female athletes in several sports [1–3]. Mean heights varied between the age-specific medians and 75th percentiles of reference data for American youth, while mean weights tended to approximate reference medians [12]. As a result, mean BMIs were slightly, but consistently, below the age-specific reference medians. The data were consistent with the notion that young female athletes tend to be taller than average and to have body weights that approximate the average; hence, they have less weight-for-height. Female artistic gymnasts and figure skaters are an exception.

Corresponding reference data for body composition are lacking. FFM has a growth pattern similar to height and weight so that variation in FFM in young athletes varies with body size. It is perhaps for this reason that most studies of body composition of young athletes focus on % Fat, although more recently attention has shifted to bone mineral due in large part to advances in DEXA technology [13]. Densitometric estimates of % Fat in non-athletic samples of girls from the early 1960s through the mid-1980s provide a reasonable reference for the general population prior to the obesity epidemic which surfaced in the late 1980s [14, 15]. Estimated % Fat in the female athletes based on NIR is shown in Figure 6. Mean values for track and field athletes 11 and 12 years were below the reference while estimates for athletes 13–15 years were above the reference. Age-adjusted means for % Fat in sprinters, middle distance runners and jumpers approximated the reference while age-adjusted means for distance runners and general athletics were, respectively, below and above the reference based on densitometry. NIR estimates of % Fat for athletes in specific track and field disciplines were consistently higher than estimates for other samples of athletes of the same age range and in the same disciplines based on densitometry, total body water, DEXA or BIA [16, 17].

The validity of NIR estimates of % Fat compared to densitometric estimates has been questioned, specifically larger standard errors of estimate. Part of the problem relates to use of equations for estimating % Fat provided by the manufacturer [7]. Sample-specific equations have been developed from measured optical density values. The approach resulted in a relatively small error (1.8%) in the prediction of % Fat with NIR in college age female athletes in several sports [18]. Corresponding studies with young athletes gave mixed results in male wrestlers [19, 20], male participants in several sports [21] and female gymnasts [22].

Estimated ages at menarche for the total sample (13.0 ± 1.1 years) and for track and field athletes (13.1
Table 8. Estimated ages at menarche based on the status quo method in samples of adolescent athletes

| Country, sport                          | Median | SD  |
|----------------------------------------|--------|-----|
| This study, total sample                | 13.0   | 1.1 |
| This study, track and field, disciplines combined | 13.1   | 1.1 |
| Hungary, track and field, events combined | 12.6   |     |
| Hungary, track and field, general athletics | 13.1   | 1.1 |
| Hungarian, team sports                 | 12.7   |     |
| United States, football (soccer)       | 12.9   | 1.1 |
| United States, swimming                | 13.1   | 1.1 |
| United States, swimming                | 12.7   | 1.1 |
| United States, diving                  | 13.5   | 1.3 |
| United States/Canada, figure skaters   | 14.2   | 0.5 |
| Hungary, artistic gymnasts             | 15.0   | 0.6 |
| International, artistic gymnasts       | 15.6   | 2.1 |

1 Comparative data are from Malina [2, 16] and Malina et al. [3] which contain references to specific studies.
2 Standard deviations were not reported for these samples.
3 This sample from the 1987 world championships in Rotterdam did not include gymnasts < 13 years of age so that the estimate may be biased towards an older age at menarche.

were similar to corresponding status quo estimates (probit analysis) for samples of young athletes in the same or similar sports (Tab. 8).

A common theme in discussions of maturation in athletes is later ages of menarche, which are attributed by some to early training. As evident in Table 8 and elsewhere [2, 3, 16], menarche data for adolescent athletes, either status quo or prospective, are quite limited. Status quo surveys of adolescent athletes give estimated ages at menarche that are generally close to the average of the population; exceptions are artistic gymnasts, figure skaters and divers. On the other hand, most data for athletes are based on the retrospective (recall) method in late adolescent and adult athletes. Within the same sport, estimated ages at menarche of athletes based on retrospective studies are, on average, later than estimates with the status quo method. The difference relates to sampling. Status quo estimates are generally based on youth 9–17 years; such samples include athletes with a wide range of abilities. Late adolescent and adult athletes are more specialized in the respective sports and have persisted in or were selected for the sport. Related factors are selective drop-out of less talented and earlier maturing girls, and perhaps selective success of later maturing girls in some sports [2, 3, 23].

Comparisons of contrasting maturity groups of athletes 13–15 years of age (Tab. 2 and 3) were generally consistent with observations for adolescent females [3]. The small sample sizes of late maturing females in the two age groups probably affected the significance of the differences in some variables. Comparisons of groups of small sample size are prone to Type II errors.

The percentage of variance explained in each of the functional indicators was greater in athletes aged 11–13 years (Tab. 6) compared to athletes aged 14–15 years (Tab. 7). Age was a significant predictor among athletes 11–13 years of age but not among athletes 14–15 years of age, emphasizing the role of age per se in the development of the functional indicators. This was generally consistent with literature on adolescent girls, though data are limited for female athletes [3]. The variance explained in grip strength, 2 kg ball throw and standing long jump was generally similar with the inclusion of either the sum of skinfolds or the NIR estimate of % Fat among predictors in both age groups. The directions of the standardized regression coefficients were straightforward for the grip, throw and jump; coefficients for age and weight were positive and those for skinfolds were negative. By inference, older and heavier girls with thinner skinfolds tended to perform better. A standardized coefficient for the height × weight interaction appeared among predictors only for the standing long jump in athletes aged 11–13 years; it was negative suggesting that among girls of the same height, those with lower body weight, i.e., less weight-for-height performed better in the jump. Height appeared among predictors of only grip strength in athletes 11–13 years of age; the standardized coefficient was positive. In contrast, height was a significant predictor of strength and the ball throw in athletes 14–15 years of age, but the coefficients were negative, suggesting that girls who were shorter but heavier had better performances.

Results for the 20 m sprint were more complex for interpretation. Age was a predictor in athletes 11–13 years and skinfolds (but not % Fat) had a negative influence (Tab. 6). Among athletes 14–15 years, there were no significant predictors of the sprint when % Fat was included among independent variables. With the small sample sizes among independent variables, the coefficients for height and skinfolds were positive and that for weight was negative. By inference, 14- to 15-year-old athletes who were taller and lighter and who had a thicker sum of skinfolds performed better in the 20 m sprint. The results may reflect the limited range of variation in sprint times among athletes aged 14–15 years (2.58 to 4.14 sec) in contrast to the wide range of variation in the sum of skinfolds (17.4 to 50.6 mm). The coefficients of variation for the 20 m sprint and skinfolds were 12.7% and 28.4%, respectively.
Although height, weight and adiposity accounted for significant portions of variation in the four functional indicators, a considerable amount of variation was not explained by size and fatness in this sample of female athletes. Strength and performance are affected by motivation, quality of instruction and practice and other factors. Although experience in the sport school programs increased with age in this sample of female athletes, the amount of time spent in training per week was similar across age groups. This would seem to imply a need for more refined indicators of the duration and intensity of training in the sport schools to estimate potential influences on functional capacity.

The study was limited to four indicators of functional capacity. There is a need to expand observations to other indicators, e.g., aerobic endurance, anaerobic capacity, agility, etc., and also to sport-specific skills in team (basketball, soccer, etc.) and individual sports (tennis) and to more technical skills in track and field and swimming. It would also be interesting to expand the number of sports considered.

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