

Tracking of health-related physical fitness in adolescent girls: a 3-year follow-up study

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Abstract

Background

Evidence has shown that higher levels of physical fitness in youth have beneficial effects on adult health-related outcomes. However, the tracking of separate physical fitness components during adolescence has been less studied. Since physical fitness often starts to rapidly decline during adolescence, it is necessary to provide information regarding critical time-point for interventions. This study aimed to analyze the extent of tracking of several physical fitness tests.

Methods

In this longitudinal study, we recruited 240 adolescent girls with recoded data at 2 time-points (15 y and 17 y). Physical fitness included body composition (fat mass), explosive power of lower extremities (standing broad jump), muscle endurance of the trunk (sit-ups in 60 sec), flexibility (sit-and-reach test), muscle endurance of lower extremities (squats in 60 sec), aerobic endurance (the 800 m run test) and speed endurance (the 400 m run test). Tracking coefficients were calculated using generalized estimating equations. Tertiles (high, moderate and low) were calculated for each fitness component.

Results

The highest tracking coefficients between the two time-points were found for explosive power of lower extremities ($\beta=0.98$), followed by flexibility ($\beta=0.89$), body composition ($\beta=0.88$), speed endurance ($\beta=0.86$), aerobic endurance ($\beta=0.75$), muscle endurance of lower extremities ($\beta=0.65$), and muscle endurance of the trunk ($\beta=0.51$). Tertile ratings remained stable across the two time-points.

Conclusions

Moderate to high tracking of physical fitness in adolescent girls suggests that interventions aiming to increase the level of physical fitness should probably begin in early adolescence.

Background

Physical fitness is a multi-dimensional, well-documented marker of health [1]. It is often described as 'the capacity to perform physical activity and refers to a full range of physiological and psychological qualities' [2]. Main components of physical fitness include: (i) cardiorespiratory fitness, (ii) muscular fitness, (iii) speed and (iv) body composition [1]. In youth, maintenance of higher levels of physical fitness may reduce the incidence of cardiorespiratory and metabolic risk factors in adulthood, additionally preventing from all-cause mortality [1,3,4].

Evidence suggests that children and adolescents between ages 6 and 17 should participate in muscle-strengthening activities at least 3 days per week and in aerobic activities on a daily basis [5]. Despite health-related benefits and efforts to promote physical fitness, studies have shown that the level of

physical fitness in youth has consistently declined over the past three decades in the United States [6-8] and Europe [9,10]. Thus, by screening and monitoring physical fitness across the lifespan, professionals would be able to implement special interventions and policies in everyday settings.

Given the importance of lifelong physical fitness for health, it is assumed that such construct tracks well from point-to-point. Tracking can be defined in two ways: (i) 'a tendency of individuals to maintain their rank within a certain group over a period of time'[11] and (ii) 'the ability to predict future observations based on earlier values' [12].

Although collecting longitudinal data is relatively difficult to obtain, due to high costs, time and drop-out rates [13], several longitudinal physical fitness analyses of different components are available in the literature [13-25]. In general, moderate to high tracking of physical fitness has been observed, with the results being strongly dependent on sex [14-16], the follow-up period [17,18], the number of time-points being measured [19-23] and the selection of different fitness tests [18,19,24].

In Croatia, the most recent study has shown negative secular trends of health-related physical fitness; from 1999 to 2014 body mass index increased, while cardiorespiratory and muscular fitness decreased in both sexes [26]. A common perception has been embraced that more time spent in sedentary behavior, lack of physical activity and consuming fat-rich food are the most prevalent factors for lower physical fitness levels [27]. Since the level of physical fitness starts to rapidly decline during adolescence, it is valuable to examine how different fitness components track during this critical period.

Therefore, the main purpose of the study was to analyze the extent of tracking of several physical fitness tests. We hypothesized that the performance on physical fitness measures would track moderate to high across age comparisons and the maintenance of fitness tertile ratings would remain stable over time.

Methods

Study participants

In this longitudinal study, participants were adolescent girls measured at two time-points (15 y and 17 y). Specifically, out of ten secondary schools in the 'Varaždin' county ($\approx 45,000$ inhabitants), 3 schools were randomly selected. Randomization of schools was done with replacement by drawing school codes on slips of paper from a box, with each school having equal probability of selection. At the second stage, four classes within each school were selected, which gave a total of twelve classes and 286 girls. Of them, nineteen did not attend physical education classes when the measurements were conducted and thirty-seven had a measurement at only one time-point. Our final sample consisted of 240 adolescent girls who were measured in all physical fitness components at two time-points. Parent of each participant and all participants gave informed written consent before enrollment into the study for participation. Analyses and procedures performed in the study were conducted in accordance with the Declaration of Helsinki [28] and approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb, Croatia.

Health-related physical fitness

To assess the level of health-related physical fitness, the following tests were applied: (i) fat mass (body composition), (ii) standing broad jump (explosive power of lower extremities), (iii) sit-ups in 60 sec (muscle endurance of the trunk), (iv) sit-and-reach test (flexibility), (v) squats in 60 sec (muscle endurance of lower extremities), (vi) the 800 m run test (aerobic endurance), and (vii) the 400 m run test (speed endurance). The measuring protocol of each test has been described previously [29-31]. In brief, ***fat mass*** was measured using bioelectrical impedance analysis for three consecutive times (Omron BF500Body Composition Monitor, Omron Medizintechnik, Vernon Hills, IL, USA). The reliability for three measurements was excellent (Cronbach's alpha >0.90). ***Standing broad jump*** tests jumping distance from a standing start ('frog leap'), where each participant bends knees parallel to the ground and swings both arms, jumping vigorously as far as possible, trying to land with their feet together and stay upright [29]. ***Sit-up test*** evaluates muscle endurance of the trunk as number of sit-ups completed from lying position (knees bent at a 90°) in 60 sec [29]. ***Sit-and reach test*** assesses the level of flexibility, by sitting on the floor or a mat, legs straight under the angle of 90°, the person being tested reached forward with the arms (hands overlapping). The distance of reach was measured in centimeters using a measuring non-elastic tape attached on the floor [30]. ***Squats in 60 sec*** measures muscle endurance of lower extremities. The subject stood in a position where legs were spread in shoulder – width, heels were put at the edge of the mat and hands were relaxed in their natural position. During the performance, the subject went down till the position where the tips of both hands touched the ground and went up with both legs in full extension. The total amount of correctly performed squats in one minute was the score (reps) [31]. ***The 800 m run test*** assesses aerobic capacity. Participants were asked to complete the 800-meter course in the quickest possible time around the standardized track and field running track 400 m in length. On the command '1,2,3 and go', all participants began to run at their own pace. If a child had any kind of problem during the test, they were told to slow down or stop the test. Each trial was done with small groups of five to perform the test, to prevent from competition [32]. The final time in minutes was the score. Finally, ***the 400 m run test*** was used to assess the level of speed endurance. The same protocol as for the 800 m run test was used and the final score was recorded in minutes.

Data analysis

Basic descriptive statistics are presented as mean and standard deviation (SD). The Kolmogorov–Smirnov tests showed that data were normally distributed. Baseline and follow-up differences were calculated using paired sample t-test. Cohen *d* effect sizes (ES) were also calculated to determine the magnitude of the group differences in health-related physical fitness. ES was classified as follows: <0.2 was defined as trivial; 0.2-0.5 was defined as moderate; 0.5-0.8 was defined as large; and >0.8 was defined as very large [33]. Tracking of physical fitness was assessed using generalized estimating equations. To describe the extent of tracking, we calculated a stability coefficient, the value of the baseline measurement being regressed on the entire longitudinal development of that variable [34]. The coefficient ranges from 0 to 1, with 1 indicating perfect tracking and 0 indicating no tracking. Participants' scores in physical fitness test at both time-points were classified into tertiles (high, moderate and low).

Cross-tabulation matrices, percent agreements and kappa statistics were used to assess the ranking stability over time. Kappa tracking coefficients were classified as low ($r < 0.3$), moderate ($r = 0.3 - 0.6$), or moderately high ($r > 0.6$) [11]. Two-sided p -values were used, and significance was set at $\alpha < 0.05$. All the analyses were calculated in Statistical Packages for Social Sciences v.23 (SPSS, Chicago, IL, United States).

Results

Basic descriptive statistics are presented in Table 1. Although significant, small effect sizes were observed for height and weight changes over time. Low-to-moderate effect sizes were presented for physical fitness; the largest changes for aerobic capacity, speed endurance and flexibility were observed, followed by flexibility, muscle endurance of lower extremities and muscle endurance of the trunk. Body composition and explosive power of lower extremities exhibited the lowest effect sizes during the follow-up period of three years.

Beta coefficients for the seven fitness tests appeared in Table 2. Tracking coefficients for the whole sample were significant at $p < 0.001$. All fitness components exhibited moderate-to-high tracking. The strongest tracking coefficients were obtained for explosive power of lower extremities, flexibility, body composition and speed endurance, while aerobic capacity and muscle endurance of lower extremities exhibited somewhat lower values. Finally, muscle endurance of the trunk showed moderate tracking characteristics over time.

The maintenance in a specific group (high, medium and low) is presented in Table 3. The strongest average agreement was indicated for explosive power of lower extremities, with slightly lower values being observed for flexibility, body composition and speed endurance. Similar percentage of agreement was shown for explosive power of lower extremities, aerobic endurance and muscle endurance of the trunk ($< 70.0\%$). Kappa statistics showed moderate-to-high stability of tertile ratings (kappa = 0.43 to 0.86, $p < 0.001$).

Discussion

The main purpose of the study was to analyze the extent of tracking and the maintenance of tertile classification of several physical fitness tests in adolescent girls measured at two time-points (15 y and 17 y). The main findings of the study are: 1) the largest declines during the follow-up are observed for aerobic capacity, flexibility and speed endurance; 2) the strongest tracking coefficients are obtained for explosive power of lower extremities, flexibility, body composition and speed endurance, and 3) the highest percentage agreements are shown for explosive power of lower extremities, flexibility and body composition.

The tracking coefficients derived from our data are similar, compared to previous studies conducted in youth [13,18,22,23]. A recent longitudinal study showed that the tracking coefficients for similar fitness

test assessments ranged between 0.59 and 0.83 between ages 15 y and 18 y [13]. Pate *et al.* [18] tracked cardiorespiratory and muscular fitness assessed by the Physical Work Capacity 170 test and handgrip strength and found moderate tracking coefficients ($r=0.53$) in girls. In a study by Matton *et al.* [23], interagecorrelations between adolescence and adulthood were moderate for body composition ($r=0.53$), muscular endurance of the trunk ($r=0.34$), explosive power of lower extremities ($r=0.59$) and speed ($r=0.56$), while flexibility exhibited moderately high tracking ($r=0.76$). Additionally, in a group of girls tracked between 6 y and 11 y, tracking coefficients were moderate for the standing broad jump ($r=0.40$), the endurance shuttle run ($r=0.42$) and sprint ($r=0.50$) [22]. The averaged tracking coefficient of all seven fitness tests in our study was 0.79, which is similar, compared to one previous study with the same age range (15 y to 18 y; $r=0.71$) [13]. The adolescent period in our study has been confirmed as a critical time for girls to maintain their physical fitness levels, since they have a longer time span to achieve fitness, compared to boys [13].

As confirmed by previous literature, it is difficult to compare tracking coefficients across studies, due to different methodology, which included tests used to assess the level of physical fitness, sample size, age at first observation, and time points between repeated measures [23,35]. Nevertheless, previous longitudinal studies have documented that physical fitness components track moderately to moderately high during childhood and adolescence [13,18,22,23]. The nature of higher tracking of physical fitness may be explained by a few mechanisms. First, physical fitness has often been associated with more stable factors that do not change rapidly over time (genotype, morphology) [36]. Second, physical fitness is less sensitive to age-as do opportunities- especially with children in the household [11]. Third, physical fitness is often assessed by objective methods in the literature, reducing the level of measurement error [37].

The second purpose of the study was to analyze the maintenance in a certain tertile (high, medium and low). We found a general trend, indicating that individuals categorized in the lowest tertile at the age of 15 y remained in the lowest tertile at the age of 17 y. The similar stabilization was confirmed for individuals who started in the highest and middle tertile. Previous evidence supports our findings, pointing out that physical fitness track well from childhood to adolescence [13,16]. However, the percentage agreement in each fitness test in our study is somewhat higher, compared to previous results [13]. Specifically, a study by True *et al.* [13] showed moderate agreement between the time points, which may be explained by different methodology and the number of time point measurements. Previous studies have highlighted the importance of achieving 'average' fitness level (medium tertile), which gives them the ability to stay in the same category or to become highly fit over developmental phase [13]. On the other hand, it is relatively unlikely that an individual in the 'low' tertile improves to the 'high' tertile. Therefore, special interventions and policies aiming to improve the level of physical fitness in the 'low' group and at least maintain or enhance the level of physical fitness in the 'medium' group should be implemented within the school settings [38].

This study is not without limitations. Compared to some previous studies, the follow-up period of three years was relatively short and undertaking measures at only two time-points and conclusions should be

interpreted with caution. Also, we conducted the study among adolescent girls, and by including the boys, the findings would have been comparable between sexes. Moreover, we did not acknowledge daily or weekly attendance in the movement program. It is possible that an individual was under moderate- or vigorous- intensity physical activity, when the study had been conducted, so this variable could not be accounted for. Lastly, we did not assess maturational level, which might have affected on the development of fitness over time.

Conclusions

In conclusion, our findings show that physical fitness tracks moderately- to highly-well over a follow-up period of 3 year. The highest tracking coefficients are observed for explosive power of lower extremities, flexibility, body composition and speed endurance. Similarly, the largest percentage agreements are shown for explosive power of lower extremities, flexibility and body composition. In general, girls maintain their tertile classification of high, moderate and low for each physical fitness test. Thus, an adolescent period between the ages 15 y and 17 y is an avenue for health-related interventions targeting physical fitness levels. Also, physical fitness should be monitored annually during physical education classes for two purposes: 1) in order to detect a 'risky' group of adolescent girls with 'low' performance, and 2) to prevent those categorized in the 'medium' tertile to drop into the lower tertile. Despite the effort to track physical fitness over time, future research needs to focus on other genetic and environmental factors, which may influence the level and persistence of being in a certain physical fitness category.

Declarations

Ethics approval and consent to participate: The study was approved by the Institutional Review Board of the Faculty of Kinesiology, University of Zagreb, Croatia. We confirm that the Faculty of Kinesiology served as an institution, under which the study had been conducted. The informed consent voluntarily was signed by the participants, participants' parents or their guardians. Analyses and procedures performed in the study were conducted in accordance with the Declaration of Helsinki.

Consent for publication: Not applicable.

Availability of Data and Materials: The datasets generated and/or analysed during the current study are not publicly available due to the reason that they belong to the Secondary school 'Gospodarska škola Varaždin' but are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: AO and LŠ conducted the study. LŠ analyzed the data. MK, AO, TV, KJ and LŠ wrote and drafted the manuscript. The author(s) read and approved the final version of the manuscript.

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Tables

Table 1. Descriptive statistics of the study participants at baseline and follow-up ($N=240$)

Study variables	Baseline	Follow-up	Δ (%)	ES	p -value
	Mean (SD)	Mean (SD)			
Stature (cm)	165.8 (7.3)	167.6 (7.5)	1.1	0.24	<0.001
Weight (kg)	60.2 (14.0)	62.3 (14.8)	3.5	0.15	<0.001
Fat mass (%)	27.0 (10.5)	29.8 (10.1)	10.4	0.27	<0.001
Standing broad jump (cm)	178.5 (28.3)	170.9 (28.1)	-4.3	-0.27	<0.001
Sit-ups (reps in 60 sec)	55.4 (11.0)	51.2 (10.1)	-7.6	-0.40	<0.001
Sit-and-reach test (cm)	69.4 (8.9)	64.5 (9.6)	-7.1	-0.53	<0.001
Squats (reps in 60 sec)	48.7 (8.0)	44.9 (7.9)	-7.8	-0.48	<0.001
The 800 m run test (min)	4.49 (0.78)	4.99 (0.78)	11.1	0.64	<0.001
The 400 m run test (min)	1.47 (0.31)	1.64 (0.38)	11.6	0.49	<0.001

$p < 0.05$

Table 2. Tracking coefficients for each physical fitness component between the 2 time-points ($N=240$)

Study variables	Tracking coefficient	95% CI	<i>p</i> -value
Fat mass (%)	0.88	0.84 to 0.92	<0.001
Standing broad jump (cm)	0.98	0.97 to 0.99	<0.001
Sit-ups (reps in 60 sec)	0.51	0.41 to 0.61	<0.001
Sit-and-reach test (cm)	0.89	0.86 to 0.92	<0.001
Squats (reps in 60 sec)	0.65	0.55 to 0.74	<0.001
The 800 m run test (min)	0.75	0.67 to 0.84	<0.001
The 400 m run test (min)	0.86	0.80 to 0.90	<0.001

Table 3. Girls' maintenance of physical fitness tertile classification from baseline to follow-up (*N*=240)

Baseline	Follow-up		
Fat mass (%)	High	Medium	Low
High	88.5%	11.5%	0.0%
Medium	5.2%	87.1%	7.8%
Low	0.0%	23.8%	76.2%
Kappa statistics (<i>p</i> -value)	0.75 (<0.001)		
Agreement	83.9%		
Standing broad jump (cm)			
High	100.0%	0.0%	0.0%
Medium	0.0%	92.9%	7.1%
Low	0.0%	22.2%	77.8%
Kappa statistics (<i>p</i> -value)	0.86 (<0.001)		
Agreement	90.2%		
Sit-ups (reps in 60 sec)			
High	61.9%	28.6%	9.5%
Medium	19.0%	64.3%	16.7%
Low	17.6%	17.6%	64.7%
Kappa statistics (<i>p</i> -value)	0.43 (<0.001)		
Agreement	63.6%		
Sit-and-reach test (cm)			
High	90.5%	9.5%	0.0%
Medium	2.6%	87.2%	10.3%
Low	0.0%	20.0%	80.0%
Kappa statistics (<i>p</i> -value)	0.78 (<0.001)		
Agreement	85.9%		
Squats (reps in 60 sec)			
High	61.5%	38.5%	0.0%
Medium	10.8%	70.3%	18.9%
Low	11.8%	11.8%	76.5%

Kappa statistics (<i>p</i> -value)	0.51 (<0.001)		
Agreement	69.4%		
The 800 m run test (min)			
High	57.9%	36.8%	5.3%
Medium	19.5%	63.4%	17.1%
Low	0.0%	20.0%	80.0%
Kappa statistics (<i>p</i> -value)	0.47 (<0.001)		
Agreement	67.1%		
The 400 m run test (min)			
High	77.8%	22.2%	0.0%
Medium	12.5%	80.0%	7.5%
Low	0.0%	18.2%	81.8%
Kappa statistics (<i>p</i> -value)	0.68 (<0.001)		
Agreement	79.9%		