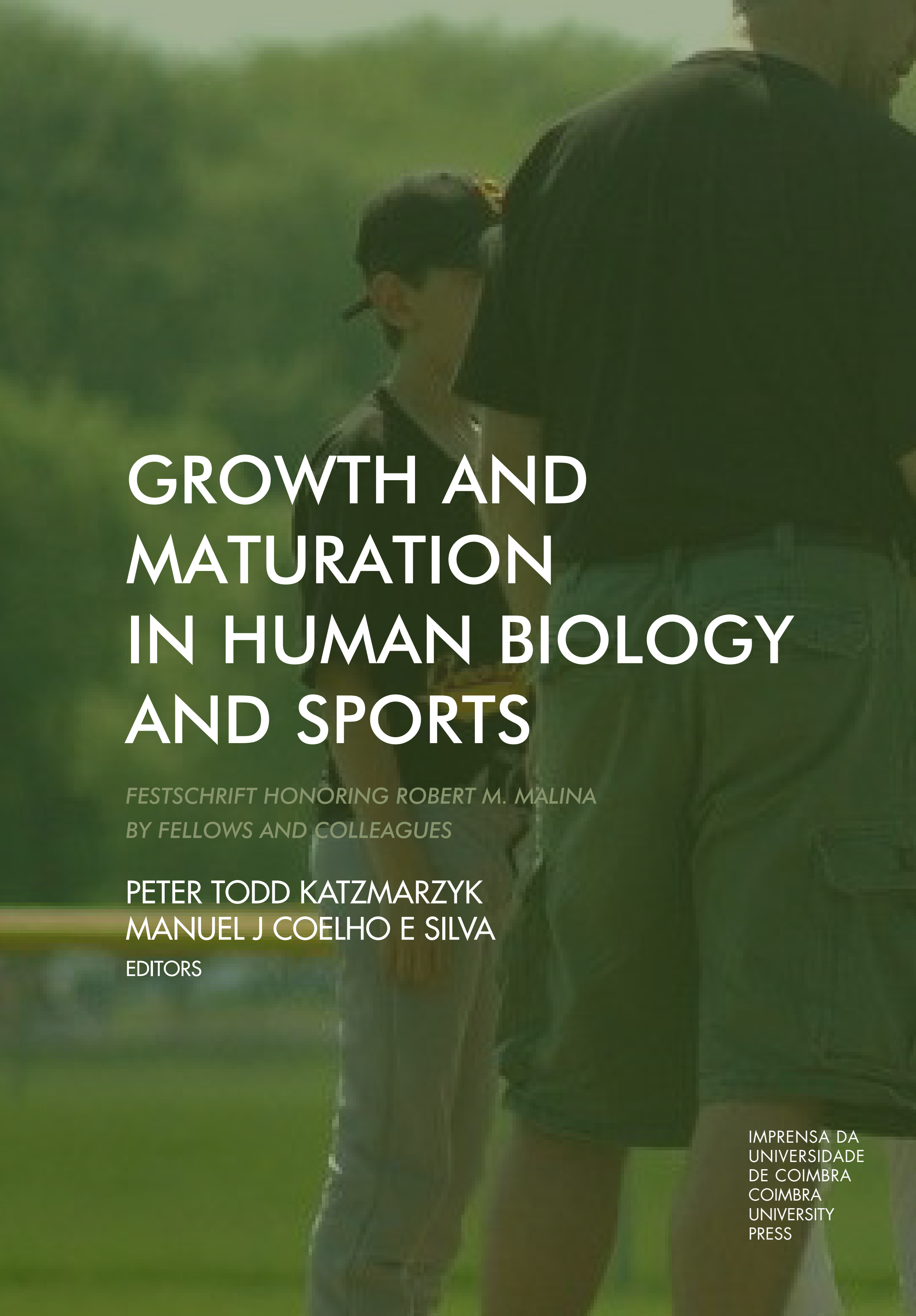

GROWTH AND MATURATION IN HUMAN BIOLOGY AND SPORTS

FESTSCHRIFT HONORING ROBERT M. MALINA BY FELLOWS AND COLLEAGUES

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TRACKING AND PREDICTION OF TRACK AND FIELD EVENTS IN UNTRAINED ADOLESCENT BOYS FROM 12 TO 17 YEARS OF AGE

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In this study tracking of track and field events (high jump, shot put, 60 m sprint and 6 minute endurance run) during adolescence (12 to 17 years) is studied and the predictive power of a variety of biological characteristics is verified. This interdisciplinary approach has demonstrated that track and field performances in late adolescence are, to a fairly high degree, predictable by the additive contribution from track and field performances, motor performances, somatic dimensions, and progression in track and field events, motor performance and/or somatic growth over a one year period (12 to 13 years).

INTRODUCTION

Many children and adolescents participate in sports and for a majority it is the major context of their physical activity behavior (Malina, 2010). Most likely only a limited number of youth participating in sports already show the characteristics of expert sports potential and only a very small minority will succeed and attain international excellence in their sport. Most countries, however, attempt to develop systematic structures and programs to identify and promote talented youth (Vaeyens *et al.*, 2009).

If talented adults can be identified at younger ages it raises the question if physical performance later in life can be predicted from characteristics earlier in life. This refers to the concept of tracking and prediction used in auxological research. Tracking is the maintenance of the relative position within a group over time (Clark *et al.*, 1976; Foulkes & Davis, 1981; Malina, 1990; McMahan, 1981). In exercise science it is mostly quantified by calculating inter-age correlations. Malina (2001) summarized the available evidence and concluded that most physical performance characteristics track reasonably well from childhood to adolescence and from adolescence to adulthood. In general, with increasing time interval the tracking coefficients decrease. Only a few studies tried to predict future physical performance from observations made earlier in life (Beunen et al. 2004).

In the present study it is hypothesized that: (1) three track and field events (high jump, shot put and 60 m sprint) and the 6 minute endurance run demonstrate moderate to moderately high tracking during adolescence and (2) that physical fitness and somatic dimensions contribute significantly to the prediction of results in these events in late adolescence.

METHODS

Subjects were sampled from two secondary schools in Flanders (Belgium). At the start of the study boys were between 10 and 13 years old. These boys were followed at annual intervals for six consecutive years. In total 144 adolescents (from 156 possible participants) gave their consent for participation. At the start of the study, they were placed into four groups, with a respective mean chronological age of 10, 11, 12 and 13 years. A total of 94 boys (65% response rate) completed the study and had complete records. For this manuscript, only data from the third group are used. Boys (n = 41) were about 12 years old (11.99 y ± 0.15) at the onset of the study. Final age at follow up was about 17 years of age (16.92 ± 0.17).

The project was approved by the Medical Ethics Committee of the Faculty of Physical Education and Kinesitherapy (presently Faculty of Kinesiology and Rehabilitation Sciences) of the KULeuven. The parents of the boys received a letter with an explanation about the main goals of the study, the reason why their son was included in the sample, and a brief description of the tests and measurements. Since the study design required a collection of longitudinal data, parents and youngsters were asked if they were willing to participate during six consecutive years. In addition, it was clearly stipulated that yearly an X -ray of the left hand and wrist would be taken, to assess skeletal maturity. Parents had to complete a form and gave their informed consent by signature.

Performances in high jump, shot put (4 kg), 60 m sprint and 6 minute endurance run at the age of 17 years were chosen as dependent characteristics. Independent variables at the age of 12 years were the track and field events (high jump, shot put, 60 m sprint, 6 minute endurance run) and 20 somatic variables (lengths, breadths, circumferences, skinfolds and Heath-Carter somatotype components), 15 motor fitness tests, and skeletal maturity.

Skeletal age was estimated according to the TW2 method (Tanner *et al.*, 1989). Relative skeletal age was calculated by subtracting chronological age from RUS-age (radius, ulna and short bones). Measurement procedures of all somatic variables have extensively been described by Claessens *et al.* (1990).

The choice of the motor fitness variables was based on the available evidence of biological characteristics that correlate with track and field events (high jump, shot put, 60 m sprint and 6 minute endurance run) (Burwitz *et al.*, 1994; Thomas, 1989). Three tests of static strength were included (arm pull, leg extension, bench press), five tests of explosive strength (vertical jump, vertical jump running approach, standing broad jump, multiple jump, reactive jump from a bench of 30 cm), two speed tests (plate tapping, 50 meters shuttle run), and one test of respectively muscular endurance of the lower body (leg lifts), muscular endurance of the upper body (bent arm hang), hip flexibility (sit and reach), total body balance (flamingo balance) and cardio-vascular endurance (6 minutes endurance run). Testing procedures of all tests have been described by Claessens *et al*. (1990). For the prediction of future performance from the age of 13 years, in addition to the previously mentioned characteristics, growth and development variables were calculated. This was done by calculating the differences between the measurements obtained at 12 and 13 years of age, respectively.

A major problem in longitudinal studies is the appearance of testing effects. Three comparable control groups of boys that were never tested before were used to verify the testing effect. The mean results of the longitudinal sample did not differ significantly ($p<0.01$) from those of the control groups at none of the occasions (second year, fourth year, sixth year).

The purpose of the main analysis was to explain performance in high jump, shot put, 60 m sprint and a 6 minute endurance run at the age of 17 years by tests and measurements observed at 12 and 13 years of age. Analyses were performed in a progressive way: (1) calculation of tracking in the four track and field events between 12 and 17 years, and 13 and 17 years of age, (2) calculation of stepwise multiple regressions using adjusted R^2 (SAS, 2004). Four different predictions were calculated with each of the four track and field events as dependent variables and progressively the motor variables and the somatic variables as independent variables. The track and field performance at the younger age, and the variables that entered significantly in former steps were forced into the regressions, so that the separate contribution of every set of variables could be computed. From 13 years onward also the possible contribution from progression (change) in track and field performance, motor performance and somatic growth between 12 and 13 years of age in the explanation of performance at 17 years was verified. The performance gain and somatic growth were progressively entered into the regressions to predict performance from 13 years onward. The significance level was set at $p < 0.05$.

RESULTS

Tables 1, 2, 3 and 4 show the best possible performance explanation at 17 years for respectively performance in high jump, shot put, 60 m sprint and 6 minute endurance run, through tests and measurements at 12 and 13 years of age.

For conformity with the subsequent stepwise analyses, tracking was quantified as the squared inter-age correlation. High jump performance at 12 years of age explained 40.1% of the performance at 17 years, which is higher than the performance explanation at 13 years (30.7%). Standard errors of prediction (SEP) were respectively 9.3 cm at 12 years and 10.0 cm at 13 years. Subsequently motor performance added 10.3% (from the age of 12 years) and 19.3% (from the age of 13 years) to high jump performance variation at 17 years. From the age of 12 years, standing broad jump (explosive leg power) entered the equation, and from the age of 13 years multiple jump (combination of explosive power and reactive leg power) and shuttle run (agility speed) added to the prediction. The addition of anthropometric dimensions (biacromial and biiliac widths) added another 12.1% (12 years) but did not contribute to the explained variance from 13 years onward. Both progression in track and field performance and somatic growth add significantly ($p < 0.05$) to the prediction. There is only an improvement in performance prediction through the progression in leg power (reactive jump) in the age interval 12-13 years. Explained variance in high jump performance now reached 55.0% from 13 years (5% increase), but was still lower than from 12 years (62.5%). High jump performance at 17 years of age was thus better predicted from the age of 12 years (62.5% with SEP=7.3 cm) than it was from 13 years of age (55.0% with SEP=8.0 cm).

Table 1. Prediction of high jump at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	High jump	40.1	40.1	9.3
	+ Motor Perf.	Stand. broad jump	10.3	50.4	8.4
	+ Somat. Dim.	Biacr. and biiliac.	12.1	62.5	7.3
From 13 years	Track events	High jump	30.7	30.7	10
	+ Motor Perf.	Mult. jump & Shuttle run	19.3	50.0	8.5
	+ Somat. Dim.				
	+ Progr. (Δ) track				
	+ Progr. (Δ) motor perf.	Reactive jump	5.0	55.0	8.0
	+ Progr. (Δ) growth				

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

Table 2. Prediction of shot put at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	Shot put	41.1	41.1	1.02
	+ Motor Perf.	6'run			
		Leg lifts	10.4	51.5	0.93
From 13 years	Track events	Shot put	40.8	40.8	1.02
	+ Motor Perf.				
	+ Somat. Dim.				
	+ Progr. (Δ) track	Shot put	6.3	47.1	0.97
	+ Progr. (Δ) motor perf.	Reactive jump & Leg lifts	16.6	63.6	0.80
	+ Progr. (Δ) growth				

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

Tracking coefficients for shot put were 41.1% and 40.8% from 12 and 13 years respectively. From 12 years motor performance (6 minute endurance run and leg lifts) added to the explained variance (10.4%) of the shot put performance at 17 years. Somatic dimensions did not further improve the prediction neither from 12 years nor from 13 years. The improvement in shot put between 12 and 13 years added another 6.3% in predictive power and the gain in leg power (reactive jump) and trunk/lower body muscular endurance (leg lifts) added another 16.6% of explained variance in shot put performance at 17 years of age.

Tracking for 60 m sprint was also fairly high, 46.6 % from 12 years and 47.5 % from 13 years. Power, static strength and muscular endurance added another 16% from 12 years and 18.4% from 13 years to the explained variance in sprint performance at 17 years. From 12 years maturation (relative skeletal age) also added 3.3% to the prediction. From 13 years, the gain in leg muscle development (calf circumference) and in leg length between 12 and 13 years improved the prediction by another 7.5%. In total 65.9% and 73.4% of the variance in 60 m sprint at age 17 was explained by characteristics observed at 12 and 13 years, respectively.

Table 3. Prediction of 60 meter sprint at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	60 m sprint	46.6	46.6	0.35
	+ Motor Perf.	Reactive jump & Bench press	16.0	62.6	0.29
	+ Somat. Dim.	Relative skeletal age	3.3	65.9	0.28
From 13 years	Track events	60 m sprint	47.5	47.5	0.34
	+ Motor Perf.	Arm pull, Bent arm hang, vertical jump	18.4	65.9	0.28
	+ Somat. Dim.				
	+ Progr. (Δ) track				
	+ Progr. (Δ) motor perf.				
	+ Progr. (Δ) growth	Calf circumf. & leg length	7.5	73.4	0.24

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

Tracking in 6 minute endurance run was somewhat lower, 35.8% from 12 years but again considerable (49.5%) from 13 years. From 12 and 13 years static strength improved the predictive power by 5.3% and 4.7%, respectively. From 12 years also somatic dimensions (subscapular skinfold and calf circumference) added 13.4% to the explained variance in endurance run at 17 years. Furthermore, from 13 years, change in biceps skinfold thickness and skeletal breadths added 17.2% of explained variance in 6 minutes endurance run at 17 years. The total explained variance was 54.0% from 12 years and 71.4% from 13 years.

Table 4. Prediction of 6 minutes endurance run at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	6' run	35.8	35.8	194
	+ Motor Perf.	Arm pull	5.3	41.1	186
	+ Somat. Dim.	Subscap. Skinf. & calf circumf.	13.5	54.0	163
From 13 years	Track events	6' run	49.5	49.5	172
	+ Motor Perf.	Bench Press	4.7	54.0	164
	+ Somat. Dim.				
	+ Progr. (Δ) track				
	+ Progr. (Δ) motor perf.				
	+ Progr. (Δ) growth	Biceps skinf., biacrom. epicond. femur & biiliac.	17.2	71.4	129

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

DISCUSSION

To our knowledge very little is known about tracking in sport specific events. Compared to physical fitness test results (Beunen, *et al.* 1979; Ellis, *et al*. 1975; Espenschade, 1940; Malina, 2001, Rarick & Smoll, 1967) tracking in the four track and field events (high jump, shot put, 60 m sprint and 6 minute endurance run), are fairly high ranging from r = 0.55 for high jump at 13 years to r = 0.70 for 6 minute endurance run at 13 years. Furthermore this longitudinal study demonstrated clearly that traditional physical fitness tests and somatic dimensions added significantly to the explained variance in performance in these track and field events at 17 years. The total explained variance of the track and field events observed at 17 years is surprisingly high ranging from $R^2 = 0.52$ for shot put at 12 years to $R^2 = 0.73$ for 60 m sprint at 13 years.

This biological approach demonstrated that track and field performances in late adolescence are, to a reasonable degree, predictable by the additive contribution from track and field performances, motor performances, somatic dimensions, performance progression and somatic growth in early adolescence (12 to 13 years). From the respective standard errors of prediction however (tables 1-4), it is clear that these errors are too large to permit accurate individual predictions. But, these results clearly demonstrate that the inclusion of classical somatic dimensions, physical fitness tests and to some extent skeletal maturity in the identification programs of talented youth, even before the adolescent growth spurt, makes perfect sense.

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