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Health-related physical fitness according to chronological and biological age in adolescents. The AVENA study

F. B ORTEGA [1, 2], J. R RUIZ [1, 2], M. J CASTILLO [1], L. A MORENO [3], A. URZANQUI [4], M. GONZÁLEZ-GROSS [4], M. SJÖSTRÖM [2], Á. GUTIÉRREZ [1], AVENA Study Group*

[1]*EFFECTS-262 group*
Department of Physiology, School of Medicine
University of Granada, Granada, Spain
[2]*Unit for Preventive Nutrition*
Department of Biosciences and Nutrition at NOVUM
Karolinska Institutet, Huddinge, Sweden
[3]*E. U. Ciencias de la Salud*
University of Zaragoza, Zaragoza, Spain
[4]*Facultad de Ciencias de la Actividad Física y del Deporte*
Universidad Politécnica de Madrid, Madrid, Spain

Aim. **Physical fitness has been proposed as a major marker of health status at any age. The aim of the present study was to determine the levels of several health-related physical fitness components with respect to chronological and biological age (sexual maturation status) in Spanish adolescents.**

Methods. **Physical fitness was measured in a sample of Spanish adolescents (N.=2 859; 1 357 males, 1 502 females) from the AVENA study, by means of the following tests: sit and reach, handgrip, standing broad jump, bent arm hang, 4×10 m shuttle run, and 20 m shuttle run. Percentage body fat, fat free mass and leisure-time physical activity were used as confounders. Adolescents were classified according to chronological age and biological age (measured by Tanner stages). All the analyses were adjusted for the above- mentioned confounders.**

Results. **Muscular fitness was higher in older adolescents than in younger adolescents. Cardiorespiratory fitness was higher in younger compared to older females, as well as in early puberty compared to late puberty. In males, cardiorespiratory fitness was higher in younger adolescents, but no differences were observed when it was analysed according to sexual maturation status.**

Conclusion. **Normative data for several health-related physical**

*AVENA Study Group:
Coordinator: A. Marcos, Madrid.
Main investigators: M.J. Castillo, Granada; A. Marcos, Madrid; S. Zamora, Murcia; M. García Fuentes, Santander; M. Bueno, Zaragoza, Spain.
Granada: M.J. Castillo, M.D. Cano, R. Sola (Biochemistry); A. Gutiérrez, J.L. Mesa, J. Ruiz (Physical fitness); M. Delgado, P. Tercedor, P. Chillón (Physical activity); F.B. Ortega, M. Martín, F. Carreño, G.V. Rodríguez, R. Castillo, F. Arellano (collaborators). Universidad de Granada. E-18071 Granada.
Madrid: A. Marcos, M. González-Gross, J. Wärnberg, S. Medina, F. Sánchez Muniz, E. Nova, A. Montero, B. de la Rosa, S. Gómez, S. Samartín, J. Romeo, R. Álvarez, (Coordination, immunology); A. Álvarez (Cytometric analysis); L. Barrios (Statistical analysis); A. Leyva, B. Payá (Psychological assessment). L. Martínez, E. Ramos, R. Ortiz, A. Urzanqui (collaborators). Instituto de Nutrición y Bromatología. Consejo Superior de Investigaciones Científicas (CSIC). E-28040 Madrid.
Murcia: S. Zamora, M. Garaulet, F. Pérez-Llamas, J.C. Baraza, J.F. Marín, F. Pérez de Heredia, M.A. Fernández, C. González, R. García, C. Torralba, E. Donat, E. Morales, M.D. García, J.A. Martínez, J.J. Hernández, A. Asensio, F.J. Plaza, M.J. López (Diet analysis). Departamento de Fisiología. Universidad de Murcia. E-30100 Murcia
Santander: M. García Fuentes, D. González-Lamuño, P. de Rufino, R. Pérez-Prieto, D. Fernández, T. Amigo (Genetic study). Departamento de Pediatría. Universidad de Cantabria. E- 19003 Santander.
Zaragoza: M. Bueno, L.A. Moreno, A. Sarriá, J. Fleta, G. Rodríguez, C.M. Gil, M.I. Mesana, J.A. Casajús, V. Blay, M.G. Blay (Anthropometric assessment). Escuela Universitaria de Ciencias de la Salud. Universidad de Zaragoza. E-50009 Zaragoza.

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Address reprint requests to: F. B. Ortega Porcel, Departament of Physiology, Faculty of Medicine, University of Granada, av. Madrid. s/n E-18012, Granada, Spain. E-mail: ortegaf@ugr.es

fitness components according to chronological and biological age are provided in this report. Discrepancies between biological and chronological age analysis were higher for cardiorespiratory fitness than for muscular fitness.

Key words: Physical fitness - Age factors - Adolescent - Sexual maturation.

Physical fitness has been proposed as a major marker of health status at all ages.[1-5] Even in children and adolescents, physical fitness is inversely associated with physiologic risk factors for chronic disease including high blood pressure,[6, 7] hyperinsulinemia,[8] total fatness [9] and abdominal adiposity,[10, 11] an atherogenic lipid profile,[12] insulin resistance, inflammatory markers,[13] and clustering of metabolic risk factors.[14, 15]

While chronological age, *i.e.* age in years and months, has been widely used when reporting physical fitness levels,[7, 16-23] large scale studies describing how health-related physical fitness components differ according to biological age, *i.e.* sexual maturation status, in adolescents are scarce.

Since an inverse correlation between physical fitness components, such as cardiorespiratory fitness (CRF), and fatness has been reported,[9, 24] it is possible that differences initially ascribed to physical fitness may be partially due to the influence of fatness. In fact, it has been reported that for physical fitness comparisons and interpretation in adolescents, percentage body fat is an important factor.[25] Similarly, fat free mass has been proposed as a major determinant of physical fitness, even more important than other body composition factors such as body mass or percentage body fat.[24] Finally, whatever physical fitness component is studied, physical activity should be also taken into account. In this report, the potential influence of fatness, fat free mass and leisure-time physical activity on physical fitness levels has been statistically controlled.

The aim of the present study was to determine the levels of several health-related physical fitness components with respect to chronological and biological age in a representative sample of Spanish adolescents.

Materials and methods

The Spanish data presented in this paper were gathered as part of the AVENA study (Alimentación y Valoración del Estado Nutricional de los Adolescentes/Feeding and assessment of nutritional status of Spanish adolescents).[26] The subjects of the AVENA study were adolescents aged 13-18.5 y. Sampling was multi-staged and stratified by place of origin (five Spanish cities), socioeconomic status, sex and age, and was carried out between 2000 and 2002. The final sample size included in this report was 1 947 (958 males and 989 females). The study protocol was designed and followed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki (in the last up-dated amended version of 2000 in Edinburgh), and approved by the Review Committee for Research Involving Human Subjects of the Hospital Universitario Marqués de Valdecilla (Santander, Spain).

In this report, the chronological age groups used were 13 y (from 13.0 to 13.9 y), 14 y (from 14.0 to 14.9 y), 15 y (from 15.0 to 15.9 y), 16 y (from 16.0 to 16.9 y), and 17-18.5 y (from 17.0 to 18.5 y).

Physical fitness assessment

The health-related physical fitness components, *i.e.* flexibility, muscular strength, speed/agility and CRF, were assessed by the physical fitness tests described below. The tests selected are part of the EUROFIT test battery,[27] and the scientific rationale for all these tests has been published elsewhere.[28]

Flexibility: sit and reach test

Sitting on the floor, and using a standard and validated support, the maximum distance reached with the fingertips when bending forward was recorded. This assessed the mobility of the trunk and hips, and was taken to reflect overall flexibility.

Maximal handgrip strength of upper limb: handgrip test

A Takei TKK 5101 digital dynamometer (range 5-100 kg, precision 0.1 kg; Tokyo, Japan) was used to measure the maximum handgrip strength that could be applied by each hand separately. The sum of the left- and right-hand scores was used in the analysis.

Lower limb explosive-strength: standing broad jump

The explosive-strength developed by the legs from a standing position was recorded as the maximum horizontal distance covered in a jump keeping feet together.

UPPER LIMB ENDURANCE-STRENGTH: BENT ARM HANG

The endurance-strength of the upper body was measured using this standard test, which determines the maximum length of time a subject can remain suspended by the arms from a bar.

SPEED-AGILITY: SHUTTLE RUN (10 M X 4)

This test evaluated the subjects' speed and coordination in an integrated fashion. Subjects ran back and forth four times along a 10 m track at the highest speed possible. At the end of each track section the subjects deposited or picked up a sponge from a line on the floor. The EUROFIT version of this test includes a slight variation, *i.e.* 10 m × 5 without sponges instead of 10 m × 4 with sponges. The main difference between these two tests is that the 10 m × 4 shuttle run test requires a higher coordination component than the 10 m × 5 shuttle run test (depositing and picking up sponges while running at maximum speed).

CARDIORESPIRATORY FITNESS: 20 M SHUTTLE RUN TEST

Cardiorespiratory fitness was assessed by running back and forth over a distance of 20 m.[29] The equations of Léger *et al*. were used to estimate the maximal oxygen consumption ($\dot{V}O_{2max}$).[30] The reliability and validity of this test for determining the $\dot{V}O_{2max}$ in children and adolescents has been widely demonstrated.[30-32]

A muscular fitness index was computed from the following variables: handgrip, standing broad jump and bent arm hang. These variables were transformed into sex-specific Z-score variables as follow: Z score=(value-mean)/standard deviation. The muscular fitness index was calculated as the averaged value of these three standardized variables.

Physical examination and physical activity

The procedures used in this study to assess anthropometry have been previously published.[26, 33] Briefly, height and body mass were measured by standardized protocol. Percentage body fat was calculated from skinfold thicknesses (triceps and subscapular) using Slaughter's equations.[34] These equations have been proposed as the most accurate equations for estimation of percentage of body fat from skinfold thickness in adolescents.[35] Fat free mass (kg) was derived by subtracting fat mass from total body mass.

Biological age was based on sexual maturation status (Tanner stages I-V) classified as proposed by Tanner and Whitehouse.[36] The standard staging of pubertal maturity describes breast and pubic hair development in females and genital and pubic hair development in males. No subject was at Tanner stage I, and only 5% of males and 1% of females were at Tanner stage II. Therefore, the five established Tanner stages were regrouped as Tanner stages II+III, IV, and V; hereafter called early puberty, mid puberty and late puberty, respectively.

Habitual practice of physical activity was determined from the answers to a question designed specifically for the AVENA study:[26] Do you undertake any physical-sporting activity after school?

Statistical analysis

Physical fitness levels, stratified by chronological and biological (sexual maturation stages) age groups, are presented as means±standard deviations. The residuals showed a satisfactory pattern, in terms of skewness and kurtosis.

All physical fitness variables were analysed by analysis of variance (one-way ANOVA) separately for males and females, with either chronological or biological age as fixed factor. Additionally, CRF ($\dot{V}O_{2max}$) and muscular fitness (averaged Z-score value) were analysed by analysis of covariance (one-way ANCOVA), with either chronological or biological age as fixed factors, and percentage body fat, fat free mass and leisure-time physical activity as covariates. Pairwise comparisons were also analysed.

All calculations were performed using SPSS v.14.0 software for Windows. For all analyses, the significance level was set at 5%.

Results

Distributions of sexual maturation status (Tanner stages) by age in the study population are shown in Table I. The age range of adolescents within each stage of sexual maturation was large. In fact, in most of the Tanner stages the age ranged from 13-18.5 y, both in male and female adolescents.

In all the age and sexual maturation groups studied, females had higher flexibility than males ($P \leq 0.001$), while the males were stronger, had higher CRF and were faster than females ($P \leq 0.001$).

Tables II and III show the physical fitness scores

TABLE I.—*Sexual maturation (Tanner stages) distribution by chronological age in male and female adolescents.*

Sex	Tanner stages		Age group					
			13	14	15	16	17-18.5	All
Males (N.=958)	II	N.	31	9	4	2	1	47
		%	66.0	19.1	8.5	4.3	2.1	100
	III	N.	57	46	28	10	6	147
		%	38.8	31.3	19.0	6.8	4.1	100
	IV	N.	56	98	90	104	43	391
		%	14.3	25.1	23.0	26.6	11.0	100
	V	N.	36	98	139	108	73	454
		%	7.9	21.6	30.6	23.8	16.1	100
Females (N.=989)	II	N.	5	3	0	0	0	8
		%	62.5	37.5	0.0	0.0	0.0	100
	III	N.	32	31	19	17	17	116
		%	27.6	27	16	15	15	100
	IV	N.	95	127	158	87	90	557
		%	17.1	22.8	28.4	15.6	16.2	100
	V	N.	47	69	118	108	99	441
		%	10.7	15.6	26.8	24.5	22.4	100

TABLE II.—*Physical fitness scores (means±standard deviation) stratified by chronological age in male and female adolescents.*

	13 y	14 y	15 y	16 y	17-18.5 y	P for trend
Males (N.=958)						
Handgrip (kg) [1]	53.8±13.3	65.6±14.2	71.9±13.2	77.4±13.6	79.3±13.9	<0.001
Bent arm hang (s)	14.9±13.0	19.5±14.6	23.0±16.2	26.8±17.3	26.7±15.1	<0.001
Standing broad jump (cm)	168.1±25.5	181.4±27.1	192.9±28.4	202.2±24.4	201.5±24.3	<0.001
4×10 m shuttle run (s)	12.2±1.1	11.7±1.1	11.7±1.7	11.6±1.5	11.5±1.3	<0.001
Sit and reach (cm)	15.6±6.8	18.1±7.7	19.5±7.8	19.0±8.1	21.4±7.3	<0.001
20 m shuttle run (stages)	6.1±2.4	6.5±2.5	7.1±2.4	7.6±2.4	7.3±2.5	<0.001
Females (N.=989)						
Handgrip (kg) [1]	48.2±9.0	49.7±7.6	51.5±8.4	53.1±9.4	50.8±8.1	<0.001
Bent arm hang (s)	7.3±12.6	8.2±8.8	8.4±8.7	8.9±11.1	9.4±17.1	NS
Standing broad jump (cm)	143.6±20.3	146.4±24.4	151.6±24.0	153.2±21.0	148.4±21.6	<0.001
4×10 m shuttle run (s)	12.9±1.0	12.9±1.2	12.9±1.7	12.8±1.3	13.2±1.2	0.032
Sit and reach (cm)	21.6±6.5	23.3±7.6	24.5±7.1	25.2±7.4	24.0±7.7	<0.001
20 m shuttle run (stages)	3.4±1.5	3.9±1.6	4.4±1.9	4.6±1.8	4.3±1.8	<0.001

[1]The sum of left and right hand scores is shown. To convert kg to Newton (N), multiply by 9.80665. One-way ANOVA was performed for males and females separately.

stratified by age and stages of sexual maturation, respectively, in male and female adolescents. In overall, the one-way ANOVA showed that physical fitness was higher in older adolescents, both chronologically and biologically, compared to their younger peers. Only the bent arm hang test did not show significant differences among age and sexual maturation groups in females. When the score in the bent arm hang test was adjusted for body mass, a clearer improvement in the performance by increasing age groups was found in both males and females, but still significant only in males (data not shown). When comparing sexual maturation groups instead of age groups with regard to the bent arm hang test, after adjustment for body mass the relationship remained highly significant in males (P for trend <0.001) and met the significance in females (P for trend=0.026) (data not shown).

Muscular fitness index mean values according to age and sexual maturation groups are shown in Figures 1, 2, respectively, after adjustment for percentage body fat, fat free mass and leisure-time physical activity. Pairwise comparison analysis showed: in males, differences between every group (for all, P<0.001), except between the 14 y and 15 y group, between the 16 y and

TABLE III.—*Physical fitness scores (means±standard deviation) stratified by biological age (Tanner stage III, IV and V) in males and female adolescents.*

	Tanner III (early puberty)	Tanner IV (mid puberty)	Tanner V (late puberty)	P for trend
Males (N.=958)				
Handgrip (kg) [1]	56.4±14.2	69.5±13.6	74.9±15.2	<0.001
Bent arm hang (s)	14.6±13.7	20.5±14.9	25.4±15.4	<0.001
Standing broad jump (cm)	169.2±28.4	189.0±27.1	197.8±25.7	<0.001
4×10 m shuttle run (s)	12.3±1.4	11.7±1.1	11.3±1.0	<0.001
Sit and reach (cm)	16.3±7.3	18.3±7.7	19.5±8.3	<0.001
20 m shuttle run (stages)	5.9±2.8	7.0±2.6	7.3±2.3	<0.001
Females (N.=989)				
Handgrip (kg) [1]	48.4±7.0	50.6±8.8	52.1±8.3	<0.001
Bent arm hang (s)	7.3±7.4	8.3±8.2	8.3±15.3	NS
Standing broad jump (cm)	146.8±20.5	152.0±22.3	147.2±22.1	0.002
4×10 m shuttle run (s)	13.1±1.1	12.7±1.1	12.8±1.1	0.004
Sit and reach (cm)	23.5±6.9	23.7±7.0	24.2±7.9	NS
20 m shuttle run (stages)	4.8±2.0	4.3±1.7	4.0±1.8	<0.001

[1]The sum of left and right hand scores is shown. To convert kg to Newton (N), multiply by 9.80665. One-way ANOVA was performed for males and females separately. NS: not significant.

17-18.5 y group; in females, differences between the 13 y group and the 15 y and 16 y groups (P=0.018 and P=0.002, respectively), and between the 14 y and 16 y group (P=0.014). Pairwise comparison analysis showed: in males, differences between the early puberty group and the mid and late puberty groups (for all, P<0.001); in females, differences between the early and mid puberty group (P=0.043).

Cardiorespiratory fitness mean values according to age and sexual maturation groups are shown in Figures 3, 4, respectively, after adjustment for percentage body fat, fat free mass and leisure-time physical activity. Pairwise comparison analysis showed: in males, differences between the 17-18.5 y group and the 13 y, 14 y and 15 y groups (P=0.001, P=0.058, P=0.004, P=0.004, respectively); in females, differences between the 17-18.5 y group and the 13 y, 14 y, 15 y and 16 y groups (for all, P<0.001). Pairwise comparison analysis showed differences between the late puberty group and the early and mid puberty groups (P<0.001) in females, whereas no significant difference was found in males.

Discussion

The actual (chronological) age range of children and adolescents within each stage of sexual maturation [37] or for a given skeletal age [38] is quite widespread. This is supported by the results obtained in this study, which showed that in most of the sexual maturation stages the age ranged from 13–18.5 y, both in male and in female adolescents. Since young people are routinely grouped by chronological age, irrespective of biological development, some misclassification for children and adolescents in relation to their biological development may occur. Therefore, it is of interest to examine the associations between health-related physical fitness components and biological age in young people.

The results show that the performance in the health-related physical fitness tests studied is generally higher in chronologically older adolescents compared to younger peers. The same applies when the data were analysed according to biological age, the more mature the adolescent, the better the performance.

After adjustment for percentage body fat, fat free mass and leisure-time physical activity, muscular fitness was higher in chronologically older adolescents, compared to their younger counterparts. The same applies when the data were analysed according to biological age, the more mature, the better the performance. Moreover, the Pairwise comparison analysis showed that the significant differences were found among the youngest groups, but not among the oldest groups. This suggests that the muscular fitness development may take place mainly during early and middle adolescence, and not so much in late adolescence. Longitudinal data are needed to confirm this hypothesis.

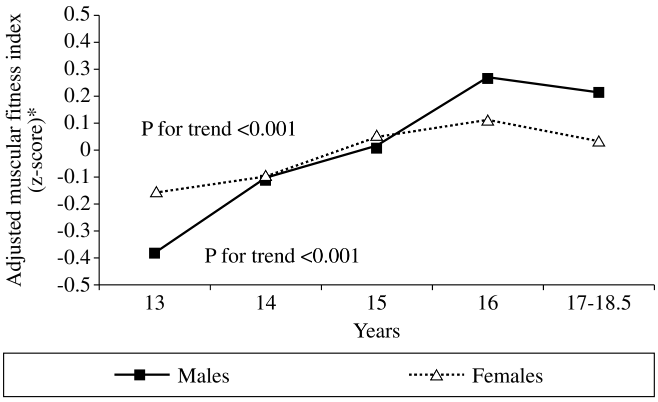

Figure 1.—Muscular fitness according to chronological age in male and female adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity. *The muscular fitness index (z-score) is the averaged value computed from the handgrip, bent arm hang and standing broad jump Z-score variables. One-way ANCOVA was performed for males and females separately.

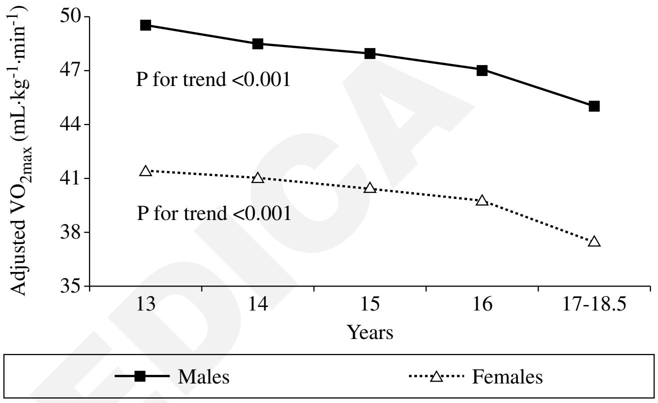

Figure 3.—Cardiorespiratory fitness (VO2max) according to chronological age in male and females adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity. One-way analysis of the covariance (one-way ANCOVA) was performed for males and females separately.

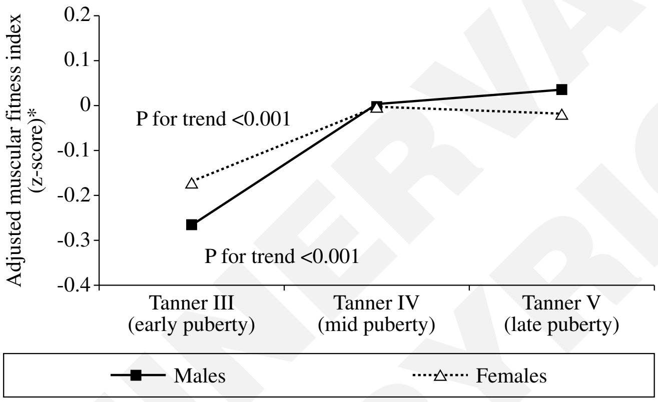

Figure 2.—Muscular fitness according to biological age (Tanner III, IV and V) in male and females adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity. *The muscular fitness index (z-score) is the average value computed from the handgrip, bent arm hang and standing broad jump Z-score variables. One-way ANCOVA was performed for males and females separately.

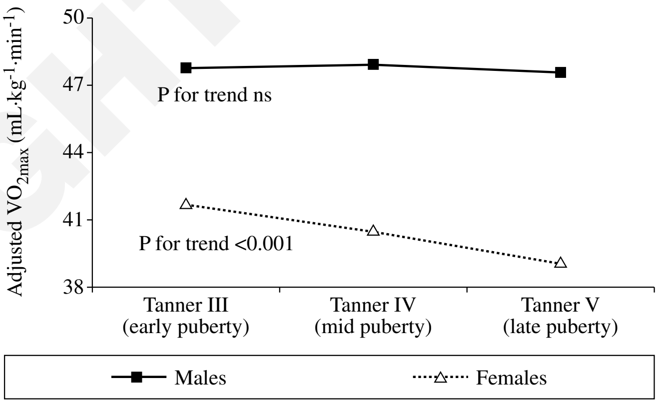

Figure 4.—Cardiorespiratory fitness ($\dot{V}O_{2max}$) according to biological age (Tanner III, IV and V) in male and female adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity. One-way analysis of the covariance (one-way ANCOVA) was performed for males and females separately.

The results also showed that older adolescents had a lower CRF than younger adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity. These differences were observed in females, but not in males, according to biological age groups. This suggests that when male adolescents are grouped by biological age, instead of by chronological age, CRF could be stable during adolescence. Although, further longitudinal studies are required to confirm this finding, the concept of stability of CRF in males, and a trend towards a decrease in females during the adolescence, seems to be supported by others.[39, 40]

Data from CRF levels in a representative sample of American adolescents aged 12-19 y have been reported.[16] In accordance with the present results, the CRF levels in that study were significantly lower in older females (aged 18-19 y) than in younger females (aged 12-13 y); however, the older males showed higher CRF levels than younger males, in contrast to the results of the present study. Unfortunately, in that study biological age was not reported, so comparison with present results in this regard cannot be done. In this context, a study conducted in adolescents aged 11-16 y, sexual maturation status had a large influence (positive correlation) on CRF in males, whereas a weaker association was observed in females.[37] Mota *et al.*,[41] observed that CRF ($\dot{V}O_{2max}$, $mL \cdot kg^{-1} \cdot min^{-1}$) was higher in more sexually mature male adolescents, but lower in more mature female adolescents, compared to their less mature peers.[41] The decline in CRF reported in females is usually attributed to the effect of increased adiposity associated with maturation; however, since in the present report the potential influence of fatness was controlled for, the cause of this decline remains unknown.

Another finding was that when assessing and interpreting the bent arm hang scores in young people, especially in female adolescents, two confounder variables should be taken into account, namely body mass and sexual maturation status. When body mass influence was statistically controlled for and the adolescents grouped by sexual maturation stages, a higher performance on this test was observed in more mature adolescents, in both males and females, compared to less mature adolescents.

As expected, for all chronological and biological age groups, males generally have better physical fitness levels than females, which is in accordance with other studies.[16, 18, 19, 25] This might be due to the greater development of muscle mass that occurs in males during adolescence.[43] The latter could also be linked to the greater amount of physical activity undertaken by males in the present study in all age groups [42] and to hormonal changes. The smaller CRF of the females might be due to their lower hemoglobin concentration (13.5±0.8 *vs* 14.9±1.0 g/dL, data not published), their greater quantity of subcutaneous fat and their smaller lean mass than in males of this age.[44]

Longitudinal data have shown that from childhood to adolescence (from age 11 to 16 y), positive and significant regression coefficients have been observed for the standing broad jump, 20-m shuttle run, number of sit-ups, 10×5-m shuttle run test in both sexes.[18] Similarly, indicators of musculoskeletal fitness have been noted to be moderately stable from childhood to adolescence (from age 11 to 18 y).[45] These figures have also been reported from adolescence (15 y) to adulthood (40 y) for sit-and-reach, sit-up and handgrip tests, with body mass and height-adjusted correlation coefficients ranging from 0.4 to 0.7.[19] Another longitudinal study performed in Flemish female concluded that fitness characteristics demonstrated moderate-high levels of stability from adolescence to middle adulthood, with correlation coefficients raging from 0.5 to 0.9.[46] In an eight year follow-up study conducted in Danish youths, the tracking coefficients in CRF, directly measured by means of an incremental bike test, were between 0.4 and 0.7.[47]

Collectively, the available longitudinal data on tracking physical fitness suggest that the level of physical fitness during adolescence largely determines one's physical fitness as an adult.[18, 19, 45-50]. Given that physical fitness has been proposed to be an important marker of the health status at adolescence,[51] and a strong predictor of mortality and morbidity for cardiovascular and for all causes at adulthood,[1-3] it can be suggested that improving the physical fitness of young people could be a useful strategy for government programs aimed at the prevention of cardiovascular disease at adolescence and later in life.[52]

Conclusions

Normative data of several health-related physical fitness components according to chronological and biological age have been provided in a representative sample of Spanish adolescents. Discrepancies between biological and chronological age analysis were higher for CRF than for muscular fitness. Biological age, as measured by sexual maturation status, seems to influence muscular fitness in male and female adolescents, and CRF in female adolescents. In addition, the results suggest that the muscular fitness development could take place mainly during early and middle adolescence. Further large scale longitudinal studies focused on health-related physical fitness and the influence of maturation are needed.

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