Journal of Physical Activity and Health, 2014, 11, 1239-1247
http://dx.doi.org/10.1123/jpah.2012-0137

JOURNAL OF
Physical Activity & Health
Official Journal of ISPAH
www.JPAH-Journal.com
ORIGINAL RESEARCH

Motor Coordination, Activity, and Fitness at 6 Years of Age Relative to Activity and Fitness at 10 Years of Age

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***Background*:** Health benefits of physical activity (PA) and physical fitness (PF) are reasonably well established, but tracking studies of PA and PF in childhood have not ordinarily considered the role of motor coordination. ***Objectives*:** To compare the growth status, gross motor coordination (GMC), PA, and PF characteristics of children at 6 years of age relative to aerobic fitness (fit, unfit) and PA (active, sedentary) at 10 years. ***Methods*:** 285 primary school children (142 girls, 143 boys) resident on the 4 main Azorean islands, Portugal, were measured annually (in the fall) from 6 to 10 years. ANOVA and *t* tests were computed with SPSS 17. ***Results*:** Children with either high aerobic fitness or with high level of PA at 10 years of age tended to have a more favorable profile at 6 years compared with those with low fitness or low activity, respectively. Children who were both fit and active at 10 years of age had a more favorable activity and fitness profile and had better GMC at 6 years compared with children who were unfit and sedentary. ***Conclusions*:** Results highlight the need to consider not only PA, but also PF and GMC in health promotion through the primary school years.

***Keywords*:** growth, aerobic fitness, movement control, tracking, children

Childhood is an important window of opportunity for the development of physical activity and fitness behaviors as children learn and consolidate movement and social skills, learn to interact with peers and make choices that can influence behaviors later in life.[1] Contemporary thinking in public health holds that physical activity (PA) and physical fitness (PF) influence health status during childhood and adolescence, and is associated with a reduction in risk for several chronic diseases through adulthood.[2] It is generally assumed that children who are more physically active and physically fit will become physically active and physically fit adults. This has prompted regular calls for intervention programs to improve PA and PF in childhood and adolescence.[2]

Successful interventions should be grounded in the context of the PA and PF of children and also in available information on the tracking of both variables.[1–3] Information about the dynamics of change in PA and PF during childhood provides knowledge about their stability and permits the identification and prediction of potential determinants that may be useful in the implementation of preventive measures.[3]

Indicators of PA and PF track moderately during childhood and the transition from childhood into adolescence. Several factors influence the magnitude of tracking coefficients, including the interval between observations (the closer the time span between measurements, the higher the coefficient), age at first observation (the younger the child, the lower the coefficient), individual characteristics (gender, body size and composition, motor coordination, biological maturity status, functional characteristics, among others),[2,4] cultural and environmental factors, and increased availability of sedentary behaviors which may influence attitudes toward and opportunities for PA.[5,6] However, tracking studies of PA and PF in childhood have not ordinarily considered the potential role of motor coordination as a factor influencing both PA and PF.

Available methodologies to quantify tracking vary and depend on assumptions about the stability-instability of the relevant characteristics.[7] The current study considers the tracking of PA and PF from a different perspective in children 6 to 10 years. It attempts to move "back in time" to verify if children who were physically fit/unfit or sedentary/very active at 10 years of age were also fit/unfit or sedentary/very active at 6 years. We attempted to identify the multivariate profile of growth status, PF and gross motor coordination (GMC) at 6 years relative to activity and fitness status at 10 years of age. It was anticipated that such information would provide educators with specific characteristics of children at 6 years age that may be classified as "at risk" later in childhood and by inference inform the need for the introduction of more efficient intervention programs earlier in childhood to ensure healthy levels of PA and PF in later childhood. This longitudinal study thus had 2 purposes: first, to describe the antecedents of growth, GMC, PA, health- and performance-related PF of children at 6 years of age relative to their aerobic fitness and PA at 10 years of age; and second, to explore the same characteristics at 6 years of age in children who are fit and active compared with those who are unfit and sedentary at 10 years.

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Methods

The sample was selected from a mixed-longitudinal study of the growth status, PA, GMC, PF, biological maturation, body composition, and motivation for sport among Azorean (Portuguese) youth 6 to 19 years of age. A total of 1000 to 1200 subjects in 4 cohorts of 250 to 300 subjects were sampled and followed for 4 to 5 years (ie, cohorts followed from 6 to 10 years, 10 to 13 years, 13 to 16 years, and 16 to 19 years, respectively).[8] Subjects were resident on the 4 main Azores Islands: Faial, Pico, São Miguel, and Terceira, and represented about 99% of the total population of school children in the 9 islands comprising the Azores. Sampling within each island was random, and no differences were noted across the 4 islands. The objectives and procedures of the study were thoroughly explained to parents and their informed consent was obtained. The study was approved by the Government Board of Education, the Government Directorate of Sports, by the Director of different educational areas and ethically approved by the Faculty of Sport, University of Porto.

Sample

This study considers only 285 children of the first cohort: 142 girls and 143 boys (representing 24.6% of the overall sample). The children were observed initially at 6 years of age and were followed annually from 6 to 10 years (primary school). Drop-out was insignificant, < 10%. All measurements were taken annually in the fall during September and October by physical education teachers of each participating school. All teachers were previously trained and supervised by the principal investigators. All assessments were done in the schools using similar testing conditions and protocols. Within the Azorean school system, physical education is mandatory twice per week in primary school; voluntary programs for children ("sport little schools") are also available. The teachers and children are also used to physical fitness testing across all school years.

Anthropometry

Height was measured with a Siber-Hegner anthropometer and weight was measured with a Secca scale. Body Mass Index (BMI) was calculated. Approximately 30% of the sample was overweight and obese, based on criteria of the International Obesity Task Force.[35] This prevalence was consistent with observations for Portuguese children of the same age.[36] The triceps and subscapular skinfolds were measured with Holtain Calipers to the nearest millimeter. The sum of the 2 skinfold thicknesses was used as a proxy for subcutaneous fatness. The procedures described in Lohman et al[9] were used.

Physical Activity (PA)

PA was assessed with personal interview using the Godin and Shephard questionnaire,[10] which has been validated in children and youth.[11] The interview was conducted in a one-on-one setting and all questions were placed in the context of daily routines. Children reported the number of times/week that they spent in different activities for a period of at least 15 minutes. Three PA categories were considered: mild (3 METs)—activities such as easy walking, walking the dog; moderate (5 METs)—activities such as fast walking, miniature golf, tennis, jump rope, leisurely swimming; or strenuous (9 METs)—activities such as running, jogging, soccer, basketball, judo, roller skating, vigorous swimming. A total score was derived by multiplying the frequency of each category by the MET value and the products were summed.[10] A weekly physical activity = (3 × number of time in mild activities + 5 × number of times in moderate activities + 9 × number of times in strenuous activities) was derived.

Gross Motor Coordination (GMC)

GMC was assessed with the KTK test battery (*Körper-Koordinationstest für Kinder*) which has demonstrated validity in children 5 to 14 years of age.[12] The battery has been used in motor development research with normal and special children in Portugal.[8,13] It included 4 items:

1. Balance—backward walking on balance beams with 3 different widths (3 cm, 4.5 cm, 6 cm). The number of successful steps was recorded
2. Hopping on 1 leg over an obstacle—the child hopped on 1 foot over a stack of foam squares; after a successful hop with each foot (the child clears the square without touching it and continues to hop on the same foot at least 2 times), the height was increased by adding a square (50 cm × 20 cm × 5 cm). The child had 3 attempts at each height and foot; the height of the final successful jump was recorded
3. Jumping from side to side—the child made consecutive jumps from side to side over a small beam (60 cm × 4 cm × 2 cm) as fast as possible for 15 seconds. The child was instructed to keep his/her feet together; the number of correct jumps was recorded
4. Shifting platforms—the child stood with both feet on 1 platform (25 cm × 25 cm × 2 cm supported on 4 legs 3.7 cm high) and held a second identical platform in his/her hands; the child then placed the second platform alongside the first and stepped on to it; the first box was then lifted and placed alongside the second and the child stepped on to it; the sequence continued for 20 seconds. For each successful transfer, from one platform to the other, 2 points were scored (one for shifting the platform, the other for transferring the body); the number of points in 20 seconds was recorded.

The sum of the scores on the 4 tests provided an overall indicator of GMC adjusted for age and sex, labeled a "motor quotient." Although the test items included specific components of motor performance (eg, dynamic balance, agility, and power), each test has a relatively complex task structure which differentiates them from more traditional performance-related test batteries. Further, the 4 items all loaded on a single factor.[12]

Health-Related Physical Fitness

Health-related fitness was assessed with 4 items of the Fitnessgram[14]:

1. Aerobic capacity—1-mile run/walk (1609 m): the child ran/walked this distance in the shortest time possible
2. Abdominal muscular strength and endurance—curl-ups: the child correctly performed as many curl-ups as possible
3. Trunk extensor strength—trunk lifts: lying in a prone position, the child lifted the trunk as much as he/she could
4. Upper body muscular strength and endurance—push-ups: the child correctly performed as many push-ups as possible.

Performance-Related Physical Fitness

Performance-related fitness was assessed with several items from the 1988 AAHPERD Youth Fitness Test[15]:

1. Speed—50-yard dash: the child ran this distance in the shortest time possible
2. Explosive power—standing long jump: the child jumped as far as possible from a standing position
3. Static strength—grip strength: the child gripped the dynamometer with maximum force during 5 to 10 seconds
4. Agility—shuttle-run: the child ran as fast as possible from the starting line to a line 9 m away where 2 small wooden blocks

were placed, picked up 1 of the blocks, returned to the starting line, placed the block on the line, and then repeated route. The distance between departure and the line with the 2 little blocks is 9 m apart.

Quality Control

An in-field test-retest design was used for all variables during the first wave of data collection. A random sample of 24 children (8.5% of the total sample in the 6 to 10 year cohort) from the 4 islands was selected. Intraclass correlation coefficients (R) were as follows: height: $0.93 \leq R \leq .99$; weight: $0.95 \leq R \leq .99$; skinfolds: $0.92 \leq R \leq .96$; GMC tests: $0.79 \leq R \leq .98$; PA: $0.74 \leq R \leq .88$; health-related physical fitness tests: $0.65 \leq R \leq .97$; performance-related physical fitness tests: $0.64 \leq R \leq .87$. Lowest correlations, albeit moderate to moderately high, were noted in the 1-mile run/walk ($R = .64$), agility shuttle-run ($R = .65$), shifting platforms ($R = .79$), and backward balance (0.79).

Analysis

Exploratory and descriptive analyses were used to check for outliers and normality. Appropriate transformations were used to normalize distributions of BMI (square root), skinfolds (natural logarithm), PA (square root), and curl-ups, trunk lifts, and 1-mile run/walk (natural logarithms).

Moving back in time was done as follows. In the first approach, children at 10 years of age were classified on the basis of PA and aerobic PF. Tertiles for PA were as follows: sedentary: up to 23 METs per week (PA < P33); moderate: from 23 to 42 METs per week (PA between P33 and P66); very active: > 42 METs per week (PA > P66). Tertiles for the 1-mile run were as follows: low fitness: subjects completed the test with a time > 13.4 minutes (> P66); moderate fitness: subjects who completed the test with a time between 10.6 minutes and 13.3 minutes (P66 to P33); high fitness: subjects who completed the test in < 10.5 minutes (< P33). Growth status, health- and performance-related PF, and GMC of children in each tertile at 10 years were then back traced to 6 years of age. In the second approach and using the same cut-offs as above, children who were classified as both fit and very active (aerobically fit and highly active) or as unfit and sedentary at 10 years of age were then back traced to 6 years to identify growth, health- and performance-related PF and GMC profiles. ANOVA with Bonferroni adjusted *P*-values for post hoc multiple comparisons were used in the first, while *t* tests were used in the second analysis. Two nonparametric tests, Kruskal-Wallis and Mann-Whitney, were used for the push-up because its distribution was resistant to any transformation. All computations were done in SPSS 17.0. Significance levels were set at 5%.

Results

Descriptive statistics for growth status, GMC, PA and PF of children at 6 years of age as a function of aerobic fitness (1-mile run/walk) at 10 years of age are shown in Table 1. Low fit girls at 10 years had a higher BMI and sum of skinfolds at 6 years compared with fit girls. Low fit girls also performed poorer in agility, speed and push-ups compared with their fit peers, but comparisons with medium fit girls in agility and speed were variable. Medium and low fit girls at 10 years differed only in push-ups, agility shuttle-run, and 50-yard dash at 6 years, while medium and low fit girls at 10 years differed only on push-ups at 6 years.

Boys high and low in aerobic fitness at 10 years differed at 6 years of age in body weight, BMI and skinfolds (lower in high fit) and in GMC, 1-mile run-walk, push-ups, and agility (better in high fit). Performances in GMC, 1-mile run-walk, push-ups, and agility shuttle run at 6 years were also better in high fit than medium fit boys at 10 years, whereas PA, GMC, and indicators of PF at 6 years did not differ between medium and low fit boys at 10 years of age. High and medium fit boys at 10 years did not differ in growth status at 6 years, while medium and low fit boys at 10 years differed only in body weight (medium fit lower) at 6 years. The most physically fit boys at 10 years of age had lower body weight, BMI, and sum of skinfolds and higher GMC, and performed better in push-ups, 1-mile run/walk, and agility shuttle run than low fit boys at 6 years. High and medium fit boys at 10 years differed only in GMC, push-ups, 1-mile run/walk and agility shuttle run at 6 years, while medium and low fit boys at 10 years did not differ in growth status (except weight), GMC, PA, and PF at 6 years.

Corresponding comparisons at 6 years of age relative to PA status at 10 years of age are shown in Table 2. GMC and performances in the curl-up, push-up and 50-yard dash at 6 years of age were poorer in girls classified as sedentary and high active at 10 years. Sedentary girls at 10 years of age had lower GMC and poorer performances in the curl-up, push-up and 50-yard dash compared with high active girls at 6 years. In contrast, only the 50-yard dash at 6 years of age was poorer in sedentary than moderately active girls at 10 years, while only push-ups at 6 years were lower in moderately than highly active girls at 10 years. Sedentary and moderately active girls at 10 years differed only in the 50-yard dash at 6 years, while moderately and very active girls at 10 years differed only in the push up at 6 years. Corresponding comparisons of boys at 10 years indicated thicker skinfolds, lower GMC, and fewer push-ups among sedentary than high active boys at 6 years of age. Other group comparisons of boys by PA level at 10 years indicated only poorer push-up performances among sedentary than moderately active boys and among moderately than highly active boys at 6 years of age. Sedentary boys at 10 years of age had a higher sum of skinfolds and lower GMC and did not perform as well in the push-up compared with high active boys at 6 years. Sedentary and moderately active boys at 10 years differed only in the push up at 6 years, the same was apparent between moderately and very active boys.

Table 3 contrasts the growth status, GMC, PA, and PF at 6 years of children who were both aerobically fit and very active and who were both aerobically unfit and sedentary at 10 years of age. Unfit and sedentary girls at 10 years had lower GMC and poorer performances in curl-ups, 1-mile run/walk, agility shuttle-run, and 50-yard dash compared with the most active and fit girls at 6 years. Unfit and sedentary boys at 10 years had thicker skinfolds, lower GMC, and poorer performances in the 1-mile run/walk and 50-yard dash compared with boys active and fit at 6 years of age.

Discussion

This study compared the growth, GMC, PA, and PF characteristics of children at 6 years of age relative to their aerobic fitness and PA at 10 years and also compared contrasting aerobic fitness and PA groups. Children with lower aerobic fitness at 10 years of age were fatter than peers with high aerobic fitness at 6 years (Table 1). Presumably the children with higher subcutaneous fat at 6 years had certain nutritional and perhaps sedentary behaviors that

Table 1 Means and Standard Deviations (± SD) for Body Size, BMI, Sum of Skinfolds, Motor Coordination, Physical Activity, and Health- and Performance-Related Fitness at 6 Years of Age of Children With Contrasting Levels of Aerobic Fitness (1-Mile Run) at 10 Years of Age

	Aerobic fitness tertiles at 10 years pairwise comparisons				*P*-values for difference		
	Upper ($P < 33$)	Medium ($33 \leq P < 66$)	Lower ($P > 66$)				
Girls	**Mean ± SD at 6 years**	**Mean ± SD at 6 years**	**Mean ± SD at 6 years**	***F***	**U-M**	**M-L**	**U-L**
Weight (kg)	21.56 ± 4.07	22.84 ± 2.78	23.51 ± 3.49	2.341	0.484	0.999	0.100
Height (cm)	115.34 ± 6.18	117.20 ± 4.86	118.45 ± 5.77	2.354	0.647	0.767	0.107
BMI (kg/m^2)*	16.21 ± 1.39	16.16 ± 1.47	17.08 ± 1.66	3.063	0.455	0.592	**0.049**
ΣSkinfold (mm)**	15.22 ± 2.76	17.83 ± 6.61	19.76 ± 8.27	5.039	0.054	0.941	**0.006**
Gross motor coordination	97.26 ± 25.90	85.81 ± 26.16	80.18 ± 27.63	2.897	0.356	0.879	0.055
Physical activity (METs/week)*	52.44 ± 34.71	46.38 ± 34.87	41.26 ± 28.80	0.180	1.000	1.000	1.000
Curl up**	13.11 ± 18.62	11.91 ± 12.15	10.12 ± 14.39	0.986	1.000	0.992	0.586
Push up	6(16)***	9(11)***	7.5(9)***	0.756****	**0.001**	**0.020**	**0.001**
Trunk Lift (cm)**	26.31 ± 8.32	25.36 ± 5.09	28.82 ± 6.86	0.437	1.000	1.000	1.000
1-mile (min)**	11.22 ± 0.51	12.93 ± 0.56	15.11 ± 0.84	0.042	1.000	1.000	1.000
Standing long jump (cm)	0.92 ± 0.20	0.89 ± 0.14	0.86 ± 0.13	1.099	1.000	1.000	0.446
Handgrip (kg)	8.22 ± 1.76	8.17 ± 1.87	8.06 ± 1.63	0.081	1.000	1.000	1.000
Agility shuttle-run (s)	13.65 ± 1.28	15.18 ± 1.38	15.26 ± 1.31	11.157	**0.001**	1.000	**0.001**
50-yard dash (s)	11.58 ± 1.33	12.65 ± 1.25	12.59 ± 1.31	5.231	**0.008**	1.000	**0.012**

	Aerobic fitness tertiles at 10 years pairwise comparisons				*P*-values for difference		
	Upper ($P < 33$)	Medium ($33 \leq P < 66$)	Lower ($P > 66$)				
Boys	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	***F***	**U-M**	**M-L**	**U-L**
Weight (kg)	23.10 ± 2.71	23.19 ± 3.72	25.76 ± 3.92	5.513	1.000	**0.021**	**0.005**
Height (cm)	118.71 ± 4.57	117.05 ± 5.19	120.20 ± 4.87	2.903	0.397	0.054	0.601
BMI (kg/m^2)	16.38 ± 1.12	16.77 ± 1.51	17.06 ± 1.49	5.010	0.471	0.278	**0.007**
ΣSkinfold (mm)	12.53 ± 3.74	16.6 ± 7.80	20.66 ± 11.66	6.482	0.261	0.235	**0.002**
Gross motor coordination	101.93 ± 27.55	82.03 ± 21.14	84.83 ± 25.92	7.207	**0.003**	1.000	**0.023**
Physical activity (METs/week)	61.18 ± 33.21	50.15 ± 28.68	42.36 ± 29.66	0.411	1.000	1.000	1.000
Curl up	18.55 ± 24.20	8.53 ± 10.90	9.34 ± 14.32	1.109	0.442	1.000	1.000
Push up	14(15)***	11(17)***	6(9)***	17.96****	**0.001**	0.260	**0.001**
Trunk lift (cm)	28.36 ± 8.13	26.25 ± 9.03	24.21 ± 7.31	0.149	1.000	1.000	1.000
1-mile (min)	10.60 ± 0.87	12.88 ± 0.61	16.17 ± 1.57	9.831	**0.003**	1.000	**0.001**
Standing long jump (cm)	0.99 ± 0.22	0.92 ± 0.14	0.92 ± 0.18	1.771	0.336	1.000	0.450
Handgrip (kg)	10.00 ± 2.03	9.04 ± 2.43	9.73 ± 1.82	2.018	0.142	0.700	1.000
Agility shuttle-run (s)	13.91 ± 1.08	14.75 ± 1.07	14.60 ± 1.36	6.369	**0.005**	1.000	**0.050**
50-yard dash (s)	11.24 ± 1.35	12.01 ± 1.28	11.99 ± 1.47	4.338	0.043	1.000	0.072

* Squareroot transformed and ** Log transformed for statistical testing.

*** Median and interquartile range.

**** Kruskal-Wallis test statistics.

Table 2 Means and Standard Deviations (± SD) for Body Size, BMI, Sum of Skinfolds, Motor Coordination, Physical Activity, and Health- and Performance-Related Fitness at 6 Years of Age of Children With Contrasting Levels of Physical Activity at 10 Years of Age

	Aerobic fitness tertiles at 10 years pairwise comparisons						
	Sedentary ($P < 33$)	Moderate ($33 \le P < 66$)	Very active ($P > 66$)		*P*-values for difference		
Girls	**Mean ± SD at 6 years**	**Mean ± SD at 6 years**	**Mean ± SD at 6 years**	***F***	**S-M**	**M-VA**	**S-VA**
Weight (kg)	12.94 ± 3.74	22.37 ± 3.02	23.39 ± 3.44	1.101	0.422	1.000	1.000
Height (cm)	118.38 ± 6.68	116.68 ± 4.91	117.44 ± 5.43	0.650	1.000	0.808	1.000
BMI (kg/m^2)*	16.82 ± 1.63	16.28 ± 1.55	16.82 ± 1.63	1.68	0.315	0.450	1.000
ΣSkinfold (mm)**	19.93 ± 8.10	17.57 ± 7.31	16.99 ± 5.44	1.22	0.419	1.000	1.000
Gross motor coordination	79.36 ± 24.80	87.65 ± 25.89	99.72 ± 33.21	4.23	0.366	0.325	**0.016**
Physical activity (METs/week)*	46.26 ± 32.71	43.31 ± 34.11	42.47 ± 29.52	0.17	1.000	1.000	1.000
Curl up**	9.53 ± 12.90	10.53 ± 12.66	22.28 ± 21.22	3.57	0.894	0.260	**0.028**
Push up	9(11)***	7(10)***	7(15)***	1.136****	0.233	**0.001**	**0.001**
Trunk lift (cm)**	26.76 ± 5.83	26.48 ± 6.49	27.94 ± 8.88	0.25	1.000	1.000	1.000
1-mile (min)**	13.44 ± 1.58	13.34 ± 1.60	13.28 ± 1.57	1.95	1.000	0.318	0.161
Standing long jump (cm)	0.88 ± 0.13	0.88 ± 0.14	0.94 ± 0.19	1.15	1.000	0.577	0.421
Handgrip (kg)	8.06 ± 1.64	8.23 ± 1.79	8.47 ± 1.84	0.41	1.000	1.000	1.000
Agility shuttle-run (s)	15.20 ± 1.29	14.80 ± 1.47	14.55 ± 1.66	1.91	0.480	1.000	0.263
50-yard dash (s)	12.97 ± 1.25	12.09 ± 1.28	11.72 ± 1.30	9.40	**0.003**	0.913	**0.001**

	Physical activity tertiles at 10 years pairwise comparisons						
	Sedentary ($P < 33$)	Moderate ($33 \le P < 66$)	Very active ($P > 66$)		*P*-values for difference		
Boys	**Mean ± SD at 6 years**	**Mean ± SD at 6 years**	**Mean ± SD at 6 years**	***F***	**S-M**	**M-VA**	**S-VA**
Weight (kg)	23.34 ± 3.44	23.99 ± 2.72	24.40 ± 4.63	0.804	1.000	1.000	0.819
Height (cm)	117.98 ± 4.72	119.93 ± 5.15	119.52 ± 5.45	1.980	1.000	0.185	0.704
BMI (kg/m^2)*	16.92 ± 1.50	16.72 ± 1.10	16.60 ± 1.51	0.34	1.000	1.000	1.000
ΣSkinfold (mm)**	22.24 ± 11.92	15.48 ± 7.50	14.21 ± 6.04	3.24	0.238	1.000	**0.038**
Gross motor coordination	80.05 ± 21.72	91.13 ± 26.89	97.55 ± 27.11	3.35	0.381	0.726	**0.035**
Physical activity (METs/week)*	43.80 ± 27.24	55.74 ± 37.53	48.46 ± 28.87	0.68	0.821	1.000	1.000
Curl up**	5.80 ± 11.45	7.95 ± 9.82	18.58 ± 22.76	2.66	1.000	0.096	0.662
Push up	11(6)**	10(16)**	12(13)**	3.435****	**0.001**	**0.001**	**0.001**
Trunk lift (cm)**	23.80 ± 5.66	24.13 ± 6.03	28.77 ± 9.57	4.02	1.000	0.052	0.095
1-mile (s)**	13.84 ± 3.07	12.94 ± 2.64	12.81 ± 2.56	1.00	0.782	1.000	0.495
Standing long jump (cm)	0.88 ± 0.16	0.95 ± 0.19	0.98 ± 0.20	1.75	0.620	1.000	0.193
Handgrip (kg)	9.98 ± 2.34	9.66 ± 1.89	9.73 ± 2.22	0.15	1.000	1.000	1.000
Agility shuttle-run (s)	14.55 ± 1.28	14.49 ± 1.13	14.07 ± 1.22	1.98	1.000	0.263	0.437
50-yard dash (s)	12.06 ± 0.96	11.82 ± 1.37	11.42 ± 1.50	1.98	1.000	0.483	0.232

* Squareroot transformed and ** Log transformed for statistical testing.
*** Median and interquartile range.
*** Kruskal-Wallis test statistics.

Table 3 Means and Standard Deviations (± SD) for BMI, Sum Of Skinfolds, Motor Coordination, Physical Activity, and Health- and Performance-Related Fitness at 6 Years of Age of Children Classified as Most Active and Most Fit and as Least Active and Unfit at 10 Years of Age

	Very active and fit	Sedentary and unfit		
Girls	**Mean ± SD at 6 years**	**Mean ± SD at 6 years**	***t***	***P*-values**
Weight (kg)	22.70 ± 4.05	23.43 ± 3.25	0.596	0.554
Height (cm)	117.63 ± 6.81	118.11 ± 5.21	0.257	0.798
BMI (kg/m^2)*	16.11 ± 1.35	16.69 ± 1.62	0.071	0.943
ΣSkinfold (mm)**	15.41 ± 3.81	19.28 ± 7.80	1.431	0.159
Gross motor coordination	104.36 ± 35.91	76.83 ± 25.47	–2.897	**0.006**
Physical activity (METs/week)*	50.67 ± 36.65	44.42 ± 32.25	0.840	0.405
Curl up**	16.11 ± 17.23	8.74 ± 12.15	–2.819	**0.008**
Push up	11(11)***	9(10)***	–1.013****	0.311
Trunk lift (cm)**	25.46 ± 7.13	27.47 ± 5.93	–0.337	0.738
1-mile (min)**	12.34 ± 1.01	13.79 ± 1.59	2.209	**0.032**
Standing long jump (cm)	0.94 ± 0.20	0.88 ± 0.11	–1.275	0.208
Handgrip (kg)	8.64 ± 2.14	8.08 ± 1.53	–0.983	0.330
Agility shuttle-run (s)	14.36 ± 1.84	15.28 ± 1.19	2.009	**0.050**
50-yard dash (s)	11.82 ± 1.54	13.12 ± 1.31	2.799	**0.007**
	Very active and fit	**Sedentary and un fit**		
Boys	**Mean ± SD**	**Mean ± SD**	***t***	***P*-values**
Weight (kg)	22.50 ± 2.67	26.02 ± 5.68	1.227	0.304
Height (cm)	117.72 ± 4.77	120.88 ± 3.92	1.655	0.105
BMI (kg/m^2)*	16.44 ± 1.25	17.05 ± 1.49	0.759	0.452
ΣSkinfold (mm)**	13.14 ± 4.15	19.63 ± 10.48	3.802	**0.001**
Gross motor coordination	100.82 ± 28.40	71.86 ± 17.77	–2.594	**0.013**
Physical activity (METs/week)*	57.55 ± 32.37	41.13 ± 28.90	–0.927	0.359
Curl up**	15.52 ± 21.03	9.87 ± 14.47	–0.759	0.453
Push up	15(17)***	14.5(16)***	–1.668****	0.097
Trunk lift (cm)**	28.18 ± 8.87	24.29 ± 6.94	–1.481	0.146
1-mile (min)**	11.34 ± 1.36	15.14 ± 2.42	3.310	**0.002**
Standing long jump (cm)	0.98 ± 0.22	0.81 ± 0.16	–1.877	0.067
Handgrip (kg)	9.75 ± 2.36	9.31 ± 1.86	–0.460	0.648
Agility shuttle-run (s)	13.98 ± 1.11	14.69 ± 1.29	1.326	0.192
50-yard dash (s)	11.25 ± 1.49	12.50 ± 1.18	2.085	**0.043**

* Squareroot transformed and ** Log transformed for statistical testing.

*** Median and interquartile range.

**** Mann-Whitney test statistics.

persisted to 10 years which may have contributed, in part, their lower aerobic fitness. Portuguese schoolchildren of both sexes with lower cardiorespiratory fitness were more likely to be fatter.[16,17] The trend suggests a need for early interventions starting in the preschool years to prevent excess weight gain which persists into childhood. Of relevance, elevated fatness is associated with indicators of metabolic risk in childhood and adolescence and also with increased risk for the development of cardiovascular disease and metabolic complications through adulthood.[18,19]

In contrast to elevated fatness, the situation for indicators of health- and performance-related PF was not as clear (Table 1). Girls with low aerobic fitness at 10 years of age performed poorly in push-ups and had lower agility and speed at 6 years. The difference in GMC at 6 years of age between low and high aerobically fit girls at 10 years of age was of borderline significance ($P = 0{,}055$). Boys with low aerobic fitness at 10 years had lower GMC and did not perform as well as high fit boys in push-ups, agility shuttle-run and 1-mile run/walk. The results suggested that children who were less fit at 6 years of age had lower aerobic fitness (1-mile run/walk) at 10 years, which indicated persistence of an unfit profile through childhood.[1,3] The results suggested that unfit and/or sedentary behaviors were seemingly entrenched early in childhood and were seemingly more resistant to change than active behaviors during middle childhood.

Comparison at 6 years of age conditioned on PA status at 10 years also showed that very active girls and boys at 10 years had a higher level of GMC. Very active girls at 10 years of age also had better performances in curl-ups, push-ups, and 50-yard dash at 6 years of age. In contrast, a 4 year follow-up study[20] of older French children from 11 to 15 years did not observe a relationships between

PA and performance- and health-related physical fitness (standing long jump, agility shuttle run, grip strength, sit and reach, sit-ups) (ie, children who were very active at follow-up did not necessarily perform better). The authors[20] suggested that PA may have less influence on performance-related PF than on physiological characteristics. Given the age range of the sample (11–15 years), it was also possible that potential relationships with PA were confounded by individual differences in the timing of the adolescent growth spurt. Several fitness tests have their own adolescent growth spurts that differ in timing relative to the growth spurt in stature, and this individuality of growth and the timing of maturation is independent of PA.[21,22] The potential of proficiency in performance-related PF in facilitating opportunities for PA was not considered.

Only very active girls at 10 years in the current study had better performances in curl-ups, push-ups and 50-yard dash at 6 years of age (Table 2). The results for childhood among girls also contrasted those for French adolescents 11 to 15 years,[20] among whom very active children of both sexes had better performances in all fitness tests, except handgrip and sit and reach compared with sedentary children.

Results of the current study were generally similar when the antecedents of growth, GMC, PA and PF at 6 years of age among children who were both aerobically fit and physically active and those who were aerobically unfit and sedentary at 10 years were compared. Children in the extreme groups did not differ in height, weight, BMI, and PA at 6 years, but the fit and active children had better GMC at 6 years. Aerobically fit and active girls performed better in 2 health-related (curl-ups, 1-mile run/walk) and performance-related (agility shuttle run, 50-yard dash) items at 6 years than unfit and inactive girls, while fit and active boys had thinner skinfolds and performed better in the 1-mile run/walk and 50-yard dash at 6 years compared with unfit and inactive boys (Table 3).

Children who were unfit and sedentary at 10 years had poorer performances in several PF tests at 6 years (girls: curl-ups, 1-mile run/walk, agility shuttle run, and 50-yard dash; boys: 1-mile run/walk and 50-yard dash), which suggested stability of an unfit/sedentary profile across the study interval at least in these test items. Results of the present analysis were generally consistent with available epidemiological data,[5,6,23] allowing for variation in samples, age groups, time-span, test items, and statistical approaches. The data suggested, in general, that habits of an unfit/inactive lifestyle established during childhood can persist through childhood into adolescence and perhaps into adulthood.

The 3 comparisons among Azorean children highlighted the importance of GMC. Boys and girls in the upper tertile of aerobic fitness (Table 1) and in the upper tertile of PA (Table 2) at 10 years, and boys and girls who were both aerobically fit and very active at 10 years (Table 3), had significantly better levels of GMC at 6 years of age compared with peers in the respective comparison groups at 10 years (low aerobic fitness, low physical activity, and low aerobic fitness and physical activity). The differences in GMC in girls classified by aerobic fitness approached statistical significance. The results thus suggested an important role of motor coordination in behaviors influencing aerobic fitness and PA later in childhood. Consistent with these observations, several recent studies have indicated a relationship, albeit moderate, between proficiency in movement skills and PA[24–26] and PF.[27,28] PA and aerobic fitness are in part associated with the development of proficiency in basic movement skills, which makes sense since movement is the substrate of PA behaviors. Accordingly, adequate levels of GMC contribute directly to enjoyable and successful participation in PA, which in turn may influence subsequent PA behaviors and aerobic fitness during childhood. On the other hand, limited proficiency in GMC may serve as a constraint to PA behaviors which may negatively influence aerobic fitness.

Results for the BMI and sum of skinfolds were variable. Boys and girls high in aerobic fitness at 10 years had a lower BMI and thinner skinfolds at 6 years compared with boys and girls low in fitness (Table 1). In contrast, boys and girls high in PA at 10 years did not differ in the BMI at 6 years compared with boys and girls low in PA, while only boys high in PA had significantly thinner skinfolds at 6 years than boys low in PA (Table 2). The same trend was apparent in the comparisons of youth high in both aerobic fitness and PA at 10 years of age. Boys and girls high in both characteristics at 10 years did not differ in the BMI at 6 years compared with boys and girls low in fitness and PA at 10 years, while only boys high in both fitness and PA at 10 years had thinner skinfolds at 6 years of age.

Results of the 3 contrasts in the current study, though somewhat variable, were generally consistent with the literature. Children who were regularly active tended to have lower levels of estimated fatness (skinfolds, percentage fat), but data for BMI were variable.[29] Nevertheless, limited longitudinal data indicated smaller gains in the BMI in physically active youth,[30] while more active children between 4 and 11 years had less fatness in early adolescence and perhaps a later adiposity rebound.[31] By inference, maintenance of smaller gains in subcutaneous fat over time through PA may prevent unhealthy weight gain and in turn may reduce the risk of overweight and/or obesity. In the current study, only aerobically fit girls at 10 years, but aerobically fit, highly active, and both fit and active boys at 10 years of age had a lower sum of skinfolds at 6 years compared with boys with low aerobic fitness, low PA, and both low fitness and PA, respectively.

The current study has several limitations. First, the estimate of PA was based on a questionnaire which is not always optimal given the difficulty of children to recall and quantify their activities. However direct interviews were used and high reliability values have been reported with the same questionnaire in children of different geographical regions in Portugal.[32–34] Second, assessing aerobic fitness in children is a difficult task and it would be appropriate to use direct laboratory measures or perhaps a more aerobically taxing test than the 1-mile run/walk. This would, however, be very difficult to implement in field studies on the 4 islands not only for financial and technical reasons but also for practicality. Third, although it is not expected that children from Azorean islands are different from those of mainland Portugal, the generalization of the results to the mainland and to other areas should be done with care. Subtle differences in lifestyle, environments, and other factors may influence GMC, PA, and PF. The statistical methodology may also be a limitation; all of the available information of the 5 data waves was not used. Although complex and sophisticated longitudinal mixed models and/or latent class analysis could have been used with time invariant and time-varying predictors such as body composition variables, the differential approach used in the present report based on *t* tests and ANOVAs was well suited for the main purposes.

Allowing for limitations, several strengths of the study should be noted. A longitudinal approach provides a better understanding of changes in variables over time. The interval from 6 to 10 years is sensitive for the refinement of movement skills and development of appropriate behaviors that may persist into adolescence and adulthood. The different analytical and comparative perspectives of tracking between 6 and 10 years also permitted evaluation of growth, GMC, PA, and PF characteristics of children relative to different levels of aerobic fitness and PA.

In summary, children with either high aerobic fitness or with high PA at 10 years of age appeared to have a more favorable profile at 6 years compared with those with low fitness or low activity, respectively. Moreover, fit and active children at 10 years of age showed a more positive profile and were more coordinated in motor skills and physically fit than unfit and sedentary children at 6 years. The findings highlight the need for school interventions to focus not only on PA but also on PF and GMC. All 3, PA, PF, and GMC, interacting with each other may have a positive influence on the overall health of children. High aerobic fitness and high PA are negatively associated with several metabolic and cardiovascular risk factors during childhood. The results highlight the importance of GMC as a correlate of PA and PF and through PA and PF an indirect correlate of metabolic and cardiovascular health in childhood.

Acknowledgments

This study was supported by the Regional Government of Azores through the Regional Directorate of Sports. The authors would like to thank the anonymous reviewers for their helpful and constructive comments to further improve the paper.

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