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Original paper

Secular trends in health-related physical fitness in Spanish adolescents: The AVENA and HELENA Studies

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Abstract

We analysed the secular trends in health-related physical fitness in Spanish adolescents between 2001–2002 and 2006–2007. Two representative population studies were conducted 5 years apart in adolescents (12.5–17.5 years) from Zaragoza (Spain) that participated in the AVENA study in 2001–2002 and in the HELENA-CSS study in 2006–2007. Both studies used the same tests to assess physical fitness: the handgrip strength, bent arm hang, standing broad jump, 4 × 10 m shuttle run and 20 m shuttle run tests. Performance in 4 × 10 m shuttle run and 20 m shuttle run tests was higher in 2006–2007 (Cohen's *d* ranging from 0.2 to 0.4, $p < 0.05$), whereas performance in handgrip strength and standing broad jump tests was lower in 2006–2007 (Cohen's *d* ranging from 0.3 to 1.1, $p < 0.001$). Adjustment for age, pubertal status, fat mass, fat free mass and parental education did not alter the results. The odds ratio (OR) of meeting the FITNESSGRAM Standards for healthy cardiorespiratory fitness was higher in 2006–2007 in both boys (OR, 95% CI: 2.123, 1.157–3.908) and girls (OR, 95% CI: 2.420, 1.377–4.255). The results indicate that levels of both speed/agility and cardiorespiratory fitness were higher in 2006–2007 than in 2001–2002, whereas muscular strength components were lower in 2006–2007.

Keywords: Cardiorespiratory fitness; Muscular strength; Youth; Physical activity

1. Introduction

Health-related physical fitness refers to cardiorespiratory fitness, muscular strength, speed-agility and body composition.[1] Fitness is considered an important marker of health already in youth,[1,2] and there is increasing evidence that high levels of fitness during childhood and adolescence have a positive influence on adult health status.[1]

Several meta-analyses showed a decrease in cardiorespiratory fitness during recent years and stabilisation in muscular strength.[3–8] Available original reports all around the world show different trends depending on geographical region.[9–14] To our knowledge, there is no information available regarding the secular trends in physical fitness in Spanish adolescents. Developing appropriate public health strategies requires

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analysing on a regular basis the evolution of fitness especially in young people.

The purpose of the present study was to analyse the secular trends in health-related physical fitness (i.e., cardiorespiratory fitness, muscular strength and speed/agility) in Spanish adolescents between 2001–2002 and 2006–2007.

2. Methods

In this study we considered data from two separate cross-sectional studies, both representative from the city of Zaragoza (Spain). Data for the first measurement point were obtained between February 2001 and March 2002 and derived from the AVENA (Alimentación y Valoración del Estado Nutricional en Adolescentes) study.[15] The AVENA study is a cross-sectional study performed in 5 Spanish cities and designed to assess the nutritional status of a representative sample of adolescents from Spain. For the present study we selected 399 adolescents (184 girls) aged 12.5–17.5 years from Zaragoza. Data for the second measurement point was obtained between October 2006 and June 2007 and derived from the HELENA-CSS (Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study).[16,17] The HELENA-CSS is a multi-centre study performed in 10 European cities and designed to obtain reliable and comparable data on nutritional status, cardiovascular profile, physical activity and fitness of a sample of European adolescents. For the present study we selected 392 adolescents (186 girls) aged 12.5–17.5 years also from Zaragoza.

Both studies were performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000). The study protocols were approved by the Review Committee for Research Involving Human Subjects of the Hospital Universitario Marqués de Valdecilla (Santander, Spain) and by the Research Ethics Committee of the Government of Aragón (CEICA; Spain), for the AVENA study and the HELENA-CSS respectively.

In both studies, AVENA study and HELENA-CSS, parents were asked to fill in a questionnaire about their socio-economic status. According to their answers about educational achievement, adolescents were classified into three categories: both parents with university degree, one of the parents with university degree and none of the parents with university degree.

Anthropometric measures in both measurement points were assessed by trained physicians following standardised procedures described in detail for both AVENA study[15,17] and HELENA-CSS.[17] Briefly, body height was measured to the nearest 0.1 cm with a stadiometer (SECA 225) while adolescents were standing barefoot. Body mass was determined to the nearest 0.05 kg using a balance scale (SECA 861) with the subject in their underwear. Body mass index (BMI) was calculated as body mass (kg) divided by height (m) squared. Skinfold thickness was measured to the nearest 0.2 mm in triplicate in the left side at biceps, triceps, subscapular, suprailiac, thigh, and medial calf with a Holtain Caliper (Crymmych, UK).[17] The sum of 6 skinfold thickness was used as an indicator of total body fat. Body fat percentage was calculated by the equation described by Slaughter et al.[18] Fat free mass was calculated by subtracting fat mass from total body weight. Pubertal status was recorded according to Tanner and Whitehouse.[19]

Health-related physical fitness was assessed in both the AVENA study[20] and HELENA-CSS[21] using identical procedures. In brief, upper body muscular strength was assessed with the handgrip strength and the bent arm hang tests. Lower body muscular strength was assessed with the standing broad jump test. Speed-agility was assessed with the 4 × 10 m shuttle run test. Cardiorespiratory fitness was assessed by the 20 m shuttle run test.[22] The scientific rationale for the selection of all these tests has been previously published,[23] and all have shown to be valid in young people.[24,25]

For comparative purposes, the equations reported by Léger et al.[22] were used to estimate the maximum oxygen consumption (VO_{2max}, mL/kg/min) from the 20 m shuttle run test score. Adolescents were classified according to their cardiorespiratory fitness levels based on the FITNESSGRAM Standards for Healthy Cardiorespiratory Fitness Zone.[26,27] Boys with a VO_{2max} of 42 mL/kg/min or higher were classified as having a healthy cardiorespiratory fitness level. Girls aged 12 and 13 years with a VO_{2max} of 37 and 36 mL/kg/min or higher, respectively, were classified as having a healthy cardiorespiratory fitness level. Girls aged 14 or older with a VO_{2max} of 35 mL/kg/min or higher were classified as having a healthy cardiorespiratory fitness level.

The data are presented as mean ± standard deviation unless otherwise stated. Gender differences for each measurement point were assessed by one-way analysis of variance (ANOVA). Mean differences of the secular trends in health-related physical fitness performances (i.e., handgrip strength, bent arm hang, standing broad jump, 4 × 10 m shuttle run and 20 m shuttle run tests) between measurement points were analysed by one-way analysis of covariance (ANCOVA) for boys and girls separately. The measurement point was entered as fixed factor, each fitness test was entered as dependent variable in separate models, and age and pubertal status were entered as covariates. We calculated the effect size statistics as Cohen's d (standardised mean differences) and 95% confidence interval. Values of Cohen's $d \sim 0.2$, ~ 0.5 and ~ 0.8 are considered small, medium and large effects, respectively.[28]

Adolescents were split into centiles by their performance in physical fitness tests to show graphically the differences between both measurement points. We also calculated the odds ratio (OR) of having a healthy cardiorespiratory fitness level and scoring zero in the bent arm hang test by binary logistic regression after controlling for age and pubertal status. The analyses were performed using the Statistical Package for Social Sciences (SPSS, v. 16.0 for WINDOWS; SPSS Inc, Chicago) and the level of significance was set to 0.05.

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Table 1
Performance in physical fitness tests by measurement point and gender.

	Fitness tests	*n*	Years 2001–2002	*n*	Years 2006–2007	*p*	Cohen's *d*	95% CI
Boys	Handgrip strength (kg)	153	36.6 ± 6.2	173	32.1 ± 6.2	<0.001	0.70	0.479 to 0.929
	Bent arm hang (s)	153	24.5 ± 16.8	173	22.4 ± 16.8	0.557	0.07	0.152 to 0.283
	Standing broad jump (cm)	151	185.9 ± 27.7	175	176.5 ± 27.6	0.003	0.34	0.118 to 0.556
	4 × 10 m shuttle run (s)[a]	153	11.4 ± 0.9	166	11.2 ± 0.9	0.016	0.27	0.050 to 0.492
	20 m shuttle run (stages)	153	6.7 ± 2.4	131	7.7 ± 2.4	0.001	0.41	0.173 to 0.645
Girls	Handgrip strength (kg)	184	27.6 ± 4.1	186	23.0 ± 4.1	<0.001	1.10	0.880 to 1.318
	Bent arm hang (s)	184	9.0 ± 13.7	184	8.1 ± 13.7	0.533	0.07	−0.140 to 0.270
	Standing broad jump (cm)	184	149.0 ± 22.9	185	137.0 ± 22.9	<0.001	0.50	0.296 to 0.712
	4 × 10 m shuttle run (s)[a]	179	12.6 ± 0.9	176	12.3 ± 0.9	0.008	0.29	0.076 to 0.495
	20 m shuttle run (stages)	180	3.9 ± 1.9	141	4.4 ± 1.8	0.032	0.24	−0.022 to 0.462

Values are adjusted means ± standard deviation. *p* values from one-way analysis of covariance after controlling for age and pubertal status.
[a] In this test, lower scores (time in s) indicate better performance.

3. Results

The characteristics of the study population by measurement point (2001–2002 and 2006–2007) and gender are shown in Table I (see supplementary material). Girls had lower levels of fat free mass and physical fitness than boys (all $p < 0.001$).

Table 1 shows the mean of physical fitness tests by gender in both measurement points after controlling for age and pubertal status. Boys and girls measured in 2006–2007 had significantly better performance in the 20 m shuttle run test (Cohen's $d \sim 0.4$ and ~0.2, respectively) and in the 4 × 10 m shuttle run test (Cohen's $d \sim 0.3$ for both) compared to those measured in 2001–2002. Levels of the handgrip strength and standing broad jump tests were significantly lower in 2006–2007 in both boys (Cohen's $d \sim 0.7$ and ~0.3, respectively) and girls (Cohen's $d \sim 1.1$ and ~0.5, respectively), whereas the bent arm hang test was similar in both measurement points (Cohen's $d \sim 0.07$ for both boys and girls). We repeated all the analyses after further controlling for fat mass, fat free mass or parental education and the results did not materially change (data not shown).

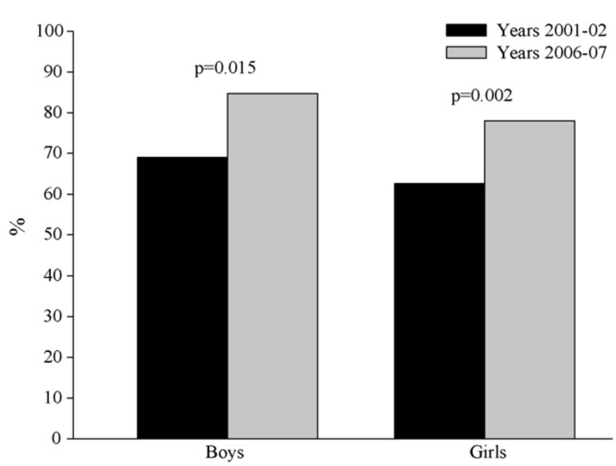

Fig. 1. Percentage of adolescents meeting the FITNESSGRAM Standards for Healthy cardiorespiratory fitness by gender and measurement point.

Fig. I (see Supplementary material) shows the centile values of the handgrip strength, bent arm hang and standing broad jump tests according to gender and measurement point. The centile values of the 4 × 10 m and 20 m shuttle run tests according to gender and measurement point are depicted in Fig. II (see Supplementary material). Prevalence of healthy cardiorespiratory fitness according to FITNESSGRAM Standards was significantly higher in 2006–2007 in both boys (OR, 95% CI: 2.123, 1.157 to 3.908) and girls (OR, 95% CI: 2.420, 1.377 to 4.255) (Fig. 1) after controlling for age and pubertal status. The results remained significant after further controlling for fat free mass or parental education, except for total body fat mass which increased the prevalence in boys (OR, 95% CI: 3.972, 1.848 to 8.538) and in girls (OR, 95% CI: 3.230, 1.733 to 6.020) in 2006–2007.

The prevalence of adolescents with value 0 in bent arm hang test was not significantly different between both measurement points (OR, 95% CI: 0.751, 0.321 to 1.758 and 1.528, 0.867 to 2.695) for boys and girls respectively (see Fig. III in supplementary material).

4. Discussion

The results of the present study showed that Spanish adolescents in 2006–2007 had higher levels of cardiorespiratory fitness and speed-agility, and lower levels of muscular strength than their counterparts 5 years before. We also observed that adolescents measured in 2006–2007 were more likely to have healthy cardiorespiratory fitness levels.

Several meta-analyses described the global changes in the main health-related physical fitness components.[4,5] Contrarily to our results, data from 27 countries and five geographical regions showed a decrease in cardiorespiratory fitness from the late 1970s until 2003,[4] whereas performance at power and speed tests remained fairly stable from 1980s.[5] Other ambitious meta-analyses with large sample sizes found similar results[3] but mainly focused on cardiorespiratory fitness.[6–8] Macfarlane and Tomkinson[3] analysed secular changes in power, speed and cardiorespiratory fitness tests performance in 23.5 million Asian children (6–19 years) between 1917

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and 2003 and found consistent declines in cardiorespiratory fitness in the last 10–15 years and a global stabilization in power and speed. Tomkinson and Olds[7] analysed 46 studies and calculated changes in cardiorespiratory fitness in 161,419 Australasian children (6–17 years) between 1961 and 2002 and found a marked decline in the youngest children and boys until about 1990 that appears to be slowing. Likewise, Tomkinson et al.[8] analysed aerobic performance data on over 22 million Koreans (6–18 years) between 1968 and 2000 and found a marked decline in the years following 1984.

The rich history of pediatric fitness testing all around the world shows many original reports about secular trends in adolescent health-related physical fitness in peer-reviewed scientific journals, especially focused on cardiorespiratory fitness.[9,14] Eisenmann and Malina[9] compared available data in directly measured peak VO_2 in US young people from the 20th century and found no changes in male adolescents since 1938 and no changes in girls since 1960. However, a decrease in cardiorespiratory fitness was observed in adolescent girls since 1980. Likewise, Huotari et al.[14] found that the cardiorespiratory fitness of Finnish adolescents was lower in 2001 than in 1976. The analyses of other health-related physical fitness components such as muscular strength or speed-agility show unequal trends in every geographical region.[10–13] Matton et al.[10] analysed a representative Flemish sample of adolescents (12–18 years) between 1969 and 2005 showing a general decrease in the bent arm hang and 10×5 m shuttle run tests in girls, and a decrease in bent arm hang and an increase in 10×5 m shuttle run tests in boys. Albon et al.[11] analysed changes among New Zealand children between 1991 and 2003 and did not find significant differences in the 4×9 m shuttle run and the standing broad jump tests. Jürimäe et al.[12] analysed secular trends of Estonian and Lithuanian children and adolescents in 1992 and 2002. Lithuanians showed a decline in bent arm hang, standing broad jump and 20 m shuttle run tests yet Estonian only presented decline in bent arm hang test. The 10×5 m shuttle run test in Lithuanians and the standing broad jump, 10×5 m and 20 m shuttle run tests in Estonian remained unchanged. Tomkinson et al.[13] examined the trends in physical fitness in 18,631 South Australian schoolchildren (12–15 years) between 1995 and 2000, and they found a significant decline in 20 m shuttle run and 40 m sprint tests but no changes were found in vertical jump test.

Though there is consistency in the secular trends reported in other young populations, our findings do not concur with the above-mentioned studies. The increase in cardiorespiratory fitness and speed-agility, the decrease in upper and lower body muscular and the increase in the prevalence of achieving a healthy cardiorespiratory fitness after controlling for confounders discard theories related to the increases of fat mass over the reported changes in physical fitness components. According to the model established by Tomkinson,[4,5] we agree in that the reported secular trends in physical fitness are caused by a network of social, behavioral, physical, psychosocial and physiological factors. Despite the lack of information about secular trends in other population during recent years that confirms our findings, it could be possible that the changes in fitness scores are the result from the initiatives of the health public institutions like the National Strategy for Nutrition, Physical Activity and Obesity Prevention (NAOS) launched at the beginning of 2005 by the Spanish Ministry of Health and Consumer Affairs.[29] Public health strategies encourage population to be more physically active, which mainly develop cardiorespiratory fitness but not other fitness components such as muscular strength.

The major strength of the present study is the use of identical protocols, sampling methods and sampling frames in two representative cohorts of adolescents from Zaragoza (Spain), as well as the use of objective and reliable fitness tests, and the recent measurement data (2006–2007). It is important to consider when interpreting the findings from the present study that only two dataset including adolescents from Zaragoza (Spain) were used over a 5 years period. Moreover, SES only includes the educational level of the parents.

5. Conclusion

In conclusion, the present study on Spanish adolescents indicates that levels of both speed-agility and cardiorespiratory fitness are higher in 2006–2007, whereas muscular strength components were lower in 2006–2007.

Practical implications

- In order to guarantee healthy levels of physical fitness, Spanish public health programs should promote physical activity among adolescents, especially focussed on muscular strength which was seen to decrease.
- Schools may play a key role, and parents also have a great responsibility to encourage and support active living of their offspring.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2010.03.004.

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