DEPARTAMENTO DE FISIOLOGÍA

FACULTAD DE MEDICINA

UNIVERSIDAD DE GRANADA

Condición física en la adolescencia

[Physical fitness in adolescence]

Universidad de Granada

FRANCISCO B ORTEGA PORCEL

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A mi familia,

por dar vida a mi vida

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CONTENIDOS

CONTENTS

Proyectos de investigación [Research projects]

The papers included in the present PhD thesis are mainly based on data from the AVENA study. Data from an intervention study and from the HELENA study were also used to complete this PhD thesis.

1. **The AVENA study** (2000-2003). The AVENA study (Alimentación y Valoración del Estado Nutricional de los Adolescentes / Feeding and assessment of nutritional status of Spanish adolescents) was conducted in 2859 Spanish adolescents aged 13–18.5 years. Many factors related with the adolescents' physiological and psychological health status were assessed.
   Web site available (in Spanish): www.estudioavena.com
   Coordinator: Ascensión Marcos.
   Responsible for physical fitness assessment: Angel Gutiérrez / Manuel J Castillo
   Involvement of the PhD candidate: Data collection, data analysis and writing of scientific papers, with special implication on physical activity, fitness and anthropometry/body composition.
2. **Intervention study** (2002-2003). A 6 month nutritional and physical activity program was conducted in 46 adolescents (14.17 ± 0.43 years old). The intervention was implemented in 22 adolescents (experimental group) to assess the effects of a nutritional and physical activity program on total and central body fat in school adolescents. A control group composed of 24 adolescents was included in the study.
   Coordinators: Palma Chillón Garzón / Manuel Delgado Fernández
   Responsible for physical fitness assessment: Palma Chillón Garzón
   Involvement of the PhD candidate: Data collection, data analysis and writing of scientific papers, with special implication on physical fitness and anthropometry/body composition.
3. **The HELENA study** (2005-2008). The HELENA study (Healthy Lifestyle in Europe by Nutrition in Adolescence) is an EU-funded project conducted in 3000 adolescents from 10 different European cities. The HELENA study aims to provide a broad picture of the nutritional status and lifestyle of the European adolescents, including objectively measured PA and a range of health-related physical fitness tests.
   Web site available (in English): www.helenastudy.com
   Coordinator: Luis A Moreno
   Responsible for physical fitness assessment: Manuel J Castillo / Michael Sjöström
   Involvement of the PhD candidate: Coordination of the assessment of physical fitness in the Project, under the supervision of Manuel J Castillo and Michael Sjöström, as well as data analysis and writing of scientific papers.

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The HELENA study takes place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD-CT-2005-007034).

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The content of this thesis reflects only the authors' views, and the European Community is not liable for any use that may be made of the information contained therein.

Lista de Publicaciones [List of Publications]

The present PhD Thesis is composed of the following scientific papers:

I. Ortega FB, Chillón P, Ruiz JR, Delgado M, Moreno LA, Castillo MJ, Gutiérrez A. Un programa de intervención nutricional y actividad física de seis meses produce efectos positivos sobre la composición corporal de adolescentes escolarizados. **Rev Esp Pediatr**. 2004;60(4):283-90.

II. Ortega FB, Ruiz JR, Castillo MJ, Moreno LA, González-Gross M, Warnberg J, Gutiérrez A. Bajo nivel de forma física en los adolescentes españoles. Importancia para la salud cardiovascular futura (Estudio AVENA). **Rev Esp Cardiol**. 2005;58(8):898-909. ***Note***: *Published both in Spanish and in English.*

III. Ortega FB, Ruiz JR, Castillo MJ, Moreno LA, Urzanqui A, González-Gross M, Sjöström M, Gutiérrez A. Health-related physical fitness according to chronological and biological age in adolescents. The AVENA study. **J Sports Med Phys Fitness**. *in press.*

IV. Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Martín-Matillas M, Mesa JL, Wärnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo MJ. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. **Obesity (Silver Spring)**. 2007;15(6):1589-99.

V. Ortega FB, Labayen I, Ruiz JR, Martín-Matillas M, Vicente-Rodríguez G, Redondo C, Wärnberg J, Gutiérrez A, Sjöström M, Castillo MJ, Moreno LA. Are muscular and cardiovascular fitness partially programmed at birth? Role of body composition. *submitted*.

VI. Ortega FB, Ruiz JR, Labayen I, Redondo C, Breidenassel C, Moreno LA, Castillo MJ. Physical fitness modify the associations between birth weight and adolescent body composition. *submitted*.

VII. Ruiz JR, Ortega FB, Gutiérrez A, Meusel D, Sjöström M, Castillo MJ. Health-related fitness assessment in childhood and adolescence; A European approach based on the AVENA, EYHS and HELENA studies. **J Public Health**. 2006;14(5):269-77.

VIII. Ortega FB, Artero EG, Ruiz JR, Vicente-Rodríguez G, Bergman P, Hagströmer M, Ottevaere C, Nagy E, Konsta O, Rey P, Polito A, Dietrich S, Plada M, Beghin L, Manios Y, Sjöström M, Castillo MJ. Reliability of health-related physical fitness tests in European adolescents. The HELENA study. *Revised version submitted to* **Int J Obes (Lond).**

IX. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. **Int J Obes (Lond)**. 2008;32(1):1-11.

Resumen

En personas adultas, la evidencia científica muestra de manera inequívoca que el nivel de condición física es un potente predictor de morbilidad y mortalidad tanto por enfermedad cardiovascular como por todas las causas, y ello tanto en hombres como en mujeres independientemente de que estuvieran o no sanos. El nivel de condición física tiene un componente genético y otro ligado al estilo de vida. Dado que este último se condiciona en gran medida durante la juventud, se plantea la hipótesis de que el nivel de condición física es ya en edades tempranas un importante determinante de salud con repercusión en la vida adulta. En base a ello, el objetivo de la presente tesis doctoral ha sido profundizar en el estudio de la condición física en una época de la vida importante y poco estudiada como es la adolescencia, caracterizando la relación existente entre los niveles de condición física y el nivel de maduración biológica, adiposidad y factores de programación que puedan ocurrir a nivel prenatal/neonatal. Igualmente, se pretende estudiar importantes aspectos metodológicos relacionados con la evaluación de la condición física, y todo ello tanto en adolescentes españoles como de otros países europeos.

La presente memoria de tesis está basada principalmente en datos procedentes del estudio AVENA (www.estudioavena.com). El estudio AVENA es un estudio trasversal multi-céntrico llevado a cabo en cerca de 3000 adolescentes, con la finalidad de obtener un mayor conocimiento acerca del actual estado de salud de los adolescentes españoles. Además, se presentan datos de un estudio de intervención educativa realizado en España (Granada) y de un estudio financiado por la Comisión Europea, el estudio HELENA (www.helenastudy.com).

Los principales hallazgos y conclusiones que se desprenden de los nueve artículos científicos incluidos en esta tesis son: I) Un programa educativo de intervención nutricional y de actividad física de 6 meses en adolescentes, tuvo un claro efecto positivo sobre la composición corporal, reduciendo la grasa corporal en los niños y evitando su aumento en las niñas. II) Los valores de referencia para la condición física mostrados en la presente tesis permiten evaluar e interpretar correctamente el nivel de condición física del adolescente tanto en términos individuales como poblacionales. III) El nivel de condición física se afecta de manera diferente según se valore en base a la edad cronológica o en base a la edad biológica del sujeto. Estas diferencias parecen ser mayores para la capacidad cardiorespiratoria que para la fuerza muscular. IV) Niveles moderados/altos de capacidad cardiorespiratoria y una baja tasa de actividades sedentarias, pero no la práctica de actividad físico-deportiva, se asocian con un menor nivel de grasa abdominal (perímetro de cintura). V) Un peso al nacer elevado se asocia con una mayor fuerza de prensión manual en adolescentes, especialmente en las niñas, aunque dicha asociación parece estar explicada por el propio nivel de masa libre de grasa del individuo. El peso al nacer no se asoció con la capacidad cardiorespiratoria. VI) El efecto "programming" del peso al nacer sobre la masa libre de grasa en niñas y sobre la grasa total y central en niños, parece ser dependiente del género, estado de sobrepeso y nivel de condición física. VII) Los tests de condición física incluidos en el estudio HELENA ofrecen una información relevante acerca del estado de salud en personas jóvenes, y se muestran viables y objetivos. VIII) Cuando la evaluación de la condición física es repetida en dos ocasiones, no parece existir ningún "efecto de aprendizaje" ni de "fatiga". Los resultados sugieren que la fiabilidad de la batería de tests de condición física incluida en el estudio HELENA es aceptable. IX) La evidencia científica muestra que la condición física es un potente indicador del estado de salud también en personas jóvenes. Las políticas de promoción de la salud y programas de actividad física deberían estar centradas no sólo en la mejora de la capacidad cardiorespiratoria, sino también en la mejora de la fuerza muscular y la velocidad-agilidad.

Las instituciones educativas pueden desempeñar un rol importante, identificando adolescentes con un bajo nivel de condición física y promoviendo estilos de vida saludables, tales como el incremento de la actividad física dentro y fuera del programa educativo, y la mejora de la condición física.

Summary

In adults, there is strong evidence indicating that physical fitness is a powerful predictor of cardiovascular disease and all-cause morbidity and mortality, both men and women, asymptomatic or with cardiovascular disease. Based on this evidence, it is reasonable to hypothesise that the physical fitness level is an important marker of health already at early phases of the life. In this context, the overall aim of this thesis was to increase the current knowledge on physical fitness in the adolescence, and its relationships with maturation, adiposity and early determinants. Additionally, important methodological issues on physical fitness assessment were investigated in adolescent population from Spain and from other European countries.

The current PhD thesis is mainly based on data from the AVENA study (www.estudioavena.com). The AVENA study is a multi-centre cross-sectional study carried out, on nearly 3000 Spanish adolescents, for a better understanding of the current situation of the Spanish adolescents' health status. The thesis also includes data from a Spanish school-based intervention study and from the HELENA study, an EU-funded study (www.helenastudy.com).

The main findings and conclusions derived from the nine scientific papers included in this thesis were: I) A 6-month school-based intervention program focused on nutritional and physical activity had a positive effect on body composition in adolescents, reducing body fat in boys and avoiding body fat increases in girls. II) The reference values for physical fitness in adolescents depicted in this thesis enable better assessment and interpretation of the physical fitness level, both in an individual and a population level. III) Discrepancies between biological and chronological age determinants on several health-related physical fitness components might be greater for cardiorespiratory fitness than for muscular fitness. IV) Both moderate to high levels of cardiorespiratory fitness and low levels of sedentary activities, but not self-reported physical-sporting activity, seem to be associated with lower abdominal adiposity, as measured by waist circumference. V) High birth weight seems to be associated with higher handgrip strength in adolescents, especially in females, yet these associations are highly explained by current fat free mass. Body weight at birth was not associated with cardiorespiratory fitness. VI) The programming effect of birth weight on fat free mass in females, and on total and central adiposity in males, is dependent on gender, weight status and physical fitness level. VII) The fitness tests included in the HELENA study seem to provide relevant information regarding the health status of the young people and are feasible and objective. VIII) When repeated, neither a "learning" nor a "fatigue effect" was found for any of the physical fitness tests. The results suggest that the reliability of the set of physical fitness tests included in the HELENA study is acceptable. IX) There is evidence indicating that physical fitness is an important maker of health in young people. Health promotion policies and physical activity programs should be designed to improve cardiorespiratory fitness, but also other physical fitness components such as muscular fitness and speed/agility.

School may play an important role by helping to identify adolescents with low physical fitness, and by promoting positive health behaviours, such as encouraging children to be active, and improving their fitness levels by means of physical education curriculum adaptations and/or after-school organised activities.

Abreviaturas [Abbreviations]

ANCOVA	Analysis of the covariance
ANOVA	Analysis of the variance
AVENA	Alimentación y Valoración del Estado Nutricional de los Adolescentes / Feeding and assessment of nutritional status of Spanish adolescents
BMI	Body mass index
CRF	Cardiorespiratory fitness
CVD	Cardiovascular disease
DEXA	Dual-energy X-ray absorptiometry
EYHS	European Youth Heart Study
HDL	High density lipoproteins
HELENA	HEalthy Lifestyle in Europe by Nutrition in Adolescence
IOTF	International Obesity Task Force
LDL	Low density lipoproteins
METs	Metabolic equivalents
PA	Physical activity
PAI	Physical activity index
TV	Television
SD	Standard deviation
VO_{2max}	Maximal oxygen consumption

Abreviations in Spanish

DT	Desviación típica
ESO	Enseñanza Secundaria Obligatoria
GC	Grupo control
GE	Grupo experimental
IMC	Índice de masa corporal

INTRODUCCIÓN [INTRODUCTION]

Paediatric obesity is a major public health concern, especially in the western countries. Data from the International Obesity Task-Force (IOTF) revealed that the prevalence of childhood overweight/obesity in Spain achieved the 2nd position in the European ranking for overweight/obesity.[1, 2] In the light of this alarming information, the Spanish Ministry of Health funded the AVENA study (Alimentación y Valoración del Estado Nutricional de los Adolescentes Españoles / Feeding and assessment of the nutritional status of Spanish adolescents), for a better understanding of the current situation of the Spanish adolescents' health status, with special focus on nutrition, eating disorders and obesity.

The AVENA study is a multi-centre cross-sectional study carried out on nearly 3000 Spanish adolescents from Madrid, Murcia, Zaragoza, Santander and Granada in 2000-2002.[3, 4] Many health parameters, such as immunology, lipid profile, haematology, genetics, anthropometry and body composition, physical activity and physical fitness were studied in addition to nutrition and dietary factors.

The AVENA study group has reported the prevalences for overweight and obesity in Spanish adolescents,[5] as well as reference data for total and body fat distribution anthropometrics.[6, 7] The data suggest a substantial increase in the prevalences of total and central overweight/obesity in Spanish adolescents in the last years,[5, 8] calling for achievable and successful programs focusing on total and central obesity prevention. For these purposes, the study of modifiable factors, such as physical fitness and physical activity/inactivity, that could be associated with adiposity, will be crucial. Consequently, the present thesis has been mainly focused on the study of physical fitness. Additionally, a second thesis[9] carried out in Swedish children and adolescents from the European Youth Heart Study (EYHS),[10-12] has been focused on physical activity and its associations with adiposity.

Simultaneously to the AVENA study, the AVENA-Granada study group carried out a school-based intervention study in adolescents, focusing on nutrition and physical activity, and their effects on body composition.[13] The most relevant results derived from this investigation are shown in **Paper I**.[14]

Physical fitness and related concepts

Physical fitness, physical exercise and physical activity are related but not interchangeable concepts.[15, 16] *Physical fitness* is a set of attributes related to a person's ability to perform physical activities that require aerobic fitness, endurance, strength or flexibility and is determined by a combination of regular activity and genetically inherited ability.[17] *Physical activity* is defined as any bodily movement produced by skeletal muscles that results in energy expenditure.[17] This broad term means that physical activity includes almost everything that a person does. *Inactivity* is, by contrast, the time spent in behaviours that do not markedly increase energy expenditure. Another related but not interchangeable term is *physical exercise*, defined as a subset of physical activity that is planned, structured and systematic.[17]

Among the health-related physical fitness components, cardiorespiratory fitness is the one that has been studied the most. *Cardiorespiratory fitness* reflects the overall capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged exercise.[18] Many terms have been used to define this physical fitness component: cardiovascular fitness, cardiorespiratory fitness, cardiorespiratory endurance, aerobic fitness, aerobic capacity, aerobic power, maximal aerobic power, aerobic work capacity, and physical work capacity. All refer to the same concept and are used interchangeably in the literature.[19] Another important related concept is maximal oxygen consumption, or VO_{2max}. The VO_{2max} attained during a graded maximal exercise is an objective measure of cardiorespiratory fitness level.[18] Although different ways have been used to express VO_{2max}, the most common way is as the volume of oxygen consumed per unit of time relative to body mass (ml/min/kg of body mass). However, researchers aiming to compare cardiorespiratory fitness level between groups of young people should consider the way in which the VO_{2max} is expressed (i.e. ml/min/kg of body mass or ml/min/kg of fat free mass or l/min), since it can influence the results and interpretation, leading to misleading conclusions.[20]

Other key health-related physical fitness components in adolescence are: muscular fitness, speed and agility. *Muscular fitness* is the capacity to carry out work against a resistance. Since the maximum force that can be generated depends on several factors (e.g. the size and number of muscles involved, the proportion of muscle fibres called into action, the coordination of the muscle groups, etc.) there is no single test for measuring muscle strength. The main muscular fitness components are: maximal strength (isometric and dynamic), explosive strength, endurance strength and isokinetic strength. *Speed* refers to the ability to perform a movement within a short period of time, and *agility* is the ability to rapidly change the position of the entire body in space with speed and accuracy.[17]

Physical fitness in Spanish adolescents

In adults, there is strong evidence indicating that physical fitness is a powerful predictor of cardiovascular disease and all-cause morbidity and mortality.[21-25] This seems to be valid in apparently healthy individuals, and also in people with diseases, such as diabetes mellitus, hypertension, metabolic syndrome and several types of cancer.[26] This association is also independent of the adiposity.[27] Based on this evidence, the study of physical fitness level in young populations has been of increasing interest in the last years. Our group has reported, for the first time in Spain, the physical fitness level of the Spanish adolescents (**Paper II**).[28] Likewise, a comprehensive investigation has been carried out to examine how physical fitness differ by chronological and biological age, when accounting for relevant confounders such as percentage body fat, fat free mass or physical activity (**Paper III**).[29]

Physical fitness and adiposity

As mentioned above, childhood obesity is a major public health concern.[1] According to the World Health Organization, overweight and obesity are defined as an abnormal or excessive fat accumulation that presents a risk to health (available at: http://www.who.int/topics/obesity/en/). However, it is not only the total amount of fat

that is associated with poor health status, but also the distribution of that fat in the body.[30] Central or abdominal body fatness is associated with cardiovascular disease risk factors including dyslipidemia, insulin resistance and hypertension in adults, as well as coronary heart disease morbidity and mortality.[31-33] Most disturbances related to obesity have been established as having their onset during childhood.[34] Physical activity and physical fitness enhancement could contribute to overweight and obesity prevention.
Waist circumference has shown to be an accurate marker of abdominal fat accumulation[35] and visceral adiposity[36] in young people. In addition, waist circumference seems to explain the variance in a range of cardiovascular disease risk factors to a similar extent as measures derived from high-technology techniques, including dual energy x-ray absorciometry (DEXA) and Magnetic Resonance Imaging.[30] Therefore, the use of waist circumference as a surrogate of abdominal adiposity, and as a powerful index associated with metabolic risk in young people, seems to be appropriate for epidemiological studies.

Klein-Platat et al., reported an inverse association between self-reported physical activity and waist circumference in French adolescents.[37] We studied the associations of self-reported physical-sporting activity, sedentary activities and cardiorespiratory fitness with waist circumference in the Spanish adolescents from the AVENA study. The main findings derived from this investigation are shown in **Paper IV**.[38]

Recently, the association between objectively measured physical activity (using accelerometry) and abdominal adiposity has been examined in young people, showing contradictory results.[39-42] Consistent associations have been shown between low levels of cardiorespiratory fitness and high abdominal adiposity in young people.[38, 41-47]

Early determinants of physical fitness

It has been suggested that the genetic contribution to cardiorespiratory fitness and muscular fitness, as assessed by heritability studies, may be up to 40-65%,[48, 49] but this still leaves scope for the influence of lifestyle factors. A major lifestyle correlate of physical fitness is current physical exercise and physical training.[50, 51] The results from intervention studies and randomised controlled trials are consistent in this regard. Different types of physical exercise programs (including or excluding diet intervention) are successful in improving cardiorespiratory fitness, as well as muscular fitness and speed/agility, in children and adolescents.[52-59]

The child or adolescent's health status can also be partially influenced by early determinants. Intra-uterine under- or over-nutrition can alter the gene expression of the foetus, causing developmental adaptations that may lead to permanent changes in physiology and metabolism; changes that may have consequences later in life.[60, 61] Birth weight is an established index of the intra-uterine conditions, and it has shown a programming effect on later body size and body composition.[61, 62] However, less is known about the associations between birth weight and physical fitness later in life. We have recently studied the relationship of birth weight with both handgrip strength and cardiorespiratory fitness in adolescents born at term from the AVENA study, examining how these associations are influenced by body size and body composition (**Paper V**).[63] As far as we are aware, no previous data based on large-scale studies have examined the associations between birth weight and handgrip strength, accounting for body size and body composition parameters in young people born at term. Likewise, only one large-scale study has previously examined early life origins of adolescent cardiorespiratory fitness in Irish males and females born at term.[64]

In recent years, the programming effect of birth weight on body composition at childhood and adolescence has been of increasing interest.[62, 65, 66] We have previously shown that this programming effect may be affected by gender.[67] Body weight at birth is associated with fat free mass in female adolescents, while is more associated to both total and abdominal adiposity in male adolescents.[67] Whether physical fitness level is a factor modifying the programming of adolescent body composition needs to be elucidated. We have examined whether handgrip strength or cardiorespiratory fitness modify the associations between birth weight and body composition in healthy female and male adolescents. The findings of this investigation are shown in **Paper VI**.[68]

Physical fitness assessment in adolescence

In children and adolescents, physical fitness is inversely associated with physiologic risk factors for chronic disease including high blood pressure,[69, 70] hyperinsulinemia,[71] total fatness[72] and abdominal adiposity,[38, 43] an atherogenic lipid profile,[73] insulin resistance, inflammatory markers,[74] and clustering of metabolic risk factors.[75, 76] Due to the evidence-based importance of physical fitness for young people's health status, attention should be paid to the assessment of physical fitness at these ages.

The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study[77, 78] includes a thorough assessment of health-related physical fitness in a sample of 3000 adolescents from nine different European countries. For this purpose, a set of standardised tests has been chosen (most of them included in the AVENA study), and the scientific rationale for the selected tests has been described in **Paper VII**.[19] When reviewing the available information on physical fitness testing, we have noticed that the literature on reliability of physical fitness assessment in healthy children or adolescents was rather scarce, and the statistical approaches used for analysing reliability were often not appropriate.

Reliability can be defined as the consistency of measurements. Terms that have been used inter-changeably with reliability in the literature, are "repeatability", "reproducibility", "consistency", "agreement", "concordance" and "stability". Another related, but different concept, is validity.[79-81] Several statistical methods have been used to evaluate certain aspects of reliability. The study of the agreement between two measurements by means of the Bland-Altman approach seems a proper and useful method for reliability analyses.[79-81]

The outcome of the reliability testing, on a test-retest basis, of the set of health-related physical fitness tests used on the HELENA study, has been described in **Paper VIII**.[82] The outcome was also discussed and compared with the outcome of an extensive overview of published data on reliability testing.

Fitness and health in young people: state of the art

A substantial number of reviews has been published on physical activity and health in young people, [83-88] while a rather smaller number has been focused on the study of physical fitness and its relations to health outcomes.[87]

As mentioned above, the associations between physical fitness and abdominal adiposity in young people have been recently examined.[38, 41-47] In addition, an increasing amount of research on physical fitness and other health outcomes, including traditional and emerging risk factors for cardiovascular disease, skeletal and mental health in young people has also been published in the last years. In this regard, **Paper IX** has summarised the latest developments in regard to physical fitness and several health outcomes in young people, providing an overall picture about the relevance of physical fitness for health status in early stages of life.[89]

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OBJETIVOS

El objetivo general de esta tesis ha sido profundizar en el estudio de la condición física en una época de la vida importante y poco estudiada como es la adolescencia, analizando la relación existente entre los niveles de condición física en sujetos sanos y el nivel de maduración biológica, adiposidad y factores de programación tempranos que puedan ocurrir a nivel prenatal/neonatal. Igualmente, se pretende caracterizar importantes aspectos metodológicos relacionados con la evaluación y valoración de la condición física, y todo ello tanto en adolescentes españoles como de otros países europeos.

Los objetivos específicos abordados en esta tesis fueron:

I. Evaluar los efectos de un programa educativo de intervención nutricional y de actividad física sobre el porcentaje graso y distribución de grasa corporal en adolescentes escolarizados.

II. Caracterizar el nivel de condición física de los adolescentes españoles y establecer valores de referencia, así como determinar la proporción de adolescentes españoles que no alcanzan valores de capacidad aeróbica indicativos de buena salud cardiovascular futura.

III. Examinar cómo el nivel de condición física varía cuando se valora en base a la edad cronológica o biológica (estado madurativo) en adolescentes españoles.

IV. Estudiar si la actividad física, las actividades sedentarias y/o la capacidad cardiorespiratoria están relacionadas con el perímetro de cintura en adolescentes.

V. Determinar si el peso al nacer está asociado con la fuerza de prensión manual y/o la capacidad cardiorespiratoria en la adolescencia, y si estas asociaciones están influenciadas por el tamaño y la composición corporal.

VI. Examinar si la fuerza de prensión manual o la capacidad cardiovascular que se posee en la adolescencia modifica las asociaciones entre peso al nacer y composición corporal en adolescentes.

VII. Revisar y sintetizar la literatura previa para sugerir un conjunto de tests de condición física relacionados con la salud, que resulten de utilidad para futuros sistemas de información sanitaria.

VIII. Describir la fiabilidad de la batería de tests de condición física usada en el estudio HELENA, usando un diseño test-retest.

IX. Resumir los últimos avances científicos en condición física y su relación con diversos parámetros indicativos del estado de salud en personas jóvenes.

AIMS

The overall aim of this thesis was to increase the current knowledge on physical fitness in the adolescence, and its relationships with maturation, adiposity and early determinants. Additionally, important methodological issues on physical fitness assessment were investigated in adolescent population from Spain and from other European countries.

The specific objectives addressed in this thesis were:

I. To assess the effects of a nutritional and physical activity program on total and central body fat in school-age adolescents.

II. To assess the physical fitness status of Spanish adolescents and establish reference values, as well as to determine the percentage of Spanish adolescents below the minimum level of cardiorespiratory fitness associated with a good future cardiovascular health.

III. To examine several health-related physical fitness components according to chronological and biological age (sexual maturation status) in Spanish adolescents.

IV. To examine whether physical activity, sedentary activities and/or cardiorespiratory fitness are related to waist circumference in adolescents.

V. To determine whether birth weight is associated with handgrip strength and cardiorespiratory fitness in adolescence, and whether these associations are influenced by body size and body composition.

VI. To examine whether handgrip strength and/or cardiorespiratory fitness modify the associations between birth weight and body composition in adolescents.

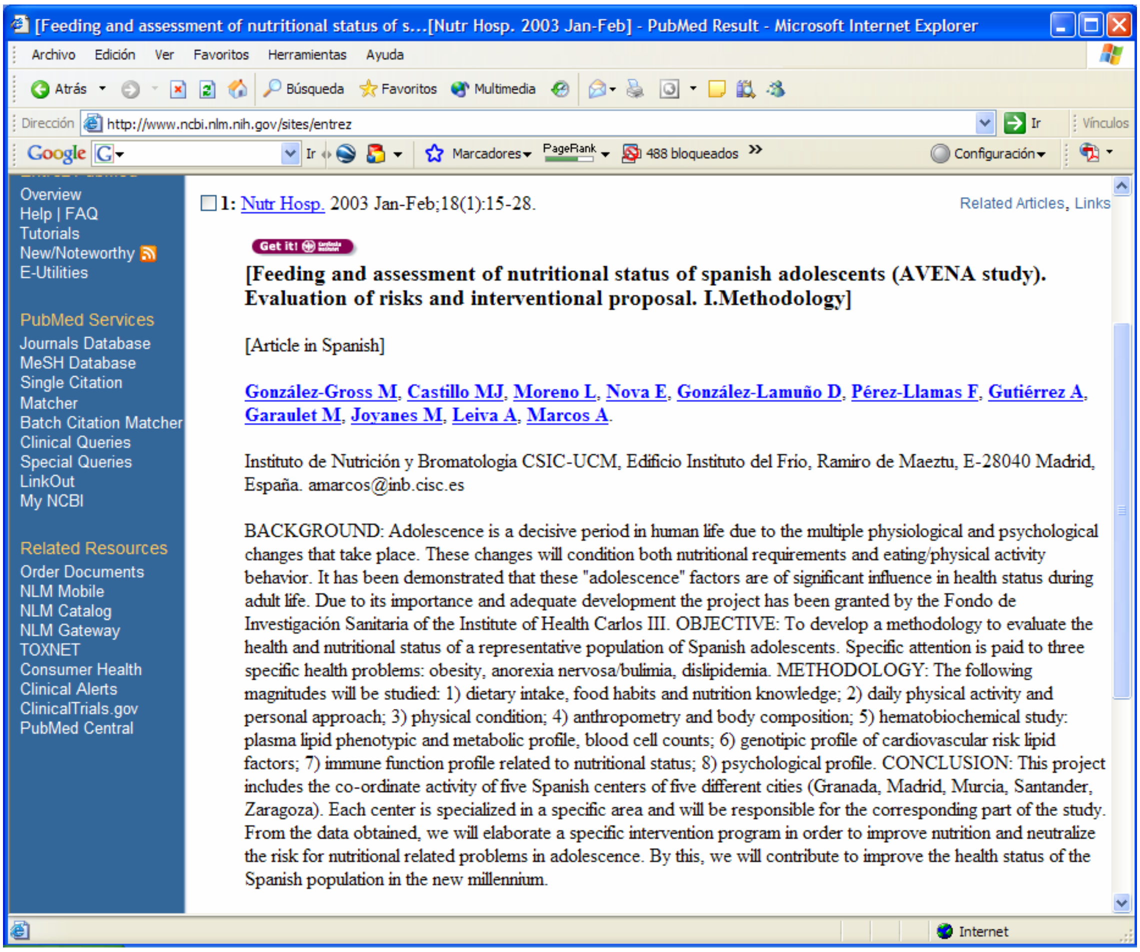
VII. To review and summarise previous results and experiences in order to suggest a set of health-related fitness tests for possible use in future health information systems.

VIII. To report the outcome of the reliability testing, on a test-retest basis, of the set of health-related physical fitness tests used on the HELENA study.

IX. To summarise the latest developments in regard to physical fitness and several health outcomes in young people.

MÉTODOS [METHODS]

The current thesis is mainly based on data from the AVENA study (Picture 1), yet data from other projects has also been used. The most relevant methodological information for papers I to IX has been summarised in Table 1.



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[Feeding and assessment of nutritional status of spanish adolescents (AVENA study). Evaluation of risks and interventional proposal. I.Methodology]

[Article in Spanish]

González-Gross M, Castillo MJ, Moreno L, Nova E, González-Lamuño D, Pérez-Llamas F, Gutiérrez A, Garaulet M, Joyanes M, Leiva A, Marcos A.

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BACKGROUND: Adolescence is a decisive period in human life due to the multiple physiological and psychological changes that take place. These changes will condition both nutritional requirements and eating/physical activity behavior. It has been demonstrated that these "adolescence" factors are of significant influence in health status during adult life. Due to its importance and adequate development the project has been granted by the Fondo de Investigación Sanitaria of the Institute of Health Carlos III. OBJECTIVE: To develop a methodology to evaluate the health and nutritional status of a representative population of Spanish adolescents. Specific attention is paid to three specific health problems: obesity, anorexia nervosa/bulimia, dislipidemia. METHODOLOGY: The following magnitudes will be studied: 1) dietary intake, food habits and nutrition knowledge; 2) daily physical activity and personal approach; 3) physical condition; 4) anthropometry and body composition; 5) hematobiochemical study: plasma lipid phenotypic and metabolic profile, blood cell counts; 6) genotipic profile of cardiovascular risk lipid factors; 7) immune function profile related to nutritional status; 8) psychological profile. CONCLUSION: This project includes the co-ordinate activity of five Spanish centers of five different cities (Granada, Madrid, Murcia, Santander, Zaragoza). Each center is specialized in a specific area and will be responsible for the corresponding part of the study. From the data obtained, we will elaborate a specific intervention program in order to improve nutrition and neutralize the risk for nutritional related problems in adolescence. By this, we will contribute to improve the health status of the Spanish population in the new millennium.

Picture 1. Summary of the AVENA study.

Table 1. Summary table of the methodology used in the current PhD thesis.

Project	**Papers**	**Study design**	**Subjects**	**Main studied variables**	**Methods**
Intervention	I. Un programa de intervención nutricional y actividad física de seis meses produce efectos positivos sobre la composición corporal de adolescentes escolarizados	Case-control	♂: 21 ♀: 25 Age: 14-16y	Dependent variables: BMI, WC, W:H ratio %BF, FFM	Anthropometric standard procedures. Scale with an incorporated stadiometer, inelastic tape, Holtain skinfold caliper
AVENA	II. Bajo nivel de forma física en los adolescentes españoles. Importancia para la salud cardiovascular futura (Estudio AVENA)	Cross-sectional	♂: 1357 ♀: 1502 Age: 13-18.5y	CRF, muscular fitness, speed-agility, flexibility	20m SRT, handgrip, standing broad jump, bent arm hang, 4x10m SRT, sit and reach
AVENA	III. Health-related physical fitness according to chronological and biological age in adolescents	Cross-sectional	♂: 1357 ♀: 1502 Age: 13-18.5y	CRF, muscular fitness, speed-agility, flexibility, %BF, FFM, PA, sexual maturation	20m SRT, handgrip, standing broad jump, bent arm hang, 4x10m SRT, sit and reach. Anthropometric standard procedures. Scale, Holtain skinfold caliper. PA questionnaire. Tanner stages
AVENA	IV. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents	Cross-sectional	♂: 1357 ♀: 1502 Age: 13-18.5y	CRF, PA, sedentarism, WC, height, BMI, sexual maturation	20m SRT. PA, TV viewing and video-game by questionnaire. Anthropometric standard procedures. Scale, inelastic tape. Tanner stages
AVENA	V. Are muscular and cardiovascular fitness partially programmed at birth? Role of body composition	Cross-sectional	♂: 818 ♀: 983 Age: 13-18.5y	Birth weight, age of gestation CRF, muscular fitness, height, BMI, WC, %BF, FFM, sexual maturation	Neonatal data from health records or reported by parents. 20m SRT, handgrip. Anthropometric standard procedures. Scale, inelastic tape. Tanner stages
AVENA	VI. Physical fitness modify the associations between birth weight and adolescent body composition	Cross-sectional	♂: 798 ♀: 942 Age: 13-18.5y	Birth weight, age of gestation, CRF, muscular fitness, height, BMI, WC, %BF, FFM, sexual maturation	Neonatal data from health records or reported by parents. 20m SRT, handgrip. Anthropometric standard procedures. Scale, inelastic tape. Tanner stages
-	VII. Health-related fitness assessment in childhood and adolescence; An European approach based on the AVENA, EYHS and HELENA studies	Review	Children / adolescents	CRF, muscular fitness, speed-agility, flexibility, several health outcomes	Bibliographic search based in PubMed and Medscape
HELENA	VIII. Reliability of health-related physical fitness tests in European adolescents	Cross-sectional	♂: 69 ♀: 54 Age: 12-14y	CRF, muscular fitness, speed-agility, flexibility	20m SRT, handgrip, standing broad jump, Bosco jumps (SJ, CMJ, ABA), bent arm hang, 4x10m SRT, back-saver sit and reach
-	IX. Physical fitness in childhood and adolescence: a powerful marker of health	Review	Children / adolescents	CRF, muscular fitness, speed-agility, several health outcomes	Bibliographic search based in PubMed, Medline and SportDiscus

AVENA, *Alimentación y Valoración del Estado Nutricional de los Adolescentes;* HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; EYHS, European Youth Heart Study; ♂, boys; ♀, girls; PA, physical activity; BMI, body mass index; WC, waist circumference; W:H ratio, waist to hip ratio; %BF, percentage body fat; FFM, fat free mass; CRF, cardiorespiratory fitness; SRT, shuttle run test; TV, television; SJ, squat jump; CMJ, counter movement jump; ABA, Abalakov jump.

RESULTADOS Y DISCUSIÓN [RESULTS AND DISCUSSION]

The results and discussion of the present thesis are shown as a compilation of scientific papers. They are enclosed in the form they have been published or submitted.

Paediatric obesity in Spain: an intervention study

(Paper I)

I

Un programa de intervención nutricional y actividad física de seis meses produce efectos positivos sobre la composición corporal de adolescentes escolarizados

Ortega FB, Chillón P, Ruiz JR, Delgado M, Moreno LA, Castillo MJ, Gutiérrez A

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Un programa de intervención nutricional y actividad física de seis meses produce efectos positivos sobre la composición corporal de adolescentes escolarizados*

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RESUMEN

Introducción. La prevalencia de obesidad y sobrepeso infantil está mostrando un importante aumento a nivel mundial, particularmente en los países desarrollados. Se precisan actuaciones educativas inmediatas para frenar esta situación.

Objetivo. Evaluar los efectos de un programa educativo de intervención nutricional y de actividad física sobre el porcentaje graso y distribución de grasa corporal en adolescentes escolarizados.

Método. Se aplicó durante 6 meses un programa de intervención nutricional y de actividad física sobre un grupo de 24 adolescentes (12 mujeres y 12 varones), grupo experimental (GE). El grupo control (GC) estuvo compuesto por 13 mujeres y 9 varones. Se evaluaron diversas variables antropométricas antes y después de la intervención: peso, talla, índice de masa corporal (IMC), % de masa libre de grasa, perímetro de cintura y ratio cintura/cadera.

Resultados. El % de masa grasa disminuyó significativamente en los niños del GE y aumentó en las niñas del GC tras la intervención. La *ratio* cintura/cadera disminuyó significativamente en los niños de ambos grupos y sólo en las niñas del GE. Se observó un incremento de la masa libre de grasa en los varones pertenecientes al GE.

Conclusiones. La aplicación de un programa educativo de intervención nutricional y de actividad física aplicado desde el área de educación física en un grupo de adolescentes durante seis meses parece haber tenido un efecto positivo sobre la composición corporal, disminuyendo el porcentaje graso en los niños y evitando su aumento en las niñas.

Palabras Clave: Adolescentes; Nutrición; Actividad física; Porcentaje graso; Distribución de grasa corporal.

ABSTRACT

Background. Prevalence of childhood obesity and overweight is increasing in developed countries. Interventions of different society institutions are required, being particularly relevant educational institutions.

Aim. To assess the effects of a nutritional and physical activity program on total and central body fat in school adolescents.

Method. 46 adolescents (14.17 ± 0.43 years old) participated in this study. An educative intervention has been applied in 24 adolescents (12 girls and 12 boys), experimental group (EG). The control group (CG) was composed by 22 subjects (13 girls and 9 boys). Weight, height, body mass index (BMI), percent body fatness, fat free mass waist circumference and waist-to-hip ratio were measured for this study.

Results. After intervention program, percent body fatness decreased in boys from EG and increased in girls from CG. Waist to hip ratio decreased in both groups in boys and only in girls from EG. An increasing in fat free mass was observed in boys from EG.

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Conclusions. Results obtained in this study suggests that a 6 month nutritional and physical activity program might have a positive effect in body composition in adolescents.

Key Words: Adolescents; Nutrition; Physical activity; Body fat percentage; Body fat distribution.

INTRODUCCIÓN

La prevalencia de obesidad en la infancia y adolescencia está mostrando un importante aumento en nuestro país[1-3], al igual que en otros países occidentales[4-8]. La obesidad está asociada a numerosos factores de riesgo para padecer enfermedad cardiovascular, como son: hiperlipidemia, hiperinsulinemia, hipertensión, diabetes mellitus y aterosclerosis[9-12].

Debido a su importancia para la salud, la composición corporal ha sido comúnmente evaluada en estudios epidemiológicos y clínicos. Para la determinación de la composición corporal se están utilizando diversas técnicas como DEXA *(dual-energy x-ray absorptiometry)*, resonancia magnética, etc. Sin embargo, la antropometría se ha convertido en el método más utilizado debido a que es portátil, no invasivo y barato. Además, ha mostrado ser un método preciso y útil en estudios de campo[13], tanto para la determinación de la cantidad de grasa total como para la distribución de la grasa corporal[14-15].

La distribución de la grasa corporal tiene una especial relevancia. Un excesivo acúmulo de masa grasa en las zonas centrales está asociada a enfermedades cardiovasculares tanto en adultos[10,16] como en niños y adolescentes[17-20].

Conscientes de la alarmante situación que presentan los adolescentes de nuestro país[3,21,22] y siguiendo la línea de acción marcada en otros países[6-19], parece necesaria la intervención desde diferentes ámbitos institucionales. En otros países, las instituciones educativas han adquirido un papel determinante en la prevención de la obesidad y la mejora de la salud cardiovascular de niños y adolescentes[23].

Aunque hay numerosos estudios científicos que evalúan los efectos de un programa de intervención nutricional sobre diferentes indicadores de salud[para revisión ver 24,25], desde nuestro conocimiento no se han analizado en profundidad los efectos combinados de un programa de intervención nutricional y actividad física sobre la cantidad de grasa total y la distribución de la grasa corporal en adolescentes. Por ello, el objetivo de este estudio fue evaluar los efectos de un programa educativo de intervención nutricional y de actividad física sobre la grasa corporal y distribución de la grasa en adolescentes escolarizados.

MÉTODO

Sujetos

Un total de 58 adolescentes escolarizados en un instituto de enseñanza secundaria obligatoria (ESO) de la provincia de Granada participaron en el estudio, previa autorización por escrito de sus padres o tutores. Los sujetos cursaban tercero de ESO (14,17 ± 0,43 años) y su desarrollo madurativo expresado en estadios de Tanner púbico fue de 4 (60%) y 5 (71,4%) para niñas y niños, respectivamente, y Tanner mamario de 4 (68%) en el caso de las niñas. Las características de los sujetos se presenta en la tabla 1.

Los cálculos estadísticos se realizaron con medias TRIMMED o muestras cortadas por las dos colas, eliminando del estudio los valores extremos y obteniéndose un tamaño de muestra final de 46 sujetos.

Diseño experimental

Se trata de un diseño cuasi-experimental intragrupo e intergrupo, en el cual se escogieron dos grupos naturales correspondientes a dos grupos de 3º de ESO. Por el tipo de diseño, existen limitaciones inherentes en cuanto a aleatoriedad y heterogeneidad inicial de la muestra, contextualizada en la realidad de un centro educativo en el que no existe control absoluto de estas variables. A un grupo se le aplicó un programa de intervención focalizado en la mejora de los hábitos nutricionales y fomento de la práctica físico-deportiva durante 6 meses, mediante programación transversal educativa en los contenidos de la asignatura de educación física. Este grupo constituyó el grupo experimental (GE) (n=24; 12 niños y 12 niñas). El grupo control (GC) (n=22; 9 varones y 13 mujeres) recibió clase con total normalidad.

Por lo tanto, se trata de un estudio longitudinal (pre – post) donde se evaluaron los efectos de un programa educativo de intervención nutricional y de actividad física sobre la composición corporal en dos grupos de adolescentes.

Intervención educativa sobre aspectos nutricionales y práctica de actividad físico-deportiva

El programa de intervención educativa fue desarrollado desde el área de educación física, y tuvo una duración total de 6 meses.

Los objetivos propuestos para el área nutricional fueron: a) consolidar hábitos alimenticios, relacionándolos con la práctica de actividad física saludable y con la vida cotidiana; b) desarrollar de forma autónoma los aprendizajes adquiridos sobre hábitos de alimentación, siendo el fin último de ambos objetivos la mejora de la salud de los adolescentes y crear las bases para un estilo de vida saludable en la edad adulta.

Para ello, algunas de las tareas específicas llevadas a cabo fueron:

– Sesión práctica de baloncesto basada en el juego, donde los equipos representaban los diferentes nutrientes básicos de los alimentos: proteínas, grasas e hidratos de carbono. Se resaltaban las consecuencias para la salud que tendría la "victoria" de unos u otros nutrientes en la dieta real.

– Organización del "desayuno andaluz" con motivo de la celebración del Día de Andalucía. El GE se ocupó de la organización y elaboración del desayuno andaluz. El desayuno andaluz contiene alimentos mediterráneos como aceite de oliva virgen, miel de caña, tomates *cherrys*, pan y leche.

– Realización de póster en colaboración con el Departamento de Plástica sobre contenidos alimenticios: dieta sana, nutrientes básicos, alimentos a evitar, etc.

– Control de la ingesta alimenticia en el desayuno y a media mañana (en el recreo) mediante una planilla semanal. Los alumnos recibían *feedback* mediante un informe semanal sobre sus hábitos alimentarios en el desayuno y media mañana orientando a la mejora de las conductas alimentarias. Este ciclo semanal se repitió sucesivamente durante el periodo de intervención.

Paralelamente, se controló la práctica de actividad físico-deportiva extraescolar del alumnado en la misma planilla semanal. Se reorientó de forma individualizada la práctica de actividad físico-deportiva fundamentando los beneficios sobre la salud e incentivando la participación física y activa del alumnado en las sesiones de educación física escolares y extraescolares.

Mediciones antropométricas y estimación de la composición corporal

Las mediciones antropométricas se llevaron a cabo por investigadores experimentados que han participado previamente en estudios poblacionales[26-27]. Para la evolución de los parámetros antropométricos se escogió aleatoriamente el hemicuerpo izquierdo siguiendo el protocolo más común para la población infantil en Europa[28].

Parámetros evaluados:

1. *Masa corporal* (báscula modelo Seca 714 con precisión de 100 g y un rango 0,1-130 kg).

2. La *talla* (tallímetro incorporado a la báscula modelo Seca 714, rango 60 – 200 cm).

3. Cuatro *pliegues cutáneos* (tricipital, bicipital, subescapular, suprailíaco) mediante un plicómetro de compás modelo Holtain con presión constante de 10 g/mm^2 de superficie de contacto (rango 0 – 40 mm).

4. Dos *perímetros corporales* (cintura y cadera) mediante una cinta métrica de material inextensible (rango 0-150 cm).

A partir de estas medidas antropométricas se calculó:

1. *Índice de masa corporal* (IMC, kg/m^2).

2. *Porcentaje graso*. Para estimación de la densidad corporal se utilizaron las fórmulas propuestas por Brook en 1971 para ambos sexos[29]. El porcentaje graso se halló mediante la ecuación descrita por Weststrate y Deurenberg's en 1989[30], que tiene en cuenta el factor edad.

$$\text{Niños - Densidad corporal} = 1{,}1690 - 0{,}0788 \times (\text{Log} \sum 4 \text{ pliegues}^{a})$$

$$\text{Niñas - Densidad corporal} = 1{,}2063 - 0{,}0999 \times (\text{Log} \sum 4 \text{ pliegues}^{a})$$

a = pliegue bicipital + pliegue tricipital + pliegue subescapular + pliegue suprailíaco

$$\text{Grasa corporal (\%)} = [562 - 4{,}2 \times (\text{Edad} - 2)] / \text{densidad} - [525 - 4{,}7 \times (\text{Edad} - 2)]$$

3. *Masa libre de grasa (kg)*. Se calcula a partir de la masa corporal y el porcentaje graso.

$$\text{Masa libre de grasa (kg)} = \text{peso total} - [(\text{\% grasa} \times \text{peso total}) / 100]$$

Para el análisis de la distribución de grasa corporal se utilizaron dos índices: a) el perímetro de cintura; b) la *ratio* cintura/cadera.

Análisis estadístico

Los cálculos estadísticos se realizaron con medias TRIMMED o muestras cortadas por las dos colas, eliminando del estudio los valores extremos. Se determinó la distribución de las variables, con el objetivo de aplicar en el análisis comparativo las pruebas oportunas. En aquellos casos en los que el test de normalidad aplicado (Shapiro-Wilk) determinó la no normalidad de la variable (nivel de significación $p \leq 0{,}1$), se utilizaron las pruebas no paramétricas de Wilcoxon para muestras apareadas (Mann-Whitney en SPSS), mientras que en los casos en que el test informó de que la variable procedía de una variable aleatoria normal se utilizó la prueba T-Student para muestras apareadas. Para el análisis inter-grupos, se siguió el mismo procedimiento pero con pruebas para muestras independientes. Para todo el análisis inferencial el error alfa se fijó en 0,05. Para el análisis de datos se utilizó el paquete estadístico SPSS v11,5 para Windows.

RESULTADOS

En la tabla 1 se presentan las características iniciales de los sujetos agrupados por géneros. Se observa cómo el porcentaje graso fue superior y la masa libre de grasa, inferior en las niñas que en los niños ($p \leq 0{,}001$ en ambos casos). No hubo diferencias en el perímetro de cintura entre ambos sexos.

Utilizando el Log Σ 4 pliegues como índice de estimación de la cantidad de masa grasa total, los datos obtenidos en el presente estudio mostraron un descenso importante del porcentaje de grasa corporal en los niños del GE

TABLA 1. Características antropométricas de niños y niñas previas a la intervención educativa sobre aspectos nutricionales y de actividad física.

	Niñas (N=25)	Niños (N=21)	P =
	Media (DT)	Media (DT)	
Edad (años)	14,20 (5,24)	14,14 (9,14)	NS
Tanner púbico (estadíos)	4 (60,0%)	5 (71,4%)	0,005*
Tanner mamario (estadíos)	4 (68%)	–	–
Peso (kg)	56,24 (5,24)	60,23 (9,14)	NS
Altura (m)	1,59 (0,63)	1,68 (0,94)	0,001**
IMC (kg/m²)	22,10 (2,20)	21,08 (2,28)	NS
% Grasa corporal	28,47 (4,66)	22,11 (5,44)	0,000**
Masa libre de grasa (kg)	40,25 (2,69)	46,66 (5,75)	0,000**
Ratio cintura / cadera	0,74 (0,05)	0,84 (0,05)	0,000**
Perímetro de cintura (cm)	70,21 (5,13)	72,52 (5,98)	NS

*DT = desviación típica; NS = No significativo (P > 0,05); *= Muy significativo (P ≤ 0,01); **= Altamente significativo (P ≤ 0,001).*

TABLA 2. Índices antropométricos de obesidad y distribución de grasa corporal, antes y después de la intervención en los niños.

	Grupo experimental (N=12)			Grupo control (N=9)		
Niños (N=21)	PreI	PostI	P=	PreI	PostI	P=
	Media (RI)	Media (RI)		Media (RI)	Media (RI)	
Peso (kg)	60,42 (18,68)	62,24 (18,30)	0,001**	60,00 (6,70)	60,74 (7,60)	NS
Altura (m)	1,67 (9,07)	1,70 (11,10)	0,000**	1,71 (9,60)	1,73 (10,00)	0,001**
IMC (kg/m²)	21,54 (4,97)	21,38 (4,24)	NS	20,47 (1,75)	20,21 (1,92)	NS
% Grasa corporal	24,57 (8,91)	(7,83)	0,000**	18,84 (7,74)	19,39 (8,55)	NS
Masa libre de grasa (kg)	45,28 (9,42)	48,31 (11,90)	0,000**	48,49 (5,96)	48,62 (7,93)	NS
Ratio cintura / cadera	0,86 (0,06)	0,79 (0,06)	0,006*	0,82 (0,04)	0,77 (0,03)	0,001**
Perímetro de cintura (cm)	73,33 (10,25)	74,33 (11,00)	NS	71,44 (10,00)	71,89 (6,00)	NS

*PreI= Pre-intervención; PostI= Post-intervención; RI= Rango Intercuartílico; NS= No significativo; (P > 0,05); *= Muy significativo (P ≤ 0,01); **= Altamentte significativo (P ≤ 0,001).*

y sin cambios significativos en el GC (Tabla 2). En el caso de las niñas, el porcentaje graso permaneció constante en el GE, pero se incrementó en el GC (Tabla 3).

Respecto a la distribución de la grasa corporal, no se observaron cambios significativos entre el GC y el GE en el perímetro de cintura para ambos sexos. La *ratio* cintura/cadera disminuyó en ambos grupos en el caso de los niños y sólo en el GE en el caso de las niñas (Tablas 2 y 3).

Tras la intervención educativa, los niños del GE mostraron un incremento de la masa libre de grasa (Tabla 2).

TABLA 3. Índices antropométricos de obesidad y distribución de grasa corporal, antes y después de la intervención en las niñas.

Niñas (N=25)	Grupo experimental (N=12) PreI Media (RI)	Grupo experimental (N=12) PostI Media (RI)	P=	Grupo control (N=13) PreI Media (RI)	Grupo control (N=13) PostI Media (RI)	P=
Peso (kg)	56,22 (8,70)	56,85 (7,45)	NS	56,25 (7,95)	58,12 (8,85)	0,013*
Altura (m)	1,60 (7,25)	1,61 (7,32)	0,000***	1,59 (9,30)	1,60 (9,40)	0,000***
IMC (kg/m^2)	21,95 (2,89)	21,82 (3,41)	NS	22,25 (2,16)	22,66 (1,77)	NS
% Grasa corporal	29,66 (10,30)	30,88 (9,32)	NS	27,28 (5,68)	29,82 (9,21)	0,001***
Masa libre de grasa (kg)	39,29 (3,48)	39,06 (3,87)	NS	41,20 (4,55)	41,07 (2,48)	NS
Ratio cintura / cadera	0,77 (0,07)	0,74 (0,05)	0,005**	0,72 (0,05)	0,73 (10)	NS
Perímetro de cintura (cm)	71,00 (8,50)	70,92 (10,25)	NS	69,42 (5,75)	71,92 (9,25)	NS

PreI= Pre-intervención; PostI= Post-intervención; RI= Rango Intercuartílico; NS= No significativo (P > 0,05);
= Significativo (P ≤ 0,05); **= Muy significativo (P ≤ 0,01); *= Altamentte significativo (P ≤ 0,001).*

DISCUSIÓN

En el estudio de la composición corporal a través de mediciones antropométricas, es de vital importancia la elección de los índices o parámetros adecuados en cada situación[31]. En este sentido, para la evaluación del sobrepeso y la obesidad, han sido propuestas diversas medidas e índices antropométricos, de entre las cuales el IMC ha sido el más utilizado. Los pliegues cutáneos tricipital, subescapular, suprailíaco y el Log Σ 4 pliegues (bicipital + tricipital + subescapular + suprailíaco), también han sido ampliamente citados en la literatura científica. Sarría y cols. (1998)[32] comprobaron la validez y fiabilidad de estas medidas antropométricas utilizando densitometría subacuática, y afirmaron que el Log Σ 4 pliegues parece ser uno de los índices antropométricos más precisos para la estimación del tejido adiposo total en la actualidad. Para todas las edades y especialmente en el periodo de la adolescencia, la sensibilidad y especificidad del Log Σ 4 pliegues superan la del IMC [2,32,33]. En el caso de la distribución de grasa corporal, concretamente la deposición de tejido graso en las áreas centrales, algunos de los índices utilizados son: perímetro de cintura, *ratio* cintura/cadera, *ratio* cintura/altura, *ratio* subescapular/tríceps, *ratio* (subescapular + suprailíaco)/tríceps. La *ratio* cintura/cadera ha sido el índice más común en la evaluación de la obesidad central, sin embargo, la mayoría de estudios recientes parecen estar de acuerdo en que el perímetro de cintura[34-40] es uno de los índices más precisos y fiables para evaluar la distribución de grasa corporal. Por todo ello, en el presente estudio se dedica especial atención a los resultados procedentes del porcentaje graso estimado a partir del Log Σ 4 pliegues para informar sobre la cantidad de grasa total y del perímetro de cintura para la cantidad de grasa central.

Cantidad de grasa total

Los resultados obtenidos en relación con la cantidad de grasa corporal total de las niñas tras la intervención educativa parecen indicar que, si bien no se consiguió una disminución significativa de la grasa en el GE, sí se evitó el aumento de grasa corporal que sufrió el GC. Similares resultados se obtuvieron en un estudio prospectivo llevado a cabo por McMurray y cols. (2002)[11], en el cual el grupo que no recibió un programa educativo nutricional y de práctica de actividad física aumentó su grasa corporal significativamente con respecto al grupo experimental. Hoelscher (2002)[24] realizó una revisión acerca de estudios sobre intervenciones nutricionales llevadas a cabo en contexto escolar y sus efectos sobre parámetros antropométricos. De todos los estudios revisados, sólo en uno se obtuvieron mejoras significativas en la composición corporal, manifestado en la reducción del índice de Rohrer[41]. En el resto hubo un mantenimiento del peso corporal tras la intervención. Por otro lado, si observamos la importante disminución del porcentaje graso ($p \leq 0,001$) producida en los adolescentes masculinos que participaron en el presente estudio, podemos afirmar que nos encontramos ante uno de los resultados más esperanzadores encontrados en la literatura. Sin embargo, es necesario albergar la posibilidad de que la ausencia de índices precisos y sensibles en la mayoría de los estudios, como el porcentaje graso estimado a partir del Log Σ 4 pliegues, sea la causa de otros resultados menos optimistas. Un ejemplo de ello serían los resultados obtenidos en el presente estudio. Si sólo se hubiera analizado el IMC, se habría concluido con que no existió ningún cambio saludable tras la intervención. Por otra parte, si el parámetro antropométrico de referencia hubiera sido el peso corporal, también hubiera llevado a error, ya que en el caso de los varones del GE, por ejemplo, el incremento de masa corporal experimentado se acompañó de un aumento en la masa libre de grasa y disminución del porcentaje graso, ambas cosas muy recomendables para la salud del adolescente.

Distribución de la grasa corporal

Se sabe que el perímetro de cintura aumenta en la infancia y la adolescencia debido, en parte, al desarrollo físico que se produce en estas edades[42]. Por ello, quizá sería arriesgado esperar una reducción de este parámetro tras una intervención de 6 meses. Plantear como objetivo orientado a la salud el mantenimiento de este índice, podría ser una decisión más razonable. Los resultados de este estudio no muestran cambios en el perímetro de cintura ni en los niños ni en las niñas de ambos grupos. Sin embargo, tanto en los niños de ambos grupos como en las niñas del GE, se observó una disminución de la ratio cintura / cadera tras la intervención, probablemente influenciada por el incremento significativo del perímetro de cadera ($p \leq 0,001$ niños de ambos grupos y $p \leq 0,05$ niñas de ambos grupos), que a su vez puede deberse al crecimiento óseo de la pelvis que se produce durante la pubertad en ambos sexos.

La gravedad real del problema recae en que aquellos adolescentes que muestren sobrepeso en las edades comprendidas entre 13 y 15 años, poseen un alto riesgo de sufrir sobrepeso u obesidad en la vida adulta[43]. Estudios longitudinales han establecido una asociación directa entre la cantidad de grasa corporal que se posee durante la infancia o adolescencia y la presentación de diversos factores de riesgo cardiovascular como hiperlipidemia, hipertensión e hipercolesterolemia en la edad adulta[44,45]

Son necesarios más estudios para verificar los efectos de un programa de intervención más prolongado sobre un número mayor de sujetos. Particular interés tendría examinar si el origen de los cambios antropométricos procede en parte de la modificación de hábitos alimentarios, del aumento de práctica de actividad físico-deportiva o de ambas simultáneamente, incentivados por el programa de intervención o, por el contrario, pueda deberse al propio desarrollo madurativo de los adolescentes.

CONCLUSIONES

De los datos obtenidos en el presente estudio, se puede concluir afirmando que un programa educativo de intervención nutricional y de actividad física aplicado desde el área de educación física en un grupo de adolescentes durante seis meses parece haber tenido un efecto positivo sobre la composición corporal, disminuyendo el porcentaje graso en los niños y evitando su aumento en las niñas. Sin embargo, dicha intervención no tuvo influencia sobre la grasa depositada en áreas centrales, según informan los índices utilizados en este estudio.

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Physical fitness in Spanish adolescents

(Papers II and III)

II

Bajo nivel de forma física en los adolescentes españoles. Importancia para la salud cardiovascular futura (Estudio AVENA)

Ortega FB, Ruiz JR, Castillo MJ, Moreno LA,
González-Gross M, Warnberg J, Gutiérrez A

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ARTÍCULOS ORIGINALES

EPIDEMIOLOGÍA Y PREVENCIÓN

Bajo nivel de forma física en los adolescentes españoles. Importancia para la salud cardiovascular futura (Estudio AVENA)

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Introducción y objetivos. En diversos estudios se ha mostrado la relación entre el nivel de forma física durante la infancia-adolescencia y el riesgo cardiovascular en la edad adulta. Dado que no se dispone de datos relativos al nivel de condición física de los adolescentes españoles, los objetivos de este estudio son: *a*) determinar el nivel de condición física de los adolescentes españoles y establecer valores de referencia que puedan ser utilizados en el medio sanitario y educativo como indicadores de salud cardiovascular, y *b*) conocer la proporción de adolescentes españoles que no alcanza valores de capacidad aeróbica indicativos de salud cardiovascular futura.

Sujetos y método. Se ha utilizado la batería EUROFIT modificada para evaluar la condición física de una muestra representativa de adolescentes españoles (n = 2.859; 1.357 varones y 1.502 mujeres) procedente del estudio AVENA (Alimentación y Valoración del Estado Nutricional de los Adolescentes).

Resultados. Se han obtenido los valores normativos de condición física de la población adolescente española. El rango del percentil 5 respecto a la capacidad aeróbica máxima (test de Course Navette) es de 2,0-3,3 y 1,4-1,9 *paliers* para varones y mujeres, respectivamente. Casi 1 de cada 5 adolescentes presenta riesgo cardiovascular futuro sobre la base de su capacidad aeróbica. Este subgrupo de adolescentes mostró también una peor forma física que el resto de adolescentes en todas las pruebas físicas realizadas.

Conclusiones. Los resultados obtenidos en el presente estudio permiten evaluar e interpretar correctamente el nivel de forma física de cualquier adolescente. Los resultados obtenidos indican la necesidad de mejorar el nivel de condición física de los adolescentes españoles.

Palabras clave: *Forma física. Adolescentes. Riesgo cardiovascular.*

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*En el anexo se relacionan los investigadores particpantes en el estudio AVENA.

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Low Level of Physical Fitness in Spanish Adolescents. Relevance for Future Cardiovascular Health (AVENA Study)

Introduction and objectives. Several studies have demonstrated that physical fitness in childhood and adolescence is related to cardiovascular risk in adulthood. Current data on the physical fitness of Spanish adolescents are not available. Therefore, the aims of this study were: *a*) to assess the physical fitness of Spanish adolescents and establish reference values for use in health and educational settings as indicators of cardiovascular health, and *b*) to determine the percentage of Spanish adolescents below the minimum level of aerobic fitness needed to guarantee future cardiovascular health.

Subjects and method. The modified EUROFIT battery of tests was used to assess physical fitness in a representative sample of Spanish adolescents (n=2859; 1357 boys and 1502 girls) taking part in the AVENA *(Alimentación y Valoración del Estado Nutricional de los Adolescentes)* study.

Results. Standard parameters for the physical condition of Spanish adolescents are reported in this study. The 5th percentile for maximum aerobic capacity (Course Navette test) ranged from 2.0-3.3 palier in boys and from 1.4-1.9 palier in girls. The findings indicate that, on the basis of aerobic fitness, approximately 20% of Spanish adolescents have an increased risk of future cardiovascular disease. This subgroup also performed poorly in all other tests of physical fitness used.

Conclusions. The results reported in this study enable the level of physical fitness in adolescents to be interpre-

ABREVIATURAS

VO_2máx: consumo máximo de oxígeno.

ted as an indicator of future cardiovascular health. They also indicate that the physical fitness of Spanish adolescents must be improved to help protect against cardiovascular disease in adulthood.

Key words: *Fitness. Adolescents. Cardiovascular risk.*

Full English text available at: www.revespcardiol.org

INTRODUCCIÓN

En recientes estudios se ha puesto de manifiesto que la capacidad aeróbica y la fuerza muscular son potentes predictores de morbilidad y mortalidad por causa cardiovascular y por todas las causas, tanto en varones[1-3] como en mujeres[2-5]. El papel de una baja forma física como factor de riesgo cardiovascular supera incluso al de otros factores bien establecidos, como la dislipidemia, la hipertensión o la obesidad[6].

Aunque las manifestaciones clínicas indicativas de enfermedad cardiovascular aterosclerótica suelen aparecer en la edad adulta, en la actualidad su inicio patogénico se establece en la infancia o la adolescencia[7,8] e incluso se han identificado factores de riesgo cardiovascular en estas edades[9-12]. Algunos de ellos pueden llegar a predecir la morbimortalidad futura, como es el caso del sobrepeso infantil[13]. El estudio de dichos factores durante la etapa crucial de la adolescencia resulta, por tanto, determinante para el diagnóstico y la prevención de las condiciones asociadas a la enfermedad cardiovascular en el adulto. En este sentido, en diversos estudios transversales se ha demostrado la relación entre el nivel de forma física y otros factores de riesgo cardiovascular durante la infancia y la adolescencia[14-16]. Del mismo modo, en importantes estudios longitudinales se ha constatado que el nivel de condición física que se posee en la vida adulta, así como la presencia de otros factores de riesgo cardiovascular convencionales (hipercolesterolemia, hipertensión, etc.), está condicionado por el nivel de forma física que se tiene en la infancia o la adolescencia[17-21]. En consecuencia, para valorar el riesgo cardiovascular futuro de la forma más precoz posible, dicha evaluación debe comenzar necesariamente en la infancia o la adolescencia. Por otro lado, para una correcta valoración del nivel de forma física bajo una perspectiva clínica es necesario disponer de valores de referencia actualizados de la población de estudio. El objeto del presente trabajo es precisamente establecer los valores de normativos de condición física de los adolescentes españoles.

SUJETOS Y MÉTODO

Sujetos y diseño experimental

El presente trabajo forma parte del Estudio AVENA (Alimentación y Valoración del Estado Nutricional en Adolescentes), cuya metodología completa ha sido publicada con anterioridad[22]. Se trata de un estudio multicéntrico realizado en adolescentes de entre 13 y 18,5 años de edad. Con objeto de abarcar la heterogeneidad de la población, el estudio se realizó tanto en centros públicos como privados de enseñanza secundaria o formación profesional.

El muestreo fue polietápico, aleatorizado y estratificado según la procedencia (Granada, Madrid, Santander, Zaragoza y Murcia), las condiciones socioeconómicas (según la localización del centro educativo, información aportada por las diferentes consejerías de educación autonómicas), el sexo y la edad. Se establecieron los siguientes criterios de exclusión: diagnóstico clínico de diabetes, embarazo, uso de alcohol o drogas y, en general, presencia de enfermedades no relacionadas directamente con la nutrición. La exclusión efectiva del estudio se aplicó *a posteriori,* sin conocimiento por parte de los alumnos, para evitar situaciones no deseadas.

Para la determinación del tamaño total de la muestra se tomó el parámetro de mayor varianza en la población, para lo que se utilizaron los datos publicados en la bibliografía cuando se planeó el estudio[23], es decir, el índice de masa corporal (IMC). El muestreo estuvo determinado por esta dispersión. El nivel de confianza es del 95% con un error ± 0,25. Se calculó un número de 2.100 sujetos para el estudio completo. El número total se distribuyó igualmente por ciudades y de manera proporcional por sexo y grupos de edad (13, 14, 15, 16 y 17-18,5 años). La muestra se sobredimensionó para prevenir pérdidas de información. Se ajustó finalmente con un factor de ponderación para equilibrar la muestra según la distribución de la población española y garantizar la representación real de cada uno de los grupos definidos por los dos factores mencionados (Fuente: Instituto Nacional de Estadística). Una vez eliminados los sujetos que no cumplían los criterios de inclusión en el estudio, el número final fue 2.859 (1.357 varones y 1.502 mujeres).

El estudio se llevó a cabo siguiendo las normas deontológicas reconocidas por la Declaración de Helsinki (revisión de Hong-Kong, septiembre de 1989) y de acuerdo con las recomendaciones de Buena Práctica Clínica de la CEE (documento 111/3976/88 de julio de 1990) y la normativa legal vigente española que regula la investigación clínica en humanos (Real Decreto 561/1993 sobre ensayos clínicos). El estudio ha sido

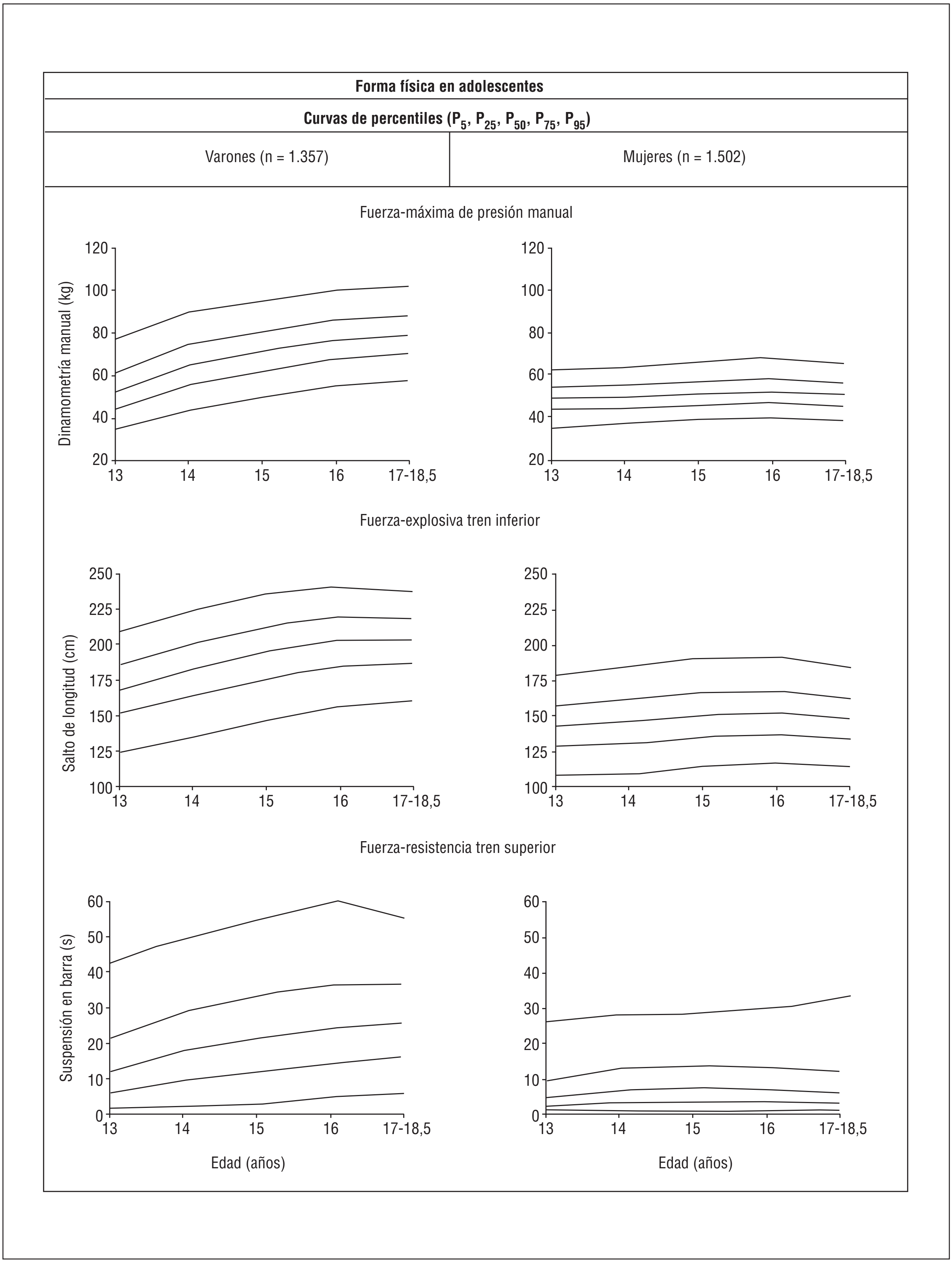

Fig. 1a. Curvas de percentiles (de abajo arriba: P_5, P_{25}, P_{50}, P_{75}, P_{95}) de 3 tests para evaluar diferentes manifestaciones de la fuerza muscular. El proceso de suavizado de percentiles se realizó mediante el método LMS.

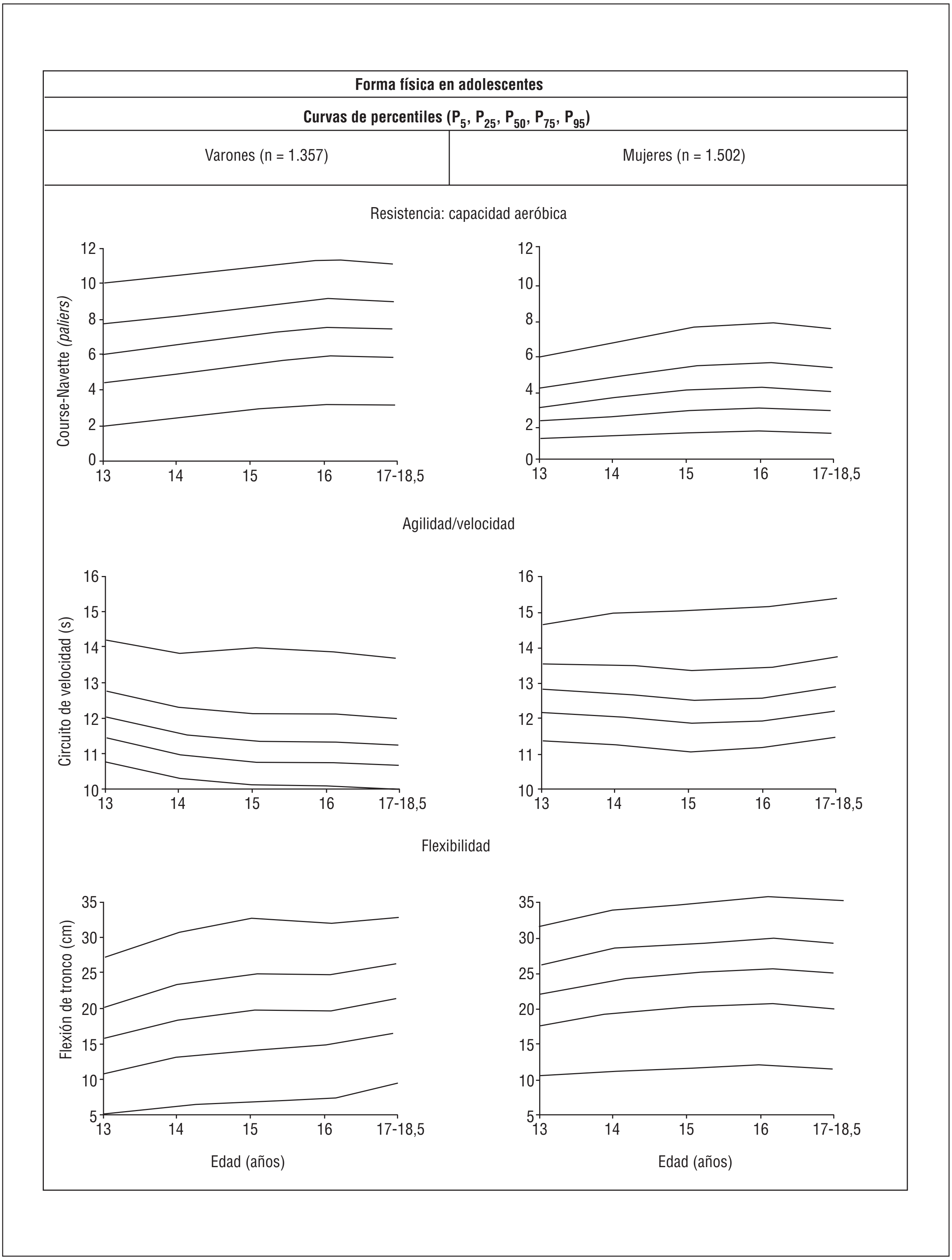

Fig. 1b. Curvas de percentiles (de abajo arriba: P_5, P_{25}, P_{50}, P_{75}, P_{95}) de 3 tests que evalúan diferentes cualidades físicas. El proceso de suavizado de percentiles se realizó mediante el método LMS.

sometido a valoración y ha obtenido la aprobación de los comités de ética del Consejo Superior de Investigaciones Científicas y del Hospital Universitario Marqués de Valdecilla (Santander, España).

Evaluación de la condición física

Antes del estudio se realizaron talleres de entrenamiento de los investigadores involucrados en el proyecto para la estandarización, validación y estudio de la fiabilidad de la medida[24]. Seis pruebas integradas dentro de la batería EUROFIT[25], validada y estandarizada por el Consejo de Europa, fueron aplicadas en el orden que se indica:

1. Flexión de tronco adelante en posición sedente. Con el sujeto sentado en el suelo y valiéndose de un soporte estandarizado[26] se determinó la máxima distancia alcanzada con la punta de los dedos mediante la flexión anterior del tronco. Test indicativo de la amplitud de movimiento o flexibilidad.

2. Dinamometría manual. Mediante el empleo de un dinamómetro digital Takei TKK 5101 (rango, 5-100 kg) se valoró la fuerza de prensión manual máxima en ambas manos.

3. Salto de longitud con pies juntos y sin impulso. Se registró la máxima distancia horizontal alcanzada. Esta prueba evalúa la fuerza explosiva de las extremidades inferiores.

4. Suspensión con flexión de brazos. Se utilizó un test estandarizado para valorar el máximo tiempo de suspensión en una barra fija. Esta prueba estima la fuerza-resistencia del tren superior.

5. Carrera de ida y vuelta: 4 × 10 m. Con esta prueba se evaluó de manera integrada la velocidad de desplazamiento y la coordinación. Para ello el sujeto hacía 4 carreras de ida y vuelta a la máxima velocidad posible entre 2 líneas separadas 10 m. En cada extremo depositaba y recogía un objeto (esponja) situado en el suelo y junto a la línea.

6. Test de Course-Navette. Esta prueba evalúa la capacidad aeróbica máxima a partir de un test de campo indirecto-incremental-máximo de ida y vuelta de 20 m[27], utilizando las ecuaciones propuestas por Léger et al[28] para estimar el consumo máximo de oxígeno (VO_2máx). La fiabilidad y validez de este test para predecir el VO_2máx en niños y adolescentes han sido suficientemente demostradas[28-30]. Para obtener de un modo fácil y rápido el VO_2máx a partir del resultado obtenido en el Course-Navette es suficiente con introducir la edad (E) y la velocidad final (V = 8 + 0,5 × último estadio completado) en la siguiente fórmula (r = 0,7; para niños/as-adolescentes de 8 a 19 años)[28]:

$$VO_2\text{máx} = 31{,}025 + 3{,}238V - 3{,}248E + 0{,}1536VE$$

Análisis estadístico

En las tablas de valores de referencia y curvas de percentiles se realizó un proceso de suavizado de los percentiles mediante la aplicación del método LMS (Latent Moderated Structural)[31], para el cual se utilizó el programa LMS versión 1.16 diseñado por Huiqi Pan (Institute of Child Health, 1998-2002). En una segunda fase del análisis, la muestra total fue dividida en: grupo con capacidad aeróbica indicativa de riesgo cardiovascular futuro y grupo formado por el resto de adolescentes. Para el análisis inferencial, destinado a detectar diferencias entre ambos grupos, se utilizó el test no paramétrico de Mann-Whitney, tras constatar previamente la no normalidad de las variables de estudio. Todo el análisis estadístico se desarrolló con el paquete estadístico SPSS v12.0.1 para Windows XP.

RESULTADOS

En las tablas 1-6 se muestran los valores de referencia de la condición física de los adolescentes españoles, clasificados por edad y sexo, y expresados en per-

TABLA 1. **Valores normales de la condición física de los adolescentes españoles. Dinamometría manual: suma de ambas manos (fuerza máxima de prensión manual)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Mujeres										
13 años	37,8	40,9	43,6	46,0	48,1	48,1	50,2	52,5	55,1	58,7
14 años	39,2	42,4	44,8	46,9	48,9	48,9	51,0	53,2	55,9	59,8
15 años	40,9	44,1	46,4	48,5	50,6	50,6	52,7	55,1	57,9	62,1
16 años	42,0	45,1	47,5	49,7	51,8	51,8	54,0	56,5	59,6	64,1
17-18,5 años	40,3	43,4	45,7	47,8	49,8	49,8	52,0	54,3	57,2	61,4
Varones										
13 años	37,7	42,2	45,8	49,0	52,2	52,2	55,5	59,2	63,9	70,8
14 años	47,7	53,2	57,3	60,9	64,4	64,4	68,0	71,9	76,7	83,5
15 años	54,3	59,8	64,0	67,6	71,0	71,0	74,5	78,3	82,8	89,1
16 años	59,7	65,4	69,6	73,2	76,6	76,6	80,1	83,9	88,4	94,7
17-18,5 años	61,8	67,5	71,6	75,3	78,7	78,7	82,1	85,9	90,3	96,5

El proceso de suavizado de percentiles se realizó mediante el método LMS.

TABLA 2. **Valores normales de la condición física de los adolescentes españoles. Suspensión con flexión de brazos (fuerza resistencia tren superior)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Mujeres										
13 años	1,3	2,0	2,6	3,4	4,4	4,4	5,7	7,5	10,5	17,1
14 años	1,7	2,8	4,0	5,2	6,7	6,7	8,5	10,9	14,5	21,0
15 años	1,7	2,9	4,2	5,6	7,1	7,1	9,0	11,5	15,0	21,1
16 años	1,8	2,8	3,9	5,2	6,6	6,6	8,4	10,9	14,6	21,7
17-18,5 años	1,5	2,3	3,2	4,2	5,5	5,5	7,1	9,5	13,4	21,8
Varones										
13 años	2,7	4,9	7,0	9,3	11,9	11,9	14,9	18,7	23,8	32,6
14 años	4,2	7,4	10,5	13,7	17,0	17,0	20,8	25,4	31,4	41,0
15 años	5,8	9,8	13,5	17,1	20,8	20,8	25,0	29,8	36,1	45,9
16 años	7,8	12,4	16,4	20,2	24,1	24,1	28,4	33,4	39,7	49,4
17-18,5 años	9,5	14,1	17,9	21,5	25,1	25,1	29,0	33,4	38,9	47,2

El proceso de suavizado de percentiles se realizó mediante el método LMS.

TABLA 3. **Valores normales de la condición física de los adolescentes españoles. Salto de longitud sin impulso (fuerza explosiva tren inferior)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Mujeres										
13 años	116,0	125,2	132,0	137,7	143,2	143,2	148,6	154,4	161,3	170,9
14 años	117,5	127,1	134,2	140,3	146,1	146,1	152,0	158,3	165,8	176,4
15 años	122,1	131,7	138,8	144,9	150,8	150,8	156,8	163,3	171,1	182,1
16 años	124,9	134,0	140,8	146,7	152,3	152,3	158,0	164,3	171,7	182,3
17-18,5 años	121,8	130,5	136,9	142,5	147,8	147,8	153,2	159,0	166,0	175,8
Varones										
13 años	134,3	146,6	155,2	162,4	168,9	168,9	175,3	182,1	189,8	200,3
14 años	146,3	159,3	168,3	175,8	182,6	182,6	189,2	196,2	204,2	215,0
15 años	158,3	171,6	180,7	188,2	195,0	195,0	201,7	208,6	216,5	227,2
16 años	168,0	180,7	189,4	196,5	202,9	202,9	209,2	215,6	223,0	232,9
17-18,5 años	171,2	182,9	190,9	197,5	203,4	203,4	209,1	215,0	221,8	230,8

El proceso de suavizado de percentiles se realizó mediante el método LMS.

TABLA 4. **Valores normales de la condición física de los adolescentes españoles. Carrera de ida y vuelta: 4 × 10 m (velocidad-agilidad)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Mujeres										
13 años	11,2	11,6	11,9	12,2	12,4	12,4	12,7	13,0	13,3	13,8
14 años	11,0	11,4	11,7	12,0	12,3	12,3	12,6	12,9	13,3	14,0
15 años	10,8	11,2	11,5	11,8	12,0	12,0	12,3	12,7	13,2	14,0
16 años	11,0	11,3	11,6	11,9	12,1	12,1	12,5	12,8	13,3	14,1
17-18,5 años	11,2	11,6	11,9	12,2	12,5	12,5	12,8	13,1	13,6	14,3
Varones										
13 años	10,4	10,8	11,0	11,3	11,5	11,5	11,8	12,1	12,5	13,2
14 años	10,0	10,3	10,6	10,8	11,1	11,1	11,4	11,7	12,1	12,8
15 años	9,8	10,1	10,3	10,6	10,8	10,8	11,1	11,4	11,9	12,6
16 años	9,7	10,0	10,3	10,6	10,8	10,8	11,1	11,4	11,9	12,7
17-18,5 años	9,7	10,0	10,3	10,5	10,8	10,8	11,1	11,4	11,9	12,7

El proceso de suavizado de percentiles se realizó mediante el método LMS.

centiles suavizados del 10 al 100. En la figura 1 a y b se observan las curvas de los percentiles (P_5, P_{25}, P_{50}, P_{75}, P_{95}), para ambos sexos y en función de la edad, de los diferentes tests de condición física. En ellas se aprecia claramente una mayor aptitud física por parte de los adolescentes varones, a excepción del test de

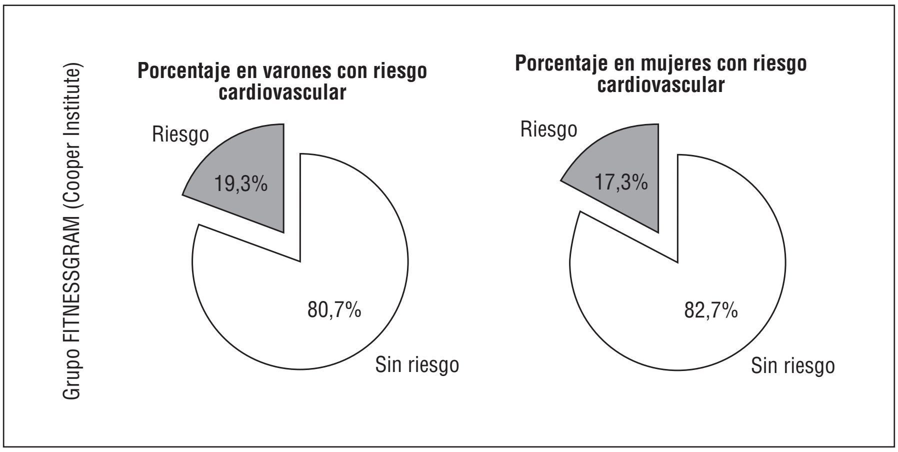

Fig. 2. Porcentajes de adolescentes con riesgo cardiovascular asociado a baja capacidad aeróbica, utilizando los puntos de corte propuestos en la bibliografía[32].
El umbral de riesgo cardiovascular para los adolescentes varones corresponde a un VO_2máx de 42 ml/kg/min y para las mujeres a un VO_2máx de 35 ml/kg/min de 14 años en adelante y de 38 ml/kg/min para las menores.

flexibilidad, en el que las mujeres mostraron un mejor rendimiento. De ambas figuras se desprende que, en general, entre los varones hay una mayor heterogeneidad que entre las mujeres en términos de aptitud física. Por otro lado, se aprecia una tendencia hacia un incremento del nivel de condición física en los varones conforme aumenta la edad, y hacia la estabilidad o un ligero aumento en el caso de las mujeres. En la figura 1b podemos observar que el rango del percentil 5 para los varones es de 2,0-3,3 y para las mujeres de 1,4-1,9, correspondiente al resultado alcanzado en el test de Course-Navette.

En la figura 2 se muestra el porcentaje de adolescentes españoles que posee riesgo cardiovascular futuro según su capacidad aeróbica actual, para lo que se utiliza el umbral de VO_2máx indicativo de salud cardiovascular propuesto por la bibliografía[32]. Como se aprecia, este porcentaje supera el 17%, tanto en varones como en mujeres. Si se analiza el rendimiento mostrado por este grupo de adolescentes en el resto de tests estudiados, se observa que el grupo de adolescentes cuya capacidad aeróbica es indicativa de riesgo cardiovascular futuro posee también un peor rendimiento en las demás cualidades físicas (fuerza, velocidad/agilidad y flexibilidad), con diferencias significativas en todos los tests utilizados ($p \leq 0,001$) excepto en la dinamometría manual en las mujeres y la flexibilidad en los varones ($p \geq 0,05$) (fig. 3).

DISCUSIÓN

Antes de la exposición y discusión de los hallazgos de este trabajo es interesante definir y diferenciar algunos términos relacionados pero distintos que, en ocasiones, son utilizados erróneamente como sinónimos en la bibliografía. Estos conceptos son: actividad física, ejercicio físico y condición o forma física. En primer lugar, podemos afirmar que *actividad física* es cualquier movimiento corporal producido por los músculos esqueléticos y que requiere un cierto gasto energético. El *ejercicio físico* estaría incluido en el concepto de actividad física, diferenciándose de ésta principalmente por la sistematización con la que se practica. El *ejercicio invisible* sería, a su vez, parte integrante del ejercicio físico, nuevo concepto que incluye todas las tareas que, con mayor o menor grado de intencionalidad, realiza el adulto diariamente (limpiar, cocinar, subir las escaleras, ir a los sitios andando, etc.) y de forma más o menos sistemática. Por último, la *forma física* o *condición física* es un concepto que engloba todas las cualidades físicas de una persona y se puede afirmar que el estado de forma física es una medida integrada de todas las funciones y estructuras que intervienen en la realización de un esfuerzo físico[33].

Valores de referencia

Conocer el nivel de condición física en la adolescencia de forma individualizada es importante para establecer el riesgo cardiovascular futuro de la persona[17-21]. Para que este dato pueda ser correctamente interpretado es preciso compararlo con los valores normativos de la población. En el presente trabajo se presentan los valores de referencia para la población adolescente española y se establecen los correspondientes percentiles estimados en función de la edad y el sexo. En términos poblacionales, poseer un nivel de condición física inferior al percentil 5 (fig. 1 a y b) es potencialmente patológico y sitúa al sujeto ante un certero riesgo cardiovascular futuro[20,21]. En este sentido, es necesario evaluar en estos sujetos la coexistencia de otros factores de riesgo cardiovascular. Con objeto de facilitar la calificación de, por ejemplo, de 1 a 10 puntos, se presentan también los percentiles 10 al 100 (tablas 1-6). Esto permite realizar una clasificación intuitiva del sujeto utilizando una escala tipo Likert: forma física muy mala ($X < P_{20}$), mala ($P_{20} \leq X < P_{40}$), media ($P_{40} \leq X < P_{60}$), buena ($P_{60} \leq X < P_{80}$) y muy buena ($X \geq P_{80}$). Esto tiene particular interés cuando la evaluación se realiza en los medios sanitario

TABLA 5. **Valores normativos de la condición física de los adolescentes españoles. Test de Course-Nowette (capacidad aeróbica máxima)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Mujeres										
13 años	1,5	1,9	2,3	2,6	3,0	3,0	3,3	3,8	4,3	5,1
14 años	1,7	2,3	2,7	3,1	3,5	3,5	3,9	4,4	5,0	6,0
15 años	2,0	2,6	3,1	3,6	4,0	4,0	4,5	5,0	5,7	6,7
16 años	2,1	2,7	3,2	3,7	4,2	4,2	4,7	5,2	5,9	6,9
17-18,5 años	2,0	2,5	3,0	3,5	3,9	3,9	4,4	4,9	5,5	6,5
Varones										
13 años	2,8	3,9	4,6	5,3	5,9	5,9	6,5	7,1	7,9	8,9
14 años	3,3	4,4	5,1	5,8	6,4	6,4	7,0	7,7	8,4	9,4
15 años	3,8	4,9	5,7	6,4	7,0	7,0	7,6	8,2	8,9	10,0
16 años	4,1	5,3	6,1	6,8	7,4	7,4	8,0	8,7	9,4	10,4
17-18,5 años	4,0	5,2	6,1	6,7	7,3	7,3	7,9	8,6	9,3	10,2

El proceso de suavizado de percentiles se realizó mediante el método LMS.

TABLA 6. **Valores normativos de la condición física de los adolescentes españoles. Flexión de tronco adelante en posición sedente (flexibilidad)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Mujeres										
13 años	13,4	16,4	18,5	20,3	21,8	21,8	23,4	25,0	26,9	29,5
14 años	14,6	18,1	20,4	22,3	24,0	24,0	25,7	27,4	29,3	31,9
15 años	15,2	18,8	21,2	23,2	24,9	24,9	26,6	28,3	30,3	32,9
16 años	15,6	19,4	21,9	23,9	25,7	25,7	27,4	29,2	31,2	33,9
17-18,5 años	14,9	18,6	21,0	23,0	24,7	24,7	26,4	28,2	30,2	32,9
Varones										
13 años	7,3	10,0	12,0	13,8	15,4	15,4	17,1	19,0	21,2	24,2
14 años	8,7	11,8	14,1	16,1	18,0	18,0	19,9	22,0	24,4	27,9
15 años	9,5	12,8	15,3	17,4	19,3	19,3	21,3	23,4	25,9	29,4
16 años	10,0	13,3	15,6	17,6	19,5	19,5	21,4	23,3	25,7	28,9
17-18,5 años	12,2	15,4	17,7	19,6	21,4	21,4	23,2	25,1	27,3	30,3

El proceso de suavizado de percentiles se realizó mediante el método LMS.

y académico, que son ejes esenciales para una detección precoz y una actuación inmediata. Cuando se lleva a cabo esta actuación, la evolución en el carril de percentiles permite determinar con precisión y sensibilidad la influencia de este tipo de intervención en el nivel de forma física del individuo o del grupo. Igualmente, permite evaluar su deterioro por efecto de cualquier proceso patológico que afecte al sujeto. Por último, también facilitaría el diagnóstico y la detección, en cada persona, de las cualidades físicas más deterioradas susceptibles de ser mejoradas mediante ejercicio físico programado.

Comparación con la situación en otros países

Con el objeto de comparar la condición física de los adolescentes españoles con la presentada por otros países se han comparado nuestros resultados con los publicados en 16 estudios pertenecientes a 11 países. La fuerza (dinamometría manual) y la capacidad aeróbica (VO_2máx) han sido las variables escogidas para este análisis por ser las cualidades de mayor interés cardiovascular. Para hacer comparables los resultados, en cada caso se realizó el análisis utilizando el mismo rango de edad, el mismo sexo y las mismas unidades de medida que las del estudio comparado. No obstante, la disparidad metodológica utilizada en los estudios obliga a interpretar de modo orientativo y aproximado las comparaciones realizadas.

La fuerza muscular se ha evaluado en 3 estudios realizados en Suecia[34], Grecia[35] y Estados Unidos[17]. Tras contrastar los resultados procedentes de estos estudios se puede afirmar que los adolescentes españoles presentan en su conjunto menor fuerza muscular que los del resto de países estudiados. Respecto a la capacidad aeróbica, se han revisado 15 trabajos de investigación realizados en los siguientes países: Países Bajos[36], Bélgica[37], Dinamarca[14,16,20], Australia[38], Grecia[35], Suecia[15], Portugal[39], Arabia Saudí[40], Japón[41], China[42] y Estados Unidos[17,43,44]. Los adoles-

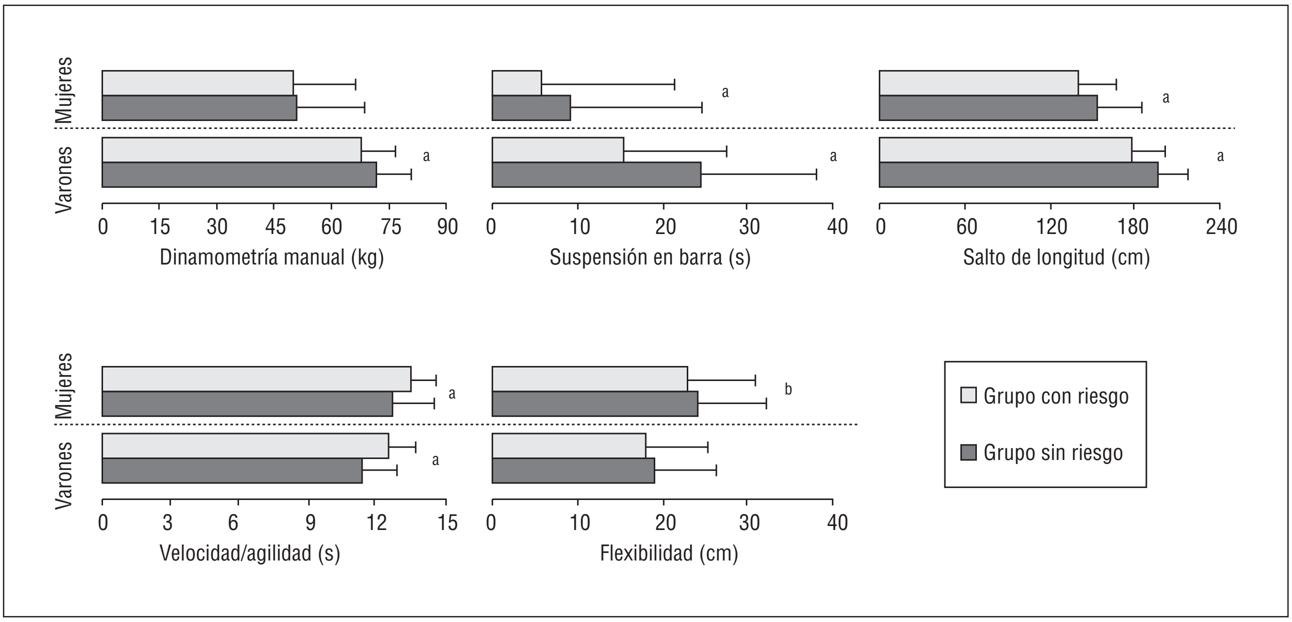

Fig. 3. Diferencias entre el grupo con capacidad aeróbica indicativa de riesgo cardiovascular futuro y el grupo formado por el resto de adolescentes, en las diferentes cualidades físicas: fuerza muscular (dinamometría manual, suspensión en barra y salto de longitud), velocidad/agilidad y flexibilidad.
[a] $p \leq 0,001$. [b] $p \leq 0,05$.

centes españoles presentaban peor capacidad aeróbica que lo referido en 11 de los 15 estudios. Algunos de estos estudios han puesto de manifiesto un progresivo y alarmante deterioro en la capacidad aeróbica de los adolescentes respecto a lo que ocurría en décadas anteriores[34,38,45], lo cual se atribuye principalmente al incremento del sedentarismo en las sociedades industrializadas[38]. Sin embargo, Eisenmann et al[43] afirman que esta tendencia sólo se ha producido en el caso de las adolescentes ≥ 15 años. En cualquier caso, el declive de la capacidad aeróbica convierte al factor tiempo en una variable contaminante en la interpretación de resultados, dificultando la utilización de valores de referencia procedentes de estudios realizados en el pasado y poniendo en valor los resultados de nuestro estudio, dada su actualidad.

Capacidad aeróbica y riesgo cardiovascular asociado

Una cuestión clave es si la población adolescente española disfruta actualmente de una capacidad aeróbica (VO_2máx) satisfactoria en términos de salud cardiovascular. No se dispone de datos para España, pero se pueden utilizar los que se recoge en la bibliografía científica como umbral cardiosaludable. Los puntos de corte propuestos por el grupo FITNESSGRAM del Cooper Institute[32] parten de umbrales de riesgo cardiovascular bien establecidos para adultos; asimismo, se estima el ritmo de deterioro que se produce en el VO_2máx a partir de la adolescencia según diferentes variables influyentes (porcentaje de masa grasa, edad y nivel de actividad física) y se calcula el límite inferior de VO_2máx que supondría un riesgo cardiovascular futuro[32]. Sobre esta base, el umbral de salud cardiovascular estaría fijado en 42 ml/kg/min para toda la adolescencia en el caso de los varones, mientras que para las mujeres sería de 35 ml/kg/min a partir de los 14 años y de 38 ml/kg/min para edades inferiores. Según estos datos, la prevalencia de adolescentes con riesgo cardiovascular según su capacidad aeróbica (estimada a partir del test Course-Navette) está en torno al 17% para las mujeres y al 19% para los varones, es decir, casi la quinta parte de los adolescentes españoles, o lo que es lo mismo, 1 de cada 5 adolescentes, se encuentra en la actualidad en riesgo de presentar algún evento de índole cardiovascular cuando sea adulto. Obviamente, se trata de una alta prevalencia que requiere atención específica por parte de las autoridades políticas, sanitarias y educativas.

Por otro lado, el grupo de adolescentes cuya capacidad aeróbica es indicativa de riesgo cardiovascular futuro posee también un peor rendimiento en las demás cualidades físicas (fuerza, velocidad/agilidad y flexibilidad) (fig. 3). Especialmente en el caso de la fuerza muscular, ello es también indicativo de un peor estado de salud, pues en el adulto, la fuerza ha demostrado ser un potente predictor de mortalidad y esperanza de vida[3,46] y, lo que es más importante, de expectativa de vida independiente[47]. En concreto, y para mejorar esta situación, es preciso implementar programas que mejoren el nivel de condición física de los adolescentes. La actividad física es una de las cuatro estrategias de prevención de enfermedades crónicas propuestas por la Organización Mundial de la Salud en el año 2002[48] y como tal debe ser introducida en la atención primaria en todo el mundo, según propone la Federación Mundial de Cardiología[49]. Sin embargo, hay que indicar que no basta con aumentar el nivel de actividad pues, como se ha puesto de manifiesto en diversos estudios longitudinales[17,19,20,36], el riesgo cardiovascular futuro está más condicionado por la forma física que se alcanza (especialmente fuerza y capacidad aeróbica) que por el nivel de actividad física que se realiza. Por último, es importante matizar que, aunque el nivel de condición física ha sido recientemente propuesto como un potente indicador del estado de salud para todas las edades, no se debe olvidar que factores clásicos de riesgo cardiovascular futuro, como las características antropométricas[50], el perfil lipídico[51] o la presión arterial[52], resultan determinantes para la aparición de la enfermedad cardiovascular. Sobre esta base, los trabajos futuros deberán centrarse en dichos factores para adquirir un mayor conocimiento del estado de salud actual de los adolescentes españoles.

CONCLUSIONES

Se han establecido los valores de referencia en cuanto a condición física de la población adolescente española que permitirán evaluar e interpretar correctamente el nivel de forma física de cualquier adolescente. En concreto, el percentil 5 del test Course-Navette (capacidad aeróbica máxima) obtenido en el presente estudio para varones y mujeres (rangos: 2,0-3,3 y 1,4-1,9, respectivamente) es, en sí mismo, un indicador biológico por debajo del cual se puede considerar que el nivel de forma física es patológico. El estado de forma de los adolescentes españoles es peor que el de otros países y se estima que 1 de cada 5 adolescentes españoles posee un nivel de condición física indicativo de riesgo cardiovascular futuro. Si valoramos este aspecto y la importancia constatada de la forma física como factor de riesgo cardiovascular, es necesario diseñar programas de prevención que mejoren la condición física (especialmente fuerza y capacidad aeróbica) de nuestros adolescentes, para lo cual la implicación directa de los medios sanitario, educativo y político-administrativo es determinante.

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ORIGINAL ARTICLES

EPIDEMIOLOGY AND PREVENTION

Low Level of Physical Fitness in Spanish Adolescents. Relevance for Future Cardiovascular Health (AVENA Study)

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Introduction and objectives. Several studies have demonstrated that physical fitness in childhood and adolescence is related to cardiovascular risk in adulthood. Current data on the physical fitness of Spanish adolescents are not available. Therefore, the aims of this study were: *a*) to assess the physical fitness of Spanish adolescents and establish reference values for use in health and educational settings as indicators of cardiovascular health, and *b*) to determine the percentage of Spanish adolescents below the minimum level of aerobic fitness needed to guarantee future cardiovascular health.

Subjects and method. The modified EUROFIT battery of tests was used to assess physical fitness in a representative sample of Spanish adolescents (n=2859; 1357 boys and 1502 girls) taking part in the AVENA *(Alimentación y Valoración del Estado Nutricional de los Adolescentes)* study.

Results. Standard parameters for the physical condition of Spanish adolescents are reported in this study. The 5th percentile for maximum aerobic capacity (Course Navette test) ranged from 2.0-3.3 palier in boys and from 1.4-1.9 palier in girls. The findings indicate that, on the basis of aerobic fitness, approximately 20% of Spanish adolescents have an increased risk of future cardiovascular disease. This subgroup also performed poorly in all other tests of physical fitness used.

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Conclusions. The results reported in this study enable the level of physical fitness in adolescents to be interpreted as an indicator of future cardiovascular health. They also indicate that the physical fitness of Spanish adolescents must be improved to help protect against cardiovascular disease in adulthood.

Key words: *Fitness. Adolescents. Cardiovascular risk.*

Bajo nivel de forma física en los adolescentes españoles. Importancia para la salud cardiovascular futura (Estudio AVENA)

Introducción y objetivos. En diversos estudios se ha mostrado la relación entre el nivel de forma física durante la infancia-adolescencia y el riesgo cardiovascular en la edad adulta. Dado que no se dispone de datos relativos al nivel de condición física de los adolescentes españoles, los objetivos de este estudio son: *a*) determinar el nivel de condición física de los adolescentes españoles y establecer valores de referencia que puedan ser utilizados en el medio sanitario y educativo como indicadores de salud cardiovascular, y *b*) conocer la proporción de adolescentes españoles que no alcanza valores de capacidad aeróbica indicativos de salud cardiovascular futura.

Sujetos y método. Se ha utilizado la batería EUROFIT modificada para evaluar la condición física de una muestra representativa de adolescentes españoles (n = 2.859; 1.357 varones y 1.502 mujeres) procedente del estudio AVENA (Alimentación y Valoración del Estado Nutricional de los Adolescentes).

Resultados. Se han obtenido los valores normativos de condición física de la población adolescente española. El rango del percentil 5 respecto a la capacidad aeróbica máxima (test de Course Navette) es de 2,0-3,3 y 1,4-1,9 *paliers* para varones y mujeres, respectivamente. Casi 1 de cada 5 adolescentes presenta riesgo cardiovascular futuro sobre la base de su capacidad aeróbica. Este subgrupo de adolescentes mostró también una peor forma física que el resto de adolescentes en todas las pruebas físicas realizadas.

Conclusiones. Los resultados obtenidos en el presente estudio permiten evaluar e interpretar correctamente el

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ABBREVIATIONS

VO_{2max}: maximal oxygen consumption.

nivel de forma física de cualquier adolescente. Los resultados obtenidos indican la necesidad de mejorar el nivel de condición física de los adolescentes españoles.

Palabras clave: *Forma física. Adolescentes. Riesgo cardiovascular.*

INTRODUCTION

Recent studies have shown that aerobic capacity and muscle strength are powerful predictors of cardiovascular and all-cause death and disease, both in men[1-3] and in women.[2-5] The role of poor physical fitness as a cardiovascular risk factor is even greater than other well established factors, such as dyslipidemia, hypertension, or obesity.[6]

Although the clinical manifestations of atherosclerotic cardiovascular disease usually appear in adulthood, the pathogenic commencement of the disease occurs in childhood or adolescence,[7,8] and cardiovascular risk factors have even been identified at these ages.[9-12] Some of these factors may be able to predict future death and disease, as is the case for overweight children.[13] The study of these factors during the crucial stage of adolescence is, therefore, relevant for the diagnosis and prevention of conditions associated with cardiovascular disease in adults. Several cross-sectional studies have demonstrated an association between the level of physical fitness during childhood and adolescence and cardiovascular risk factors.[14-16] Likewise, important longitudinal studies have shown that the level of physical fitness in an adult, as well as the presence of other conventional cardiovascular risk factors, such as hypercholesterolemia or hypertension, is conditioned by the level of physical fitness in childhood or adolescence.[17-21] In order, therefore, to evaluate future cardiovascular risk as early as possible, this evaluation should start in childhood or adolescence. However, a correct clinical evaluation of the level of physical fitness requires up-to-date reference values for the study population. Thus, the aim of this study was to establish the normative values for physical fitness in Spanish adolescents.

SUBJECTS AND METHOD

Subjects and Experimental Design

This study formed part of the AVENA (*Alimentación y Valoración del Estado Nutricional en Adolescentes*) Study, whose full methodology has been reported previously.[22] This multicenter study was undertaken in Spanish adolescents from 13-18.5 years of age. In order to account for the heterogeneity of the population, the study was undertaken in both, public and private high schools, or apprentice training schools.

The study was multistage, randomized, and stratified according to origin (Granada, Madrid, Santander, Zaragoza, and Murcia), social and economic condition (according to the site of the educational establishment; data provided by the various regional educational authorities), sex, and age. Exclusion factors included a clinical diagnosis of diabetes, pregnancy, the use of alcohol or drugs, and, in general, the presence of any disease not directly associated with nutrition. Exclusion from the study was made effective *a posteriori*, without the students being aware of it, in order to avoid any undesired situation.

To determine the overall sample size, we used the parameter of greatest variance in the population, obtained from published data at the time the study was planned,[23] that is, the body mass index (BMI). The sampling was determined by this dispersion. The confidence level was 95%, with an error of ±0.25. The number of subjects for the complete study was calculated to be 2100. The total number was distributed equally among the different cities, and proportionally by sex and age group (13, 14, 15, 16, and 17-18.5 years). The sample was overestimated to prevent loss of information. Finally, a weighting factor was applied to balance the sample according to the distribution of the Spanish population and guarantee the true representation of each of the groups defined by the above-mentioned factors (Source: National Statistics Institute). After eliminating from the study all those subjects who failed to meet the inclusion criteria, the final number of participants was 2859 (1357 boys and 1502 girls).

The study was undertaken in accordance with the deontological norms laid down in the Helsinki Declaration (Hong Kong revision, September 1989) and the European Union recommendations for Good Clinical Practice (document 111/3976/88, July 1990), and the current Spanish laws governing clinical research in human subjects (Royal Decree 561/1993 concerning clinical trials). The study was submitted for evaluation and approved by the Ethics Committees of the Spanish National Research Council and the Marqués de Valdecilla University Hospital (Santander, Spain).

Evaluation of Physical Fitness

Prior to starting the study, the researchers involved in the project undertook training sessions in order to guarantee the standardization, validation, and reliabili-

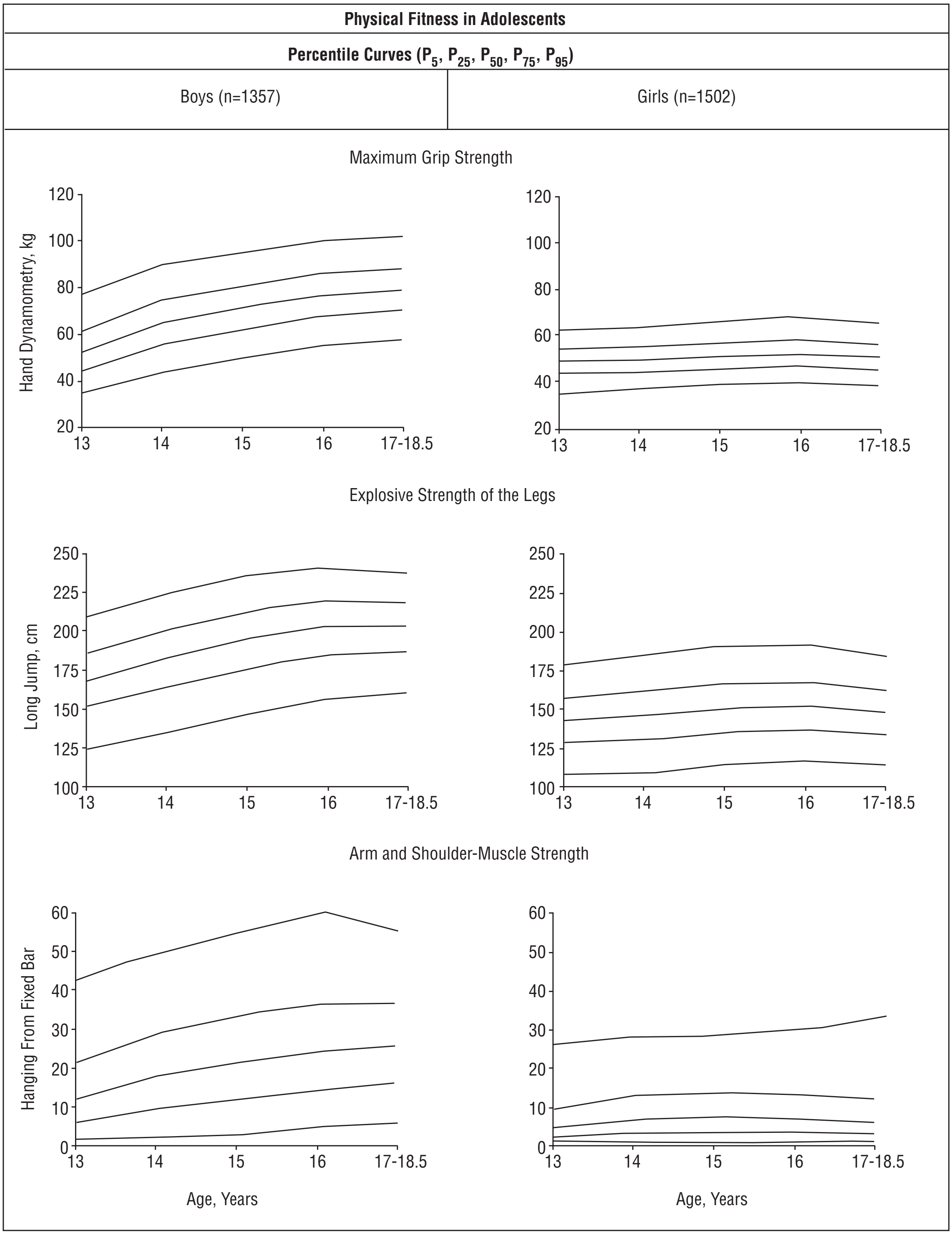

Figure 1a. Percentile curves (from bottom to top: P_5, P_{25}, P_{50}, P_{75}, P_{95}) of 3 tests to measure different manifestations of muscle strength. The smoothing of the percentiles was done with the LMS method.

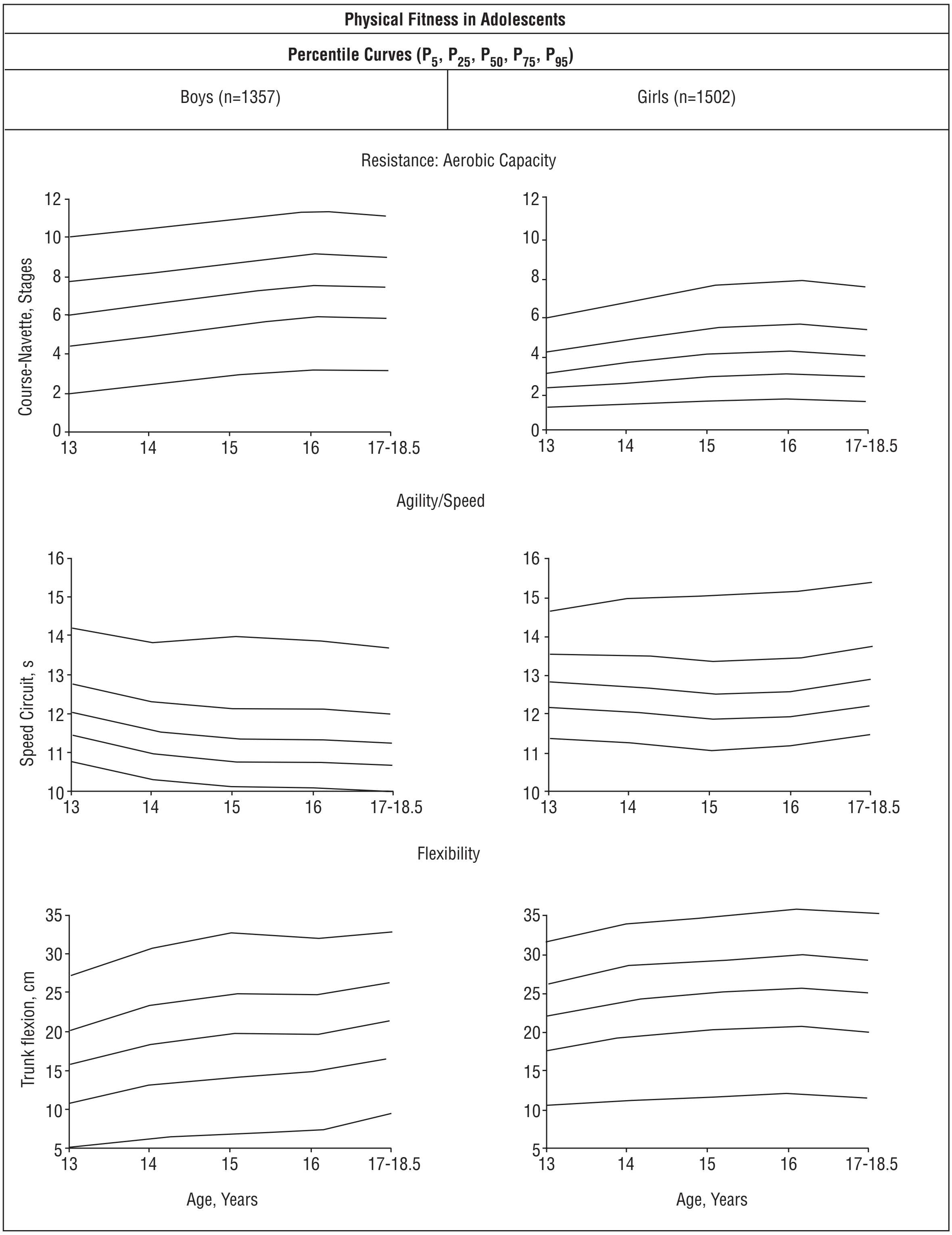

Figure 1b. Percentile curves (from bottom to top: P_5, P_{25}, P_{50}, P_{75}, P_{95}) of 3 tests to measure different physical qualities. The smoothing of the percentiles was done with the LMS method.

ty of the measurements.[24] Six tests, forming part of the EUROFIT[25] battery, validated and standardized by the European Council, were applied in the following order:

1. Reaching forward as far as possible from a seated position. With the subject seated on the floor and using a standardized support,[26] the maximum distance reached with the tip of the fingers by forward flexion of the trunk is measured. Test indicative of amplitude of movement or flexibility.

2. Hand dynamometry. With the use of a digital Takei TKK 5101 dynamometer (range, 5-100 kg), the maximum hand grip was measured for both hands.

3. Standing long jump with feet together. The maximum horizontal distance attained was measured. This test evaluates the explosive strength of the legs.

4. Bent arm hang. A standardized test was used to measure the maximum time hanging from a fixed bar. This test estimates the arm and shoulder-muscle endurance.

5. Shuttle run: 4×10 meters. This test provides an integral evaluation of the speed of movement and coordination. The subject does four shuttle runs as fast as possible between 2 lines 10 meters apart. At each end the subject places or picks up an object (a sponge) beside the line on the floor.

6. Course-Navette test. This test evaluates the maximum aerobic capacity based on an indirect-incremental-maximum field test involving a 20 meter shuttle run,[27] using the formulas proposed by Léger et al[28] to calculate the maximal oxygen consumption (VO_{2max}). The reliability and validity of the test to predict the VO_{2max} in children and adolescents have been sufficiently demonstrated.[28-30] To obtain the VO_{2max} easily and quickly from the result of the Course-Navette tests it is sufficient to introduce the age (A) and the final speed (S=8+0.5×last stage completed) into the following formula (r=0.7; for children-adolescents from 8-19 years old)[28]:

$$VO_{2max}=31.025+3.238S-3.248A+0.1536SA$$

Statistical Analysis

In the tables with the reference values and percentile curves, the percentiles were smoothed using the Latent Moderated Structural (LMS) method,[31] for which we used the LMS program, version 1.16, designed by Huiqi Pan (Institute of Child Health, 1998-2002). In the second stage of the analysis, the overall sample was divided into 2 groups, one group with an aerobic capacity indicative of future cardiovascular risk and another group composed of the remaining adolescents. For the inferential analysis, designed to detect differences between the 2 groups, we used the non-parametric Mann-Whitney test, after previously verifying the lack of normality of the study variables. The whole statistical analysis was done with the statistical program SPSS, v12.0.1, for Windows XP.

RESULTS

Tables 1-6 show the reference values for physical fitness in the Spanish adolescents, classified according to age and sex, and expressed in smoothed percentiles from 10-100. Figures 1a and 1b show the percentile curves (P5, P25, P50, P75, and P95), for both sexes and by age, of the different tests of physical fitness. The figure clearly shows greater physical aptitude in the boys, except for the flexibility test, in which the girls performed better. From both figures it can be seen that the results for the boys were generally more homogeneous than for the girls, regarding physical aptitude. There was also a trend towards increased physi-

TABLE 1. **Normal Values of the Physical Condition of Spanish Adolescents. Hand Dynamometry: Sum of Both Hands (Maximum Strength of Hand Pressure)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Girls										
13 years	37.8	40.9	43.6	46.0	48.1	48.1	50.2	52.5	55.1	58.7
14 years	39.2	42.4	44.8	46.9	48.9	48.9	51.0	53.2	55.9	59.8
15 years	40.9	44.1	46.4	48.5	50.6	50.6	52.7	55.1	57.9	62.1
16 years	42.0	45.1	47.5	49.7	51.8	51.8	54.0	56.5	59.6	64.1
17-18.5 years	40.3	43.4	45.7	47.8	49.8	49.8	52.0	54.3	57.2	61.4
Boys										
13 years	37.7	42.2	45.8	49.0	52.2	52.2	55.5	59.2	63.9	70.8
14 years	47.7	53.2	57.3	60.9	64.4	64.4	68.0	71.9	76.7	83.5
15 years	54.3	59.8	64.0	67.6	71.0	71.0	74.5	78.3	82.8	89.1
16 years	59.7	65.4	69.6	73.2	76.6	76.6	80.1	83.9	88.4	94.7
17-18.5 years	61.8	67.5	71.6	75.3	78.7	78.7	82.1	85.9	90.3	96.5

The process was smoothed using the LMS method.

TABLE 2. **Normal Values of the Physical Condition of Spanish Adolescents. Bent Arm Hang (Arm and Shoulder-Muscle Strength and Endurance)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Girls										
13 years	1.3	2.0	2.6	3.4	4.4	4.4	5.7	7.5	10.5	17.1
14 years	1.7	2.8	4.0	5.2	6.7	6.7	8.5	10.9	14.5	21.0
15 years	1.7	2.9	4.2	5.6	7.1	7.1	9.0	11.5	15.0	21.1
16 years	1.8	2.8	3.9	5.2	6.6	6.6	8.4	10.9	14.6	21.7
17-18.5 years	1.5	2.3	3.2	4.2	5.5	5.5	7.1	9.5	13.4	21.8
Boys										
13 years	2.7	4.9	7.0	9.3	11.9	11.9	14.9	18.7	23.8	32.6
14 years	4.2	7.4	10.5	13.7	17.0	17.0	20.8	25.4	31.4	41.0
15 years	5.8	9.8	13.5	17.1	20.8	20.8	25.0	29.8	36.1	45.9
16 years	7.8	12.4	16.4	20.2	24.1	24.1	28.4	33.4	39.7	49.4
17-18.5 years	9.5	14.1	17.9	21.5	25.1	25.1	29.0	33.4	38.9	47.2

The process was smoothed using the LMS method.

TABLE 3. **Normal Values of the Physical Condition of Spanish Adolescents. Standing Long Jump (Explosive Strength of the Legs)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Girls										
13 years	116.0	125.2	132.0	137.7	143.2	143.2	148.6	154.4	161.3	170.9
14 years	117.5	127.1	134.2	140.3	146.1	146.1	152.0	158.3	165.8	176.4
15 years	122.1	131.7	138.8	144.9	150.8	150.8	156.8	163.3	171.1	182.1
16 years	124.9	134.0	140.8	146.7	152.3	152.3	158.0	164.3	171.7	182.3
17-18.5 years	121.8	130.5	136.9	142.5	147.8	147.8	153.2	159.0	166.0	175.8
Boys										
13 years	134.3	146.6	155.2	162.4	168.9	168.9	175.3	182.1	189.8	200.3
14 years	146.3	159.3	168.3	175.8	182.6	182.6	189.2	196.2	204.2	215.0
15 years	158.3	171.6	180.7	188.2	195.0	195.0	201.7	208.6	216.5	227.2
16 years	168.0	180.7	189.4	196.5	202.9	202.9	209.2	215.6	223.0	232.9
17-18.5 years	171.2	182.9	190.9	197.5	203.4	203.4	209.1	215.0	221.8	230.8

The process was smoothed using the LMS method.

TABLE 4. **Normal Values of the Physical Condition of Spanish Adolescents. Shuttle Run: 4×10 Meters (Speed-Agility)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Girls										
13 years	11.2	11.6	11.9	12.2	12.4	12.4	12.7	13.0	13.3	13.8
14 years	11.0	11.4	11.7	12.0	12.3	12.3	12.6	12.9	13.3	14.0
15 years	10.8	11.2	11.5	11.8	12.0	12.0	12.3	12.7	13.2	14.0
16 years	11.0	11.3	11.6	11.9	12.1	12.1	12.5	12.8	13.3	14.1
17-18.5 years	11.2	11.6	11.9	12.2	12.5	12.5	12.8	13.1	13.6	14.3
Boys										
13 years	10.4	10.8	11.0	11.3	11.5	11.5	11.8	12.1	12.5	13.2
14 years	10.0	10.3	10.6	10.8	11.1	11.1	11.4	11.7	12.1	12.8
15 years	9.8	10.1	10.3	10.6	10.8	10.8	11.1	11.4	11.9	12.6
16 years	9.7	10.0	10.3	10.6	10.8	10.8	11.1	11.4	11.9	12.7
17-18.5 years	9.7	10.0	10.3	10.5	10.8	10.8	11.1	11.4	11.9	12.7

The process was smoothed using the LMS method.

cal fitness in the boys as their age increased, whereas the girls showed stability or a slight increase in physical fitness. Figure 1b shows that the 5th percentile range for the boys was 2.0-3.3 and for the girls it was 1.4-1.9, corresponding to the results of the Course-Navette test.

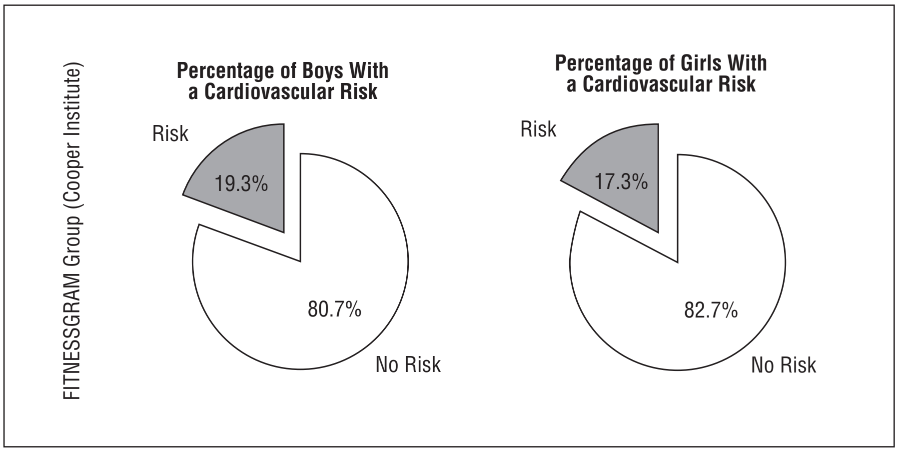

Figure 2. Percentages of adolescents with a cardiovascular risk associated with a low aerobic capacity, using the cut-off points proposed in the literature.[32] The threshold of cardiovascular risk for the boys corresponds to a VO_{2max} of 42 mL/kg/min and for the girls a VO_{2max} of 35 mL/kg/min for girls 14 years or older and 38 mL/kg/min for younger girls.

Figure 2 shows the percentage of Spanish adolescents who presented a future cardiovascular risk, according to their current aerobic capacity, for which we used the VO_{2max} threshold indicative of cardiovascular health proposed in the literature.[32] As can be seen, this percentage surpassed 17%, in both boys and girls. Analysis of the performance shown by this group of adolescents in the other tests shows that the group of adolescents whose aerobic capacity was indicative of future cardiovascular risk also performed worse in the tests measuring the other physical qualities (strength, speed/agility, and flexibility), with significant differences in all the tests undertaken ($P \leq .001$), except in the hand dynamometer test in the girls and the flexibility test in the boys ($P \geq .05$) (Figure 3).

DISCUSSION

Prior to explaining and discussing the findings of this study, we shall define and differentiate a few of the terms that are related but nevertheless different, and which are occasionally used mistakenly as synonyms in various references. These concepts are: physical activity, physical exercise, and physical condition or fitness. Firstly, physical activity is any body movement produced by the skeletal muscles and that requires a certain degree of energy expenditure. Physical exercise is included within the concept of physical activity, but the main difference relates to the systematization with which it is undertaken. Invisible exercise is, in turn, an integral part of physical exercise, and is a new concept that includes all those tasks which, with different degrees of intention, adults do every day (cleaning, cooking, going up stairs, walking to different places, etc) and more or less systematically. Finally, physical fitness or physical condition is a concept that encompasses all the physical qualities of a person, and the state of physical fitness can be said to be an integrated part of all the functions and structures involved in the performance of physical exertion.[33]

Reference Values

Determining the individual level of physical fitness in adolescence is important in order to establish the future cardiovascular risk in a particular person.[17-21] Correct interpretation of this information requires comparing it with normative values for the general population. This study reports the reference values for the adolescent population of Spain, and establishes the corresponding percentiles estimated according to age and sex. In population terms, a level of physical fitness below the 5th percentile (Figures 1a and 1b) is potentially pathologic and accurately points to future cardiovascular risk.[20,21] Subjects in this percentile should undergo evaluation for the coexistence of other cardiovascular risk factors. In order to provide a score, for example on a scale of 1-10, we also show the 10th-100th percentiles (Tables 1-6). This enables intuitive classification of the individual level of physical fitness by using a Likert type scale: very poor ($X<P_{20}$), poor ($P_{20} \leq X<P_{40}$), medium ($P_{40} \leq X<P_{60}$), good ($P_{60} \leq X<P_{80}$), and very good ($X \geq P_{80}$). This is especially interesting when the evaluation is done in the health care or educational setting, essential areas for the early detection of problems and immediate intervention. The precision and influence of the particular intervention on the level of physical fitness of an individual or a group can be observed by following the evolution of the percentile lanes. Likewise, it also enables any deterioration due to a certain disease to be measured. Finally, it also enables diagnosis and detection in each person of those physical qualities that are most deteriorated and susceptible to improvement with a physical exercise program.

Comparison With the Situation in Other Countries

To compare the level of physical fitness of Spanish adolescents with that of adolescents in other countries, we compared our results with those reported in 16

TABLE 5. **Normal Values of the Physical Condition of Spanish Adolescents. Course-Navette Test (Maximum Aerobic Capacity)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Girls										
13 years	1.5	1.9	2.3	2.6	3.0	3.0	3.3	3.8	4.3	5.1
14 years	1.7	2.3	2.7	3.1	3.5	3.5	3.9	4.4	5.0	6.0
15 years	2.0	2.6	3.1	3.6	4.0	4.0	4.5	5.0	5.7	6.7
16 years	2.1	2.7	3.2	3.7	4.2	4.2	4.7	5.2	5.9	6.9
17-18.5 years	2.0	2.5	3.0	3.5	3.9	3.9	4.4	4.9	5.5	6.5
Boys										
13 years	2.8	3.9	4.6	5.3	5.9	5.9	6.5	7.1	7.9	8.9
14 years	3.3	4.4	5.1	5.8	6.4	6.4	7.0	7.7	8.4	9.4
15 years	3.8	4.9	5.7	6.4	7.0	7.0	7.6	8.2	8.9	10.0
16 years	4.1	5.3	6.1	6.8	7.4	7.4	8.0	8.7	9.4	10.4
17-18.5 years	4.0	5.2	6.1	6.7	7.3	7.3	7.9	8.6	9.3	10.2

The process was smoothed using the LMS method.

TABLE 6. **Normal Values of the Physical Condition of Spanish Adolescents. Reaching Forward as Far as Possible From a Seated Position (Flexibility)**

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Girls										
13 years	13.4	16.4	18.5	20.3	21.8	21.8	23.4	25.0	26.9	29.5
14 years	14.6	18.1	20.4	22.3	24.0	24.0	25.7	27.4	29.3	31.9
15 years	15.2	18.8	21.2	23.2	24.9	24.9	26.6	28.3	30.3	32.9
16 years	15.6	19.4	21.9	23.9	25.7	25.7	27.4	29.2	31.2	33.9
17-18.5 years	14.9	18.6	21.0	23.0	24.7	24.7	26.4	28.2	30.2	32.9
Boys										
13 years	7.3	10.0	12.0	13.8	15.4	15.4	17.1	19.0	21.2	24.2
14 years	8.7	11.8	14.1	16.1	18.0	18.0	19.9	22.0	24.4	27.9
15 years	9.5	12.8	15.3	17.4	19.3	19.3	21.3	23.4	25.9	29.4
16 years	10.0	13.3	15.6	17.6	19.5	19.5	21.4	23.3	25.7	28.9
17-18.5 years	12.2	15.4	17.7	19.6	21.4	21.4	23.2	25.1	27.3	30.3

The process was smoothed using the LMS method.

studies from 11 different countries. Strength (hand dynamometry) and aerobic capacity (VO_{2max}) were the variables chosen for this comparison, as they are the qualities with the greatest cardiovascular interest. The results were made comparable by using, in each case, the same age range, sex, and units of measurement as in the original study. Nevertheless, the methodological differences between the various studies means that the comparisons should be interpreted as approximate.

Muscle strength was measured in 3 studies, undertaken in Sweden,[34] Greece,[35] and the United States.[17] Comparison of our results with those of the studies from these countries shows that Spanish adolescents have, in general, less muscle strength than adolescents in these other countries For aerobic capacity, we reviewed 15 research studies undertaken in the following countries: Netherlands,[36] Belgium,[37] Denmark,[14,16,20] Australia,[38] Greece,[35] Sweden,[15] Portugal,[39] Saudi Arabia,[40] Japan,[41] China,[42] and the United States.[17,43,44] The Spanish adolescents had a worse aerobic capacity than that reported in 11 of the 15 studies. Some of these studies showed an alarmingly progressive worsening in the aerobic capacity of adolescents as compared with the situation in previous decades,[34,38,45] which has been attributed mainly to the increase in sedentary lifestyles in industrialized countries.[38] However, Eisenmann et al[43] state that this trend has only occurred in adolescents ≥15 years of age. Whatever the situation, the decline in aerobic capacity converts the time factor into a contaminating variable when interpreting the results, hindering the use of reference values from studies undertaken in the past and affording greater value to the results of our study, which refer to the current situation.

Aerobic Capacity and Associated Cardiovascular Risk

A key question is whether Spanish adolescents have a satisfactory aerobic capacity (VO_{2max}) in terms of

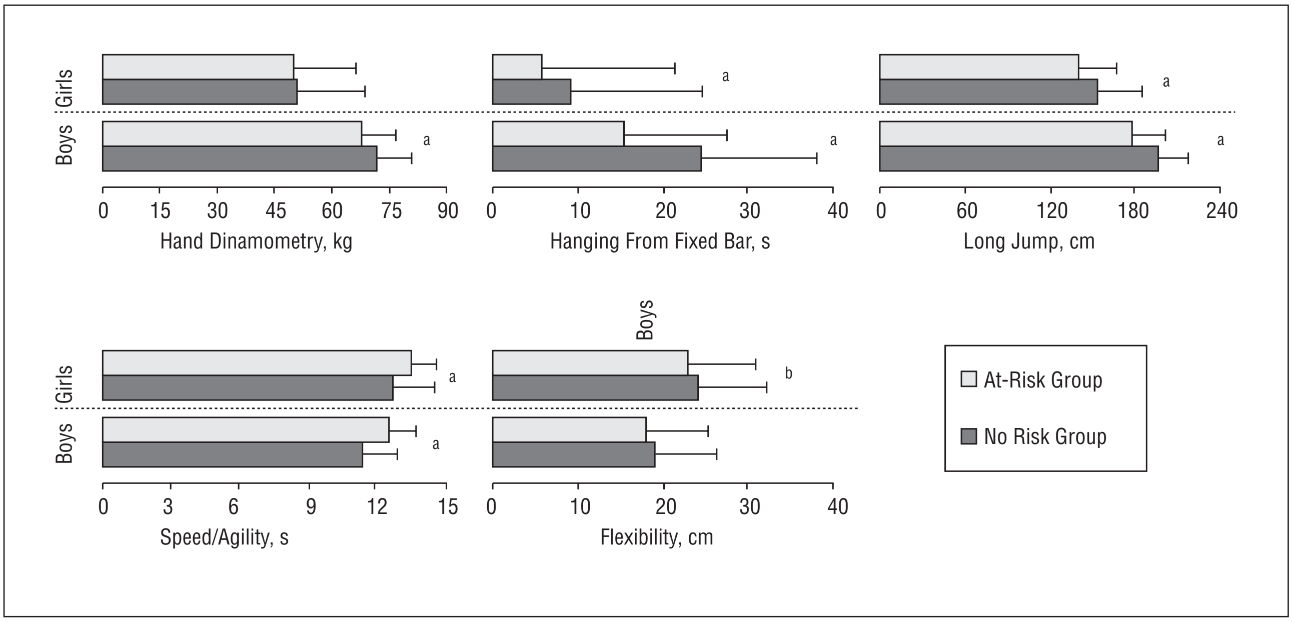

Figure 3. Differences between the group with an aerobic capacity indicative of future cardiovascular risk and the group composed of the other adolescents, for the different physical qualities: muscle strength (hand dynamometry, bar hanging, and long jump), speed/agility, and flexibility.
[a]$P \leq .001$. [b]$P \leq .05$.

cardiovascular health. No data are available for Spain, but other data from the scientific literature can be used as a threshold for the beneficial effects on the heart. The cut-off points proposed by the FITNESSGRAM group from the Cooper Institute[32] use well-established thresholds for cardiovascular risk in adults. Likewise, the group estimated the rate of deterioration produced in the VO_{2max} with effect from adolescence, based on several different influential variables (percentage fat mass, age, and level of physical activity) and calculated the lower limit of the VO_{2max} that would represent future cardiovascular risk.[32] This calculation fixed the threshold for cardiovascular health at 42 mL/kg/min for all adolescent boys, whereas for girls older than 14 years of age it was 35 mL/kg/min and 38 mL/kg/min for younger girls. Based on these data, the prevalence of Spanish adolescents with a cardiovascular risk, as defined by their aerobic capacity (estimated with the Course-Navette test) is around 17% for girls and 19% for boys. This represents almost one fifth of all Spanish adolescents, which means that one in five adolescents are currently at risk for presenting some sort of cardiovascular event when they are adults. Clearly, this high prevalence demands specific attention by the various political, health care, and educational authorities. Furthermore, the group of adolescents whose aerobic capacity was indicative of future cardiovascular risk also had a worse performance on the tests of the other physical qualities (strength, speed/agility, and flexibility) (Figure 3). This was even more marked in the case of muscle strength, which also reflects a worse state of health, as strength in an adult has been shown to be a powerful predictor of death and life expectancy,[3,46] and more importantly, expectation of independent life.[47] Thus, in order to improve this situation, programs must be implemented to improve the physical condition of adolescents. Physical activity is 1 of the 4 prevention strategies for chronic diseases proposed by the World Health Organization in 2002,[48] and as such, should be introduced into primary care worldwide, as proposed by the World Heart Federation.[49] Nevertheless, just increasing the level of activity is not in itself sufficient, as has been highlighted in various longitudinal studies.[17,19,20,36] Future cardiovascular risk is conditioned more by the physical fitness attained (especially strength and aerobic capacity) than by the level of physical activity undertaken. Finally, it should not be forgotten that, although the level of physical fitness has recently been proposed as a powerful indicator of the state of health at all ages, classic factors of future cardiovascular risk, such as the anthropometrical characteristics,[50] the lipid profile,[51] or blood pressure,[52] all determine the onset of cardiovascular disease. Future studies, therefore, should be based on these factors to learn more about the current state of health of Spanish adolescents.

CONCLUSIONS

Reference values have been established for the physical condition of Spanish adolescents. These values will enable the level of physical fitness of any Spanish adolescent to be evaluated and correctly interpreted. The results show that the 5th percentile obtained on the Course-Navette test (maximum aerobic capacity) in this study for adolescent boys and girls (ranges, 2.0-3.3 and 1.4-1.9, respectively) was also a biological indicator below which the level of physical fitness can be considered pathological. The state of fitness of Spanish adolescents is worse than that of adolescents in other countries, and 1 in 5 Spanish adolescents are estimated to have a level of physical fitness indicative of future cardiovascular risk. Evaluation of this aspect and the importance of physical fitness as a cardiovascular risk factor highlight the need to design prevention programs to improve the physical condition (especially strength and aerobic capacity) of Spanish adolescents. To this end, the direct involvement of those working in health care, education, the government, and politics is crucial.

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III

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

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

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ABSTRACT

Background: 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.

Method: Physical fitness was measured in a sample of Spanish adolescents (N=2859; 1357 males, 1502 females) from the AVENA study by means of the following tests: sit and reach, handgrip, standing broad jump, bent arm hang, 4x10m shuttle run, and 20m 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.

Conclusions: Normative data for several health-related physical 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, maturation, Tanner, adolescents.

INTRODUCTION

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 for.

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 1947 (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].

a) *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.

b) *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.

c) *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.

d) *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.

e) *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 x 5 without sponges instead of 10 m x 4 with sponges. The main difference between these two tests is that the 10 m x 4 shuttle run test requires a higher coordination component than the 10 m x 5 shuttle run test (depositing and picking up sponges while running at maximum speed).

f) *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 per 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 re-grouped 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 1. 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 the males ($P \leq 0.001$), while the males were stronger, had higher CRF and were faster than females ($P \leq 0.001$).

Tables 2 and 3 show the physical fitness scores stratified by age and stages of sexual maturation, respectively, in male and female adolescents. The one-way ANOVA showed that all physical fitness scores were 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 and 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 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 and 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.

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 to 19 y have been reported [16]. In accordance with our 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 our results. Unfortunately, in that study biological age was not reported, so comparison with our 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. (2002), 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. One possible explanation is the decrease in physical activity throughout adolescence, which is much higher in males than in females [42].

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 our 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, 10x5-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].

CONCLUSION

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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Table 1. 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 2. Physical fitness scores (means ± standard deviation) stratified by chronological age in male and female adolescents.

Males (n=958)	13 y	14 y	15 y	16 y	17-18.5 y	*P for trend*
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
4x10m 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)	**13 y**	**14 y**	**15 y**	**16 y**	**17-18.5 y**	***P for trend***
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
4x10m 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.

Table 3. Physical fitness scores (means ± standard deviation) stratified by biological age (Tanner stage III, IV and V) in males and female adolescents.

Males (n=958)	Tanner III (early puberty)	Tanner IV (mid puberty)	Tanner V (late puberty)	*P* *for trend*
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
4x10m 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)	**Tanner III (early puberty)**	**Tanner IV (mid puberty)**	**Tanner V (late puberty)**	***P* *for trend***
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
4x10m 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.

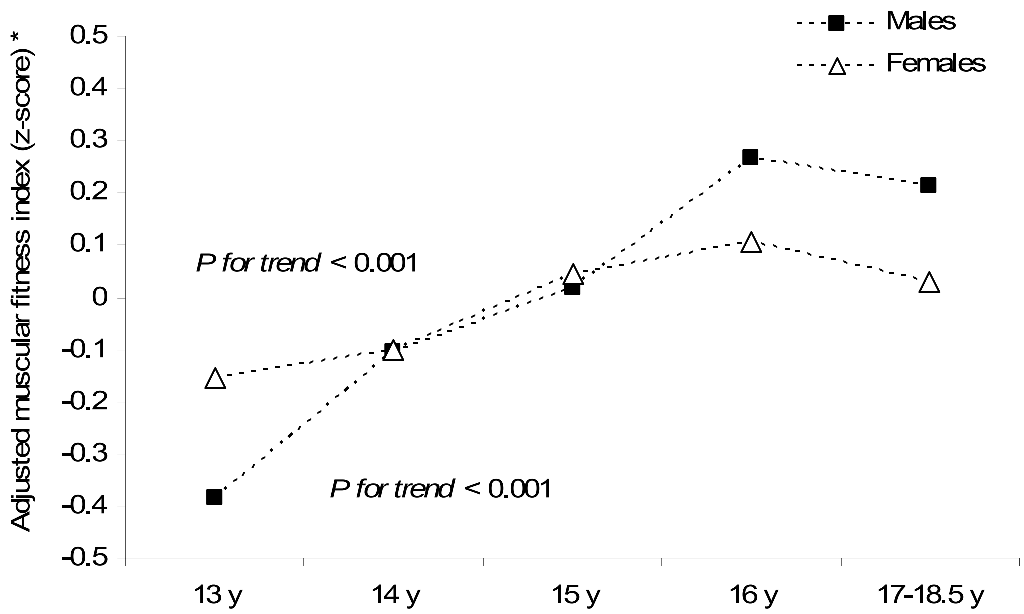

Figure 1: Muscular fitness according to chronological age in male and female adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity.
* The muscular fitness index (z-score) is the averaged value computed from the handgrip, bent arm hang and standing broad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

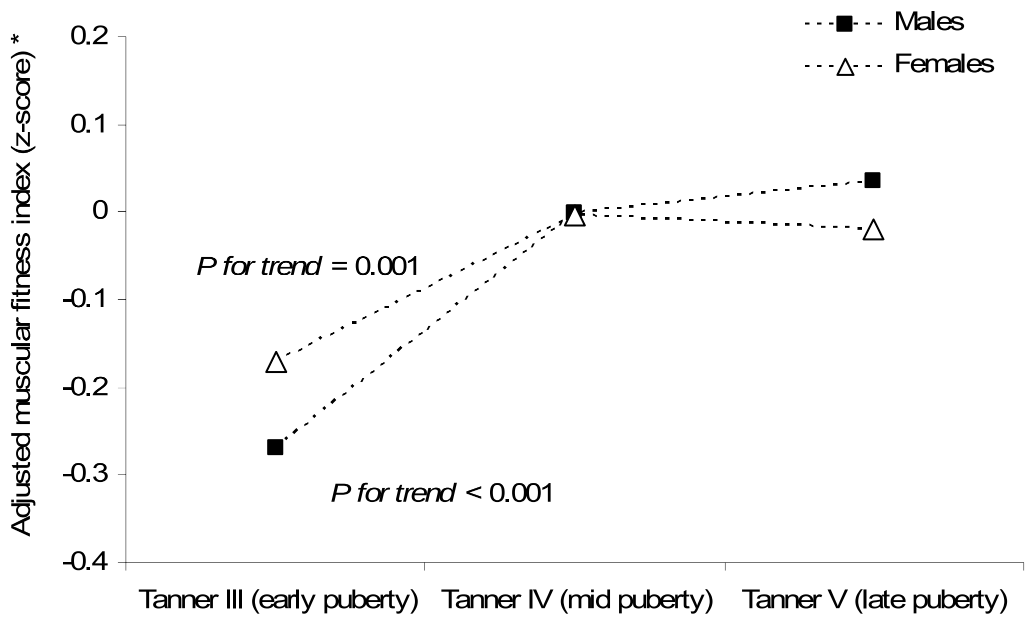

Figure 2. Muscular fitness according to biological age (Tanner III, IV and V) in male and females adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity.

* 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.

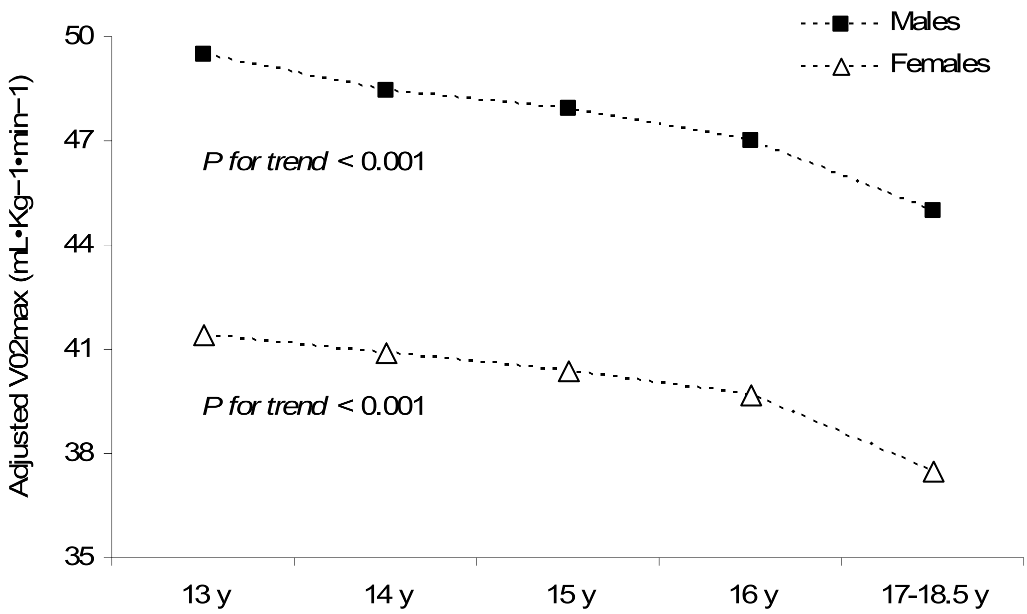

Figure 3. Cardiorespiratory fitness ($\dot{V}O_2$max) according to chronological age in male and females adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity.

One-way analysis of the covariance (one-way ANCOVA) was performed for males and females separately.

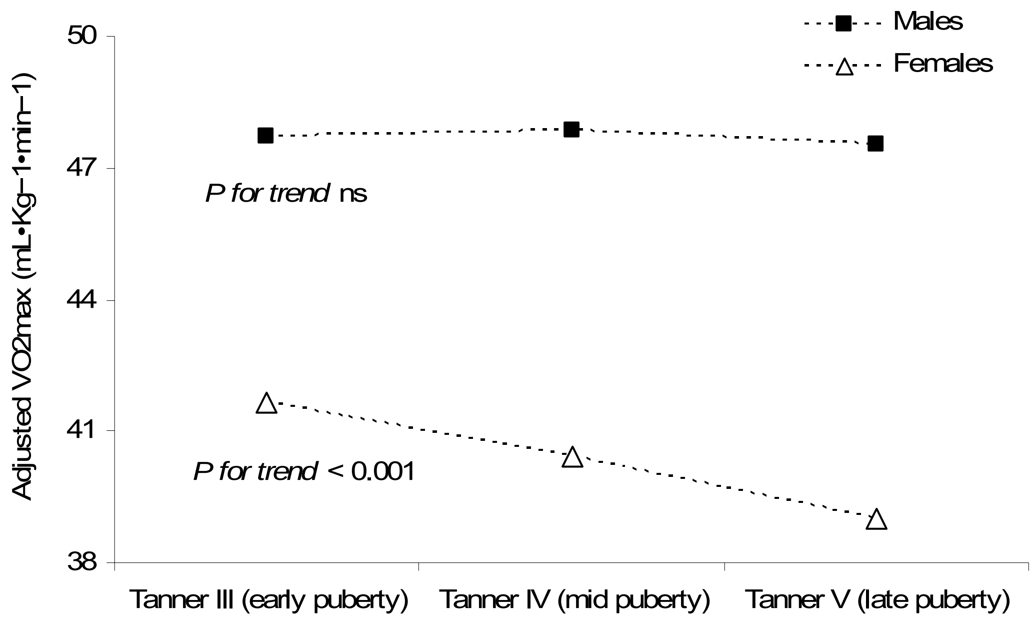

Figure 4. Cardiorespiratory fitness ($\dot{V}O_2$max) according to biological age (Tanner III, IV and V) in male and female adolescents, after adjustment for percentage body fat, fat free mass and leisure-time physical activity.

One-way analysis of the covariance (one-way ANCOVA) was performed for males and females separately.

Physical fitness and adiposity

(Paper IV)

IV

Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents

Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Martín-Matillas M, Mesa JL, Wärnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo MJ

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Cardiorespiratory Fitness and Sedentary Activities Are Associated with Adiposity in Adolescents

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Abstract

ORTEGA, FRANCISCO B., BEATRIZ TRESACO, JONATAN R. RUIZ, LUIS A. MORENO, MIGUEL MARTIN-MATILLAS, JOSE L. MESA, JULIA WARNBERG, MANUEL BUENO, PABLO TERCEDOR, ÁNGEL GUTIÉRREZ, MANUEL J. CASTILLO, AND THE AVENA STUDY GROUP. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity*. 2007;15:1589–1599.

Objective: To determine whether physical activity, sedentary activities, and/or cardiorespiratory fitness are related to waist circumference in adolescents, as previously reported in adults.

Research Methods and Procedures: The study subjects were a representative sample of Spanish adolescents (N = 2859; 1357 boys, 1502 girls; age, 13 to 18.5 years), all of whom were involved in the AVENA (Food and Assessment of the Nutritional Status of Adolescents) study. BMI, waist circumference, pubertal maturation status, and cardiorespiratory fitness were measured in all. Leisure-time physical activity, sedentary activities, active commuting to school, and socioeconomic status were assessed by self-reported questionnaires.

Results: No relationship was found between leisure-time physical activity and BMI or waist circumference. In contrast, and in both boys and girls and after adjustment for confounding variables, cardiorespiratory fitness was found to be inversely associated with waist circumference and BMI, independent of sedentary activities or physical activity ($p \leq 0.001$). The maximum oxygen consumption explained 13% of the variance in waist circumference in boys and 16% in girls. Sedentary activities were independently and directly related to waist circumference in both boys and girls ($p \leq 0.05$) and to BMI in boys ($p \leq 0.05$). Sedentary activities explained 10% of the variance in waist circumference in boys and 18% in girls. The BMI-adjusted waist circumference was inversely correlated with cardiorespiratory fitness in overweight-obese boys ($p \leq 0.05$) and showed a trend toward significance in girls ($p \leq 0.1$).

Discussion: Both moderate to high levels of cardiorespiratory fitness and sedentary activities, but not physical activity, are associated with lower abdominal adiposity, as measured by waist circumference.

Key words: physical activity, sedentary activities, waist circumference, BMI

Introduction

Childhood obesity has reached epidemic proportions worldwide and its prevalence is increasing (1–3). This increase has led to a significant growth in economic costs (4). In adults, it is well established that abdominal adiposity is a strong predictor of morbidity and mortality, independent of BMI (5,6). In addition, waist circumference has been shown to be a powerful marker of abdominal fat accumulation (7) and a significant predictor of cardiovascular disease and type 2 diabetes after adjustment for BMI (8–12). It has also been reported (13) that, within a given BMI category, children and adolescents with a large waist circumference are more likely to have elevated coronary artery disease risk

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factors compared with those with a small waist circumference. Consequently, waist circumference could be a useful tool for studying obesity in adolescents (especially central obesity) and its relationship with daily activity patterns and cardiorespiratory fitness.

The association between sedentary activities and obesity seems to be clearly established (14,15), but the results obtained so far on the relationship between physical activity and obesity in children and adolescents are inconsistent (16–18). In adults, for a given BMI, several studies have reported that individuals showing better cardiorespiratory fitness have less abdominal fat and/or smaller waist circumferences (19–21). The mechanism by which the cardiorespiratory fitness is linked to abdominal fat has not been completely clarified, but presumably this is because cardiorespiratory fitness is a marker for physical activity and its effect on energy balance. To our knowledge, this relationship has not been studied in adolescents. The aim of this study was to explore the relationships between waist circumference plus BMI and physical activity, sedentary activities, and cardiorespiratory fitness in a representative sample of Spanish adolescents.

Research Methods and Procedures

Study Sample and Design

The data presented in this paper were gathered as a part of the Food and Assessment of the Nutritional Status of Adolescents (AVENA)[1] study, a population-based cross-sectional multicenter study on the etiology and pathogenesis of obesity and related metabolic disorders during adolescence. The complete methodology has been published elsewhere (22,23). The subjects of this study were adolescents 13 to 18.5 years old. Given the heterogeneity of this population, subjects from public and private secondary schools and technical colleges were included. Sampling was multistaged, performed at random, and stratified by town of origin (five Spanish cities), socioeconomic status, sex, and age.

Subjects with metabolic diseases, who were pregnant, or who were alcohol or drug abusers were excluded. The variable that showed the greatest variance in the population, BMI, was used to determine the sample size (23). A total of 2100 subjects were deemed necessary for the full study to be properly conducted. These subjects were distributed by cities and proportionally by sex and age (13, 14, 15, 16, and 17 to 18.5 years). In fact, a greater number of subjects were initially chosen to avoid problems of drop-out and consequent data loss. The final figure was adjusted by a weighting factor to balance the sample according to the age distribution of the Spanish population and to guarantee true representation of each of the stratified groups (Instituto Nacional de Estadística, http://www.ine.es). After eliminating those subjects who failed to meet the inclusion criteria, the final sample was composed of 2859 subjects (1357 boys and 1502 girls). Parents and school supervisors were informed by letter about the nature and purpose of the study, and written informed consent to be included was requested. The study protocol was performed in accordance with the ethical standards laid down in the 1975 Declaration of Helsinki (as revised in Hong Kong in 1989 and in Edinburgh in 2000) and approved by the Review Committee for Research Involving Human Subjects of the Hospital Universitario Marqués de Valdecilla (Santander, Spain).

Anthropometric Measurements

All anthropometric measurements were made with subjects barefoot and in their underwear. Weight was measured using a Seca scale (range, 0.05 to 130 kg; precision, 0.05 kg), and height was measured using a stadiometer incorporated into this same apparatus (range, 60 to 200 cm; precision, 1 mm). Waist and hip circumferences were measured using an inelastic tape (range, 0 to 150 cm; precision, 1 mm). The harmonization and standardization of anthropometric measurements used to assess body composition in the AVENA study were strictly controlled and have been published elsewhere (2,23). The International Obesity Task Force-proposed gender- and age-adjusted cut-off points (24) were used to categorize the subjects as overweight-obese or normal weight. Trained interviewers asked the adolescents to classify themselves in one of the five stages of pubertal maturity defined by Tanner and Whitehouse (25). This standard staging describes breast and pubic hair development in girls and genital and pubic hair development in boys. The first Tanner stage corresponds to the prepubertal state; subjects classified in Tanner Stage 5 are completely mature.

Measurement of Cardiorespiratory Fitness

Maximum aerobic capacity was assessed by the 20-m shuttle run test (26). Running pace was determined by audio signals emitted from a prerecorded cassette tape; the initial velocity was 8.5 km/h, which was increased by 0.5 km/h per minute (i.e., per stage). Subjects were instructed to run in a straight line, to pivot on completing a shuttle, and to pace themselves in accordance with the audio signals. The test was finished when the subject failed to reach the end lines concurrent with the audio signals on two consecutive occasions. Scores were recorded as the number of stages completed. The equations of Léger et al. (27) were used to estimate the maximum oxygen consumption ($V\text{O}_{2\text{max}}$). The reliability and validity of this test for determining the $V\text{O}_{2\text{max}}$ in children and adolescents has been widely documented (27–29). A constant level of encouragement was

[1] Nonstandard abbreviations: AVENA, Food and Assessment of the Nutritional Status of Adolescents; $V\text{O}_{2\text{max}}$, maximum oxygen consumption; PAI, physical activity index; MET, metabolic equivalent.

given to participants throughout the test. Subjects were instructed to abstain from strenuous exercise for 48 hours before the test.

Physical Activity Assessment

To assess physical activity levels, a leisure-time physical activity index (PAI) was developed. Subjects answered four questionnaires on physical activity, at least 2 days before the 20-m shuttle run test was performed, to measure the practice of physical/sporting activity outside school hours. Energy expenditure [in metabolic equivalents (METs)] was an overall estimation, calculated from the assessed energy expenditure of 1 school day, 2 weekend days, and an average day during summer holidays. The questionnaires were designed on the basis of the previous day's activity checklist (30); they were previously translated and validated (31) for the Spanish population. These questionnaires include a list of the most common activities undertaken by adolescents, and the subjects marked those in which they had been involved. MET values were assigned to each, according to the classification of energy expenditure for each activity (32,33). The PAI was calculated from the sum of the MET values for each activity. After principal component analysis with varimax rotation identified, a single axis was obtained with an auto value of 2.23, which explained 55.9% of the variance regarding the practice of physical activity. The sensitivity and specificity for the PAI were determined, and a cut-off point was obtained from the receiver operating characteristic curve (34) to distinguish between active and non-active subjects; this was calculated using the highest value of the Youden index (35). The area under the curve was 0.766 with a standard error of 0.011, showing the PAI to have intermediate discriminating power. The optimum cut-off point discriminating between active and non-active adolescents was −0.44.

The time spent in sedentary activities, which included television viewing and computer/video games, was recorded by questionnaire (36) and divided into two classes (≤2 and >2 h/d). A further question concerned active commuting to school, which was divided into two classes (0 to 15 and >15 min/d).

Assessment of Socioeconomic Status

Socioeconomic status was assessed by examining paternal educational level and occupation. The subjects were accordingly classified into five categories: low, medium-low, medium, medium-high, and high socioeconomic status.

Statistical Analysis

Means and standard deviation values for the different variables were recorded. For comparisons of variables with respect to gender and pubertal maturation status (pubescent, Tanner Stages 2 to 4; postpubescent, Tanner Stage 5), the Student's *t* test (for parametric variables) or Mann Whitney *U* test (for non-parametric variables) were used. One-way ANOVA (parametric variables) and the Kruskal-Wallis test (non-parametric variables) were used in analyses involving age. The dichotomous variable (active vs. non-active) was only used as a descriptive indicator of participation in leisure-time physical activity (Table 1). The PAI (continuous variable) was used in the rest of the statistical analysis.

The associations of BMI and waist circumference with physical activity patterns and cardiorespiratory fitness ($\dot{V}O_{2max}$) were assessed by analysis of covariance, taking into account age and pubertal maturation status, and with the additional adjustment of waist circumference for height. General linear models with BMI and waist circumference as dependent variables were used to evaluate the independent association of leisure-time physical activity, sedentary activities, and cardiorespiratory fitness with adiposity. In this analysis, additional adjustment was made for potential confounders such as age, pubertal maturation status, height (only for waist circumference), active commuting to school, and socioeconomic status. To determine whether $\dot{V}O_{2max}$ was associated preferentially with abdominal fat, the relationship between waist circumference and $\dot{V}O_{2max}$ was further studied after additional adjustment for BMI. Because an interaction between BMI and $\dot{V}O_{2max}$ was noted, and given that physical activity patterns and lifestyle habits differ between overweight-obese and normal-overweight adolescents (37), this analysis was also performed separately for overweight-obese and normal-weight subjects according to the International Obesity Task Force cut-off points (24). Because physical activity patterns and cardiorespiratory fitness differed between boys and girls (38), all analyses were made separately for boys and girls. All calculations were performed using the SPSS/PC statistical program (version 12.0 for Windows; SPSS, Inc., Chicago, IL). For all analyses, the α error was fixed at 0.05.

Results

Anthropometric Data, Cardiorespiratory Fitness, and Activity Patterns

Table 1 shows the characteristics of the study population. Forty-four percent of the boys fell into Tanner Stage 5; 49% of the girls fell into Stage 4. The boys showed higher anthropometric measurements, BMI, and waist-to-height ratio than the girls. About one-quarter of the boys and one-fifth of the girls were overweight or obese (Table 1). Cardiorespiratory fitness performance, as measured by $\dot{V}O_{2max}$, was higher (by ~9 mL/kg per minute) among the boys. Boys were more physically active than girls (71% compared with 47%). Only 10% of subjects reported active commuting to school involving 15 min/d or more. Two thirds of the boys and one-half of the girls devoted >2 h/d to sedentary activities. In both boys and girls, waist circumference and $\dot{V}O_{2max}$ increased significantly with age, whereas participa-

Table 1. Characteristics (means ± standard deviation) of the study subjects by gender

Characteristic	Boys (n = 1445)	Girls (n = 1403)
Age (13 to 18.5 years)	15.4 ± 1.4	15.4 ± 1.4
Tanner stage (%)		
Stage 2	4.9	0.8*
Stage 3	14.0	10.8*
Stage 4	37.0	49.2*
Stage 5	44.2	39.3*
Weight (kg)	64.2 ± 13.2	56.4 ± 9.6‡
Height (m)	1.71 ± 0.08	1.61 ± 0.06‡
BMI (kg/m^2)	21.8 ± 3.6	21.5 ± 3.3*
Overweight including obesity (%)§	25.7	19.1‡
Waist circumference (cm)	76.8 ± 9.5	71.1 ± 7.9‡
Waist-to-height ratio (cm/m)	45.0 ± 5.3	44.0 ± 4.8‡
Vo_{2max} (mL/kg per minute)	50.9 ± 11.7	42.1 ± 8.0‡
1st Quartile	$x < 43.5$	$x < 36.8$
2nd Quartile	$43.5 \leq x < 49.3$	$36.8 \leq x < 40.7$
3rd Quartile	$49.3 \leq x < 55.0$	$40.7 \leq x < 45.4$
4th Quartile	$x \geq 55.0$	$x \geq 45.4$
Leisure-time physical activity: participation (%)	71.0	46.7‡
Active commuting to school		
Time (min/d)	10.7	11.2
>15 min/d (%)	9.6	12.6†
Sedentary activities		
Time (h/d)	2 h 58 min ± 1 h 56 min	2 h 11 min ± 1 h 31 min‡
> 2 h/d (%)	65.3	46.4‡
Parental socioeconomic status (%)		
Low	6.7	7.4
Medium-low	26.3	23.7
Medium	33.3	38.8
Medium-high	25.6	24.2
High	8.1	5.8

Vo_{2max}, maximum oxygen consumption.
* $p \leq 0.05$ boys vs. girls.
† $p \leq 0.01$ boys vs. girls.
‡ $p \leq 0.001$ boys vs. girls. Otherwise not significant.
§ International gender- and age-specific BMI cut-off points (24).

tion in leisure-time physical activity and sedentary activities diminished. However, after post hoc analysis, a significant decline was seen ($p \leq 0.001$) only in girls 15 years old and older and in boys 16 years old and older. Age-specific BMI values are shown in Table 2. Postpubescent (Tanner Stage 5) girls showed higher BMIs, waist circumferences, and leisure-time physical activity coefficients than pubescent girls (Tanner Stages 2 to 4) girls. A lower Vo_{2max} was also noted in postpubescent girls. These differences were not observed in boys.

Association of BMI and Waist Circumference with Activity Patterns and Vo_{2max}

Table 3 shows the univariate associations of BMI and waist circumference with activity patterns and cardiorespiratory fitness. No difference was found in BMI or waist circumference between the adolescents who practiced leisure-time physical activity and those who did not. With respect to activity patterns (physical activity, sedentary activities, and active commuting to school), the strongest relationships were observed between sedentary activities

Table 2. Age-specific BMI values (means ± standard deviation) of the study subjects by gender

Age (years)	Boys ($n = 1445$)	Girls ($n = 1403$)
13.5†	20.6 ± 3.8	21.5 ± 3.7
14.5	21.5 ± 3.6	21.3 ± 3.7
15.5*	22.0 ± 3.6	21.4 ± 3.0
16.5	21.8 ± 3.2	21.6 ± 3.1
17.5‡§	22.9 ± 3.6	21.7 ± 3.2
Total*	21.8 ± 3.6	21.5 ± 3.3

Age is listed at the half-year point for the entire year; for example, 13.5 years represents 13.0 to 13.99 years old. Differences between age groups: in boys, $p \leq 0.001$ between 13.5 and 15.5, 13.5 and 16.5, 13.5 and 17.5, 14.5 and 17.5, and 16.5 and 17.5, $p \leq 0.05$ between 15.5 and 17.5. Otherwise not significant. In girls, no significant difference between age groups.
* $p \leq 0.05$ boys vs. girls.
† $p \leq 0.01$ boys vs. girls.
‡ $p \leq 0.001$ boys vs. girls. Otherwise not significant.
§ 17.0 to 18.5 years old.

and waist circumference for boys ($p = 0.006$) and between active commuting to school and waist circumference for girls ($p = 0.002$). Cardiorespiratory fitness (Vo_{2max}) was inversely associated with both BMI and waist circumference in boys and girls ($p \leq 0.001$). Multivariate general linear models were used to assess the independent associations of Vo_{2max} and sedentary activities using BMI and waist circumference as dependent variables (Table 4). Adjustments for potential confounding factors (age, pubertal maturation status, socioeconomic status, practice of leisure-time physical activity, and active commuting to school) were made. Waist circumference was adjusted for height. In both boys and girls, sedentary activities were directly related to waist circumference, independent of Vo_{2max} ($p = 0.02$ for both boys and girls). The association between sedentary activities and BMI, independent of Vo_{2max}, was only significant in boys ($p = 0.04$). In both boys and girls, Vo_{2max} was negatively associated with BMI, independent of leisure-time physical activity and sedentary activities ($p = 0.006$ for boys and 0.0001 for girls). Similarly, Vo_{2max} was inversely related to waist circumference ($p = 0.001$ for boys and 0.005 for girls). The adjusted linear regression model showed that a strongly sedentary lifestyle (>2 h/d) was associated with a 2.5-cm waist circumference increase in boys and a 1.5-cm increase in girls. Up to 10% of waist circumference variance in boys and 18% in girls was explained by sedentary activities. Compared with 4th quartile results, the 1st quartile values for cardiorespiratory fitness ($Vo_{2max} < 43.5$ in boys and <36.8 mL/kg per minute in girls) were associated with 5.6- and 2.9-cm increases in waist circumference in boys and girls, respectively. The Vo_{2max} explained up to 13% of the variance in waist circumference in boys and 16% in girls. After paired analyses of the Vo_{2max} quartiles, significant differences were found between Quartile 1 and Quartile 4 in boys but not between Quartiles 2 and 4 or 3 and 4. Significant differences were also found between Quartiles 1 and 4 and between Quartiles 2 and 4 in girls but not between Quartiles 3 and 4. Up to 15% of waist circumference variance in boys and 18% in girls was explained by sedentary activity and cardiorespiratory fitness combined.

To determine whether Vo_{2max} was related to the amount of abdominal fat, the correlation between the former and waist circumference was examined after adjustment for BMI; age was taken into account as a covariable. Figure 1 shows the association between BMI-adjusted waist circumference and Vo_{2max} in adolescents with a BMI above (Fig. 1a) and below (Fig. 1b) the International Task Force cut-off point (24). In this adjusted model, no significant association was observed in normal-weight subjects. However, BMI-adjusted waist circumference was inversely correlated with Vo_{2max} in overweight-obese boys ($p \leq 0.05$). A similar trend was seen in girls ($p \leq 0.1$). The same model was performed for sedentary activity, and no significant association was found for either normal-weight or overweight-obese subjects.

Discussion

The relationships among physical activity, sedentary activities, and/or cardiorespiratory fitness and abdominal adiposity has been studied in adults (18–20,39,40). The present study is the first to evaluate these associations in a large cohort of adolescents.

The most interesting finding was that moderate to high levels of cardiorespiratory fitness are associated with lower abdominal adiposity (as measured by waist circumference) in both boys and girls. This association remained after adjustment for age, pubertal maturation status, and confounding factors (height, socioeconomic status, leisure-time physical activity, and active commuting to school). This suggests a mechanism exists by which cardiorespiratory fitness attenuates the health risk of obesity. Cardiorespiratory fitness in the prevention and treatment of obesity-related disease should, therefore, be encouraged. Moreover, in overweight or obese adolescents, a beneficial connection between waist circumference and cardiorespiratory fitness was observed after adjusting for BMI ($p \leq 0.05$ in boys, $p \leq 0.1$ in girls). Similar observations have been reported in adults (19–21) but, to the best of our knowledge, never before in children or adolescents. The fact that sedentary activity was not associated with BMI-adjusted waist circumference suggests that, at least in overweight-obese adolescents, cardiorespiratory fitness might be specifically

Table 3. BMI and waist circumference according to activity pattern and cardiorespiratory fitness (VO_{2max}) by gender (means ± standard deviation)

	Boys (n = 1445)				Girls (n = 1403)			
	BMI (kg/m²)*		**Waist circumference (cm)*†**		**BMI (kg/m²)***		**Waist circumference (cm)*†**	
Sedentary activities								
0 to 2 h/d	21.6 ± 3.1	p = 0.026‡	76.2 ± 8.1	p = 0.006‡	21.3 ± 3.1	p = 0.028‡	71.0 ± 7.8	p = 0.082
>2 h/d	22.0 ± 3.9		77.6 ± 10.1		21.8 ± 3.6		71.8 ± 8.1	
Active commuting to school								
0 to 15 min/d	21.8 ± 3.6	p = 0.144	76.9 ± 9.3	p = 0.341	21.5 ± 3.4	p = 0.149	71.5 ± 8.1	p = 0.002‡
>15 min/d	22.3 ± 3.8		78.1 ± 10.6		21.1 ± 2.6		69.6 ± 6.2	
Leisure-time physical activity								
1st Quartile	22.2 ± 4.1	p for trend = 0.557	77.8 ± 10.6	p for trend = 0.239	21.7 ± 3.4	p for trend = 0.340	71.9 ± 7.9	p for trend = 0.068
2nd Quartile	22.0 ± 3.6		77.8 ± 9.2		21.4 ± 3.1		70.9 ± 7.4	
3rd Quartile	21.7 ± 3.2		76.3 ± 8.1		21.3 ± 3.0		70.5 ± 7.6	
4th Quartile	21.6 ± 3.5		76.3 ± 9.5		21.8 ± 3.8		71.3 ± 9.3	
VO_{2max} (mL/kg per minute)								
1st Quartile	23.1 ± 4.2	p for trend ≤ 0.001§	80.4 ± 11.3	p for trend ≤ 0.001§	22.5 ± 3.9	p for trend ≤ 0.001§	73.3 ± 9.4	p for trend ≤ 0.001§
2nd Quartile	21.9 ± 3.4		77.1 ± 9.1		21.7 ± 3.4		71.4 ± 8.0	
3rd Quartile	21.0 ± 2.7		75.0 ± 7.2		20.8 ± 2.5		70.1 ± 6.5	
4th Quartile	21.1 ± 2.9		75.2 ± 7.3		20.9 ± 2.7		69.5 ± 6.7	

VO_{2max}, maximum oxygen consumption.
* Adjustment for age.
† Adjustment for height.
‡ In these cases, the analysis was performed separately for pubescent (Tanner Stages 2 to 4) and postpubescent (Tanner Stage 5) subjects. The difference was significant only in pubescent subjects ($p \leq 0.05$).
§ In these cases, the same analysis was performed, and the difference remained significant for both groups ($p \leq 0.01$ to ≤ 0.001). Comparisons were made by analysis of covariance.

Table 4. Multiple regression linear analyses with BMI and waist circumference as dependent variables and cardiorespiratory fitness (Vo_{2max}) and sedentary activities as explanatory variables

	Vo_{2max}				Sedentary activities		
					≤2 Hours†		
	Quarter 1* [β-coefficient (SE)]	Quarter 2* [β-coefficient (SE)]	Quarter 3* [β-coefficient (SE)]	p	β-coefficient (SE)	p	% Total variance explained (R^2)
BMI‡							
Boys	2.37 (0.64)	1.22 (0.64)	−0.51 (0.66)	0.006	−0.72 (0.90)	0.043	11
Girls	2.17 (0.67)	1.57 (0.65)	0.23 (0.68)	<0.001	0.33 (0.65)	NS	14
Waist circumference‡§							
Boys	5.61 (1.54)	2.06 (1.53)	−1.36 (1.57)	0.001	−2.46 (2.15)	0.024	15
Girls	2.93 (1.52)	2.97 (1.48)	0.77 (1.54)	0.005	−1.47 (1.47)	0.028	18

Vo_{2max}, maximum oxygen consumption; SE, standard error.
* 1st Quartile against 4th Quartile, 2nd Quartile against 4th Quartile, 3rd Quartile against 4th Quartile.
† Adolescents who devoted 0 to 2 h/d to sedentary activities compared with those who spent more than 2 h/d in sedentary activities.
‡ Adjustment for age, pubertal maturation status (Tanner stages), socioeconomic status, practice of leisure time physical activity, and active commuting to school.
§ Additional adjustment for height.

related to abdominal adiposity, rather than sedentary habits. Because waist circumference is recognized as a good indicator of cardiovascular risk in adolescents (41) and later in life (8–11), cardiorespiratory fitness may have a beneficial impact on cardiovascular risk in young people. A number of important longitudinal studies have shown that the level of physical fitness during infancy and adolescence largely determines one's physical fitness during adulthood (42,43). In addition, poor physical fitness during these stages of life is associated with later cardiovascular risk factors such as hyperlipidemia, hypertension, and obesity (44–46). Finally, several longitudinal studies (47,48) have shown that, rather than the level of physical activity, the level of physical fitness in childhood and adolescence (especially aerobic

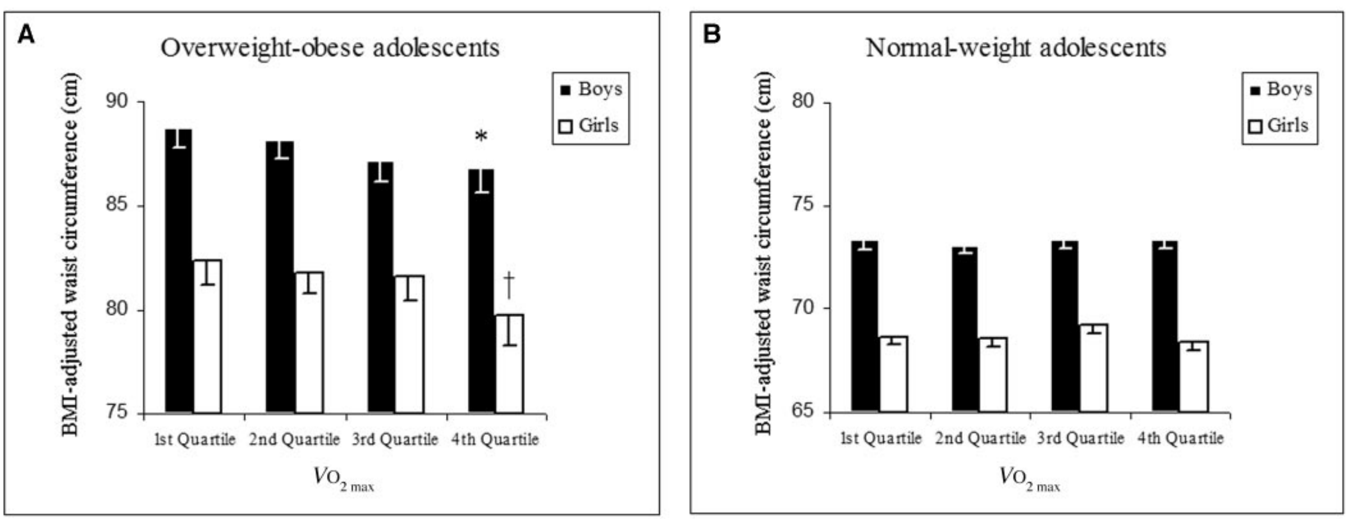

Figure 1: BMI-adjusted waist circumference (means ± standard error) according to cardiorespiratory fitness (Vo_{2max}) quartiles in adolescents with a BMI above (A) and below (B) the International Task Force cut-off point (24). Adjustment for age: * $p \leq 0.05$ and † $p \leq 0.1$.

capacity and muscular strength) determines the future risk of cardiovascular disease. This highlights the importance of routine measurements of waist circumference and cardiorespiratory fitness in clinical practice, especially in the overweight-obese adolescent population.

The high prevalence of sedentariness in the adolescent population observed in other countries can also be seen in Spain, where 46% of girls and 65% of boys spend 2 or more h/d watching television or playing computer/video games. In fact, these figures are much higher than the 33% to 40% seen in European data (18,49,50). They are lower, however, than in the U.S., where figures of 75% are seen (51). In the present study, 47% of the girls and 71% of the boys practiced physical activity in their leisure time; this is similar to recent U.S. observations where the prevalence of participation was 53% for girls and 70% for boys (52). However, they are slightly lower than in France, where the prevalence of participation is 58% among girls and 75% among boys (18).

A strong point of the present study is that no association was observed between activity and BMI, or between the former and waist circumference, after adjustment for age and pubertal maturation status and even after controlling for sedentary activities. This contrasts with a recent study conducted on adolescents 12 years old (18) in which an inverse relationship between both BMI and waist circumference with physical activity was noted. The fact that the influence of age and pubertal maturation status were not taken into account in this other study might explain these differences. Paradoxically, in a recent study of French adolescents (53), physical activity was not associated with adiposity indicators in either sex at baseline. However, after adjustment for baseline values, all adiposity indicators (waist circumference included) were higher in girls who decreased their relative level of moderate physical activity during the 2 years of follow-up. No such association was found, however, in adolescent boys. On the other hand, cardiorespiratory fitness seems stronger than self-reported physical activity as a predictor of health outcomes because fitness assessment is less prone to misclassification (54) and because factors other than physical activity may influence fitness levels and health status through related biological pathways. This fact needs to be considered when comparing the results between self-reported physical activity and those of cardiorespiratory fitness or objectively measured physical activity and when comparing self-reported physical activity results with those of others papers. Anyway, the relationship between physical activity and total or central adiposity in children and adolescents is now controversial (16,17). Given that cardiorespiratory fitness is presumably a marker for physical activity, the disassociation between both variables seen in this study seems paradoxical. However, it is necessary to highlight that only vigorous, but not light or moderate, physical activity could be strongly related to cardiovascular fitness, as Gutin et al. (55) have recently reported.

In the present study, sedentary activities were significantly and inversely associated with BMI, as previously reported by several authors (56–60). Even after adjustment for confounding variables, the associations between sedentary activities and BMI or waist circumference were significant and independent of leisure-time physical activity (except for that between sedentary activities and BMI in girls). This suggests that sedentary activities not only represent a lack of physical activity but probably also reflect other unfavorable factors such as an increased energy intake during television watching and the negative effects of food advertising (61). In agreement with this, active commuting to school was negatively associated with waist circumference in girls, indicating that active commuting to school might be representative of a lifestyle or act as a consistent contribution to total daily physical activity by which a reduction in abdominal adiposity may occur. In contrast, other authors have found a positive relationship between physical activity and waist circumference in adolescents (18). It is noted that findings for BMI and waist circumference were very similar, and this is probably because a strong association was found between BMI and waist circumference in the present sample ($R = 0.88$ and 0.81 in boys and girls, respectively; adjustment for age).

Multiple regression analysis explained the characteristics of the association between cardiorespiratory fitness and waist circumference in the present study subjects. Very low cardiorespiratory fitness levels ($V\text{O}_{2max}$ <43.5 in boys and <36.8 mL/kg per minute in girls) were associated with 5.6- and 2.9-cm increases in male and female waist circumference, respectively, compared with the results seen in subjects with a $V\text{O}_{2max} \geq 55.0$ (boys) and ≥45.4 mL/kg per minute (girls). The significant differences between $V\text{O}_{2max}$ quartiles suggests that achieving a Quartile 2 $V\text{O}_{2max}$ level (43.5 mL/kg per minute or more) in boys and a Quartile 3 level in girls (40.7 mL/kg per minute or more) might be enough to maintain waist circumference. Curiously, the minimum $V\text{O}_{2max}$ level associated with a significantly lower waist circumference in boys (43.5 mL/kg per minute) was similar to the lower limit for a low risk of cardiovascular disease (42 mL/kg per minute) proposed by the Cooper Institute for Aerobics Research (62).

The process by which excess body weight develops is complex and involves both lifestyle and genetic determinants. As in most other cross-sectional studies, even after adjustment for confounding factors, a substantial amount of BMI and waist circumference variance remained unexplained in the present multivariable models. It is also noteworthy that the present cross-sectional study only provides suggestive evidence concerning causal relations between cardiorespiratory fitness and abdominal adiposity; in addition, the direction of the cause can be suggested but never stated. Quantitative data on food intake and genetic aspects were not collected, and the use of self-reported activity data means some error is inherent. Moreover, recent studies have shown that vigorous physical activity, but not light or moderate, are inversely associated with adiposity (55). Therefore, given that the questionnaire used in the present study provides neither the intensity level of physical activity, nor the frequency or accurate duration of physical activity, it is necessary to be cautious with the physical activity-related conclusions. Further research with objective methods for measuring physical activity, such as accelerometry, will provide accurate information about physical activity patterns (intensity, frequency, and duration), helping to clarify this issue.

In conclusion, the results of this study suggest that moderate to high levels of cardiorespiratory fitness, but not physical activity, are associated with lower abdominal adiposity (as measured by BMI and waist circumference). In adolescents, a $\dot{V}O_{2max}$ of 43.5 mL/kg per minute for boys and 40.7 mL/kg per minute for girls might be considered the minimum level for limiting abdominal fat accumulation.

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Early determinants of physical fitness

(Papers V and VI)

Are muscular and cardiovascular fitness partially programmed at birth? Role of body composition

Ortega FB, Labayen I, Ruiz JR, Martín-Matillas M, Vicente-Rodríguez G, Redondo C, Wärnberg J, Gutiérrez A, Sjöström M, Castillo MJ, Moreno LA.

V

submitted

Are muscular and cardiovascular fitness partially programmed at birth? Role of body composition

Short title: Birth weight and adolescent fitness

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LIST OF ABREVIATION

AVENA	Alimentación y Valoración del Estado Nutricional de los Adolescentes / Feeding and assessment of nutritional status of Spanish adolescents
ANCOVA	Analysis of the covariance
ANOVA	Analysis of the variance
BMI	Body mass index
SD	Standard deviation
TV	Television
VO_{2max}	Maximal oxygen consumption

ABSTRACT

Objective: To determine whether birth weight is associated with handgrip strength and cardiovascular fitness in adolescence, and if so, how these associations are influenced by current body composition.

Study design: A total of 1,801 adolescents (983 females) aged 13-18.5 years from the AVENA study were gathered. Handgrip strength and cardiovascular fitness were assessed using the handgrip test and the 20m shuttle run test, respectively.

Results: Birth weight was positively associated with handgrip strength in females, after controlling for current age, gestational age, breast feeding, and adolescent body mass index (P=0.002), percentage body fat (P<0.001) or waist circumference (P=0.005), but not when controlling for fat free mass. The associations were similar, yet weaker, in males. Females with high birth weight (>90^{th} centile), presented a higher handgrip strength than those with normal (10^{th}-90^{th} centile) or low (<10^{th} centile) birth weight, after adjusting for percentage body fat (P=0.004). After adjustment for adolescent fat free mass, all the differences become non-significant. Birth weight was not associated with cardiovascular fitness.

Conclusions: High birth weight was associated with higher handgrip strength in adolescents, especially in females, yet these associations seem to be highly explained by fat free mass.

INTRODUCTION

The nutritional and hormonal milieu of the fetus is an indirect consequence of the maternal lifestyle, particularly in relation to nutrition and physical exercise.[1, 2] It is hypothesized that intra-uterine under- or over-nutrition can alter the gene expression of the fetus, causing developmental adaptations that may lead to permanent changes in physiology and metabolism; changes that may have consequences later in life.[3, 4] Birth weight is an established index of the intra-uterine conditions, and it has shown a programming effect on later body size and body composition.[4, 5] However, less is known about the associations between birth weight and physical fitness later in life. Both muscular strength and cardiovascular fitness are main components of physical fitness. Both are nowadays considered emerging risk factors for cardiovascular disease and powerful health markers already at childhood and adolescence.[6] It is therefore of interest to examine the associations of birth weight with handgrip strength and cardiovascular fitness, and how these associations are modified by body size and body composition parameters. The available information in this regard is rather scarce in young people. It has been reported a lower physical fitness level, including strength and cardiovascular fitness, in pre-term children and adolescents (extremely low birth weight individuals) compared to their peers born at term,[7, 8] while less is known about the programming effect of birthweight on these physical fitness components in adolescents born at term.

This study is a comprehensive investigation of the relationship of birth weight with both handgrip strength and cardiovascular fitness in a large sample of healthy Spanish adolescents and examines how these associations are influenced by body size and body composition.

METHOD

Study sample and design

The data presented in this paper were gathered as a part of the AVENA study (*Alimentación y Valoración del Estado Nutricional de los Adolescentes Españoles* [Food and Assessment of the Nutritional Status of Spanish Adolescents]). The complete methodology has been published elsewhere.[9] In short, the AVENA participants were adolescents aged 13–18.5 years. Given the heterogeneity of this population, individuals from public and private secondary schools and technical colleges were included. Sampling was multi-staged, performed at random, and stratified by town of origin (five Spanish cities), socioeconomic status, sex and age. Subjects with metabolic diseases, who were pregnant, or who were alcohol or drug abusers were excluded. The variable that showed the greatest variance in the population - body mass index (BMI)- was used to determine the sample size. A total of 2100 subjects were deemed necessary for the full study to be representative of the population. These subjects were distributed by cities and proportionally by sex and age (13, 14, 15, 16, and 17-18.5 years).

After excluding those adolescents from whom birth weight, age of gestation and handgrip strength data were not available, as well as those born at <35 weeks of gestation, a total of 1801 adolescents, 818 males and 983 females, were included in this study. The 99.3% and 98.5% of those adolescents, males and females respectively, were Caucasian.

A comprehensive verbal description of the nature and purpose of the study was given to the adolescents, their parents and their teachers. Written consent to participate was requested from both parents and adolescents. The study protocol was performed in accordance with the ethical standards laid down in the 1975 Declaration of Helsinki (as revised in Hong-Kong in 1989 and in Edinburgh in 2000), and approved by the Review Committee for Research Involving Human Subjects of the Hospital Universitario Marqués de Valdecilla (Santander, Spain).

Neonatal data

Birth weight (kg) and gestational age at birth were obtained from health records.[5, 10] Most of the participants, 85.8% of males and 85.6% of females, were born between 35 and 40 weeks of gestation.

Handgrip strength and cardiovascular fitness

Reference values of handgrip strength and cardiovascular fitness for the participants in the AVENA study, as well as detailed information about the protocol used, have been reported by Ortega et al.[11] Briefly, handgrip strength was assessed by means of the *handgrip test* using a hand dynamometer with adjustable grip (TKK 5101 Grip D; Takey, Tokio Japan). Two attempts per hand were performed and the best score was retained. The average of the scores achieved by both hands was used in the analysis. Cardiovascular fitness was assessed by means of the *20m shuttle run test*: The adolescents performed the test as previously described by Léger et al.[12] The equations of Léger et al.[12] previously validated in young people,[12, 13] were used to estimate the maximum oxygen consumption (VO_{2max}) from the test score.

Physical examination

Reference values of anthropometric and body composition indexes, as well as the description of the procedures used in the AVENA study have been previously published.[14] In short, weight and height were measured and BMI was calculated as weight/height squared (kg/m^2). Waist circumference was measured, using an inelastic tape, horizontally midway between the lowest rib margin and the iliac crest, at the end of gentle expiration. Percentage body fat was calculated from skinfold thicknesses using Slaughter's equations,[15] since they have been considered to be accurate in this particular population of adolescents.[16] Fat free mass (kg) was derived by subtracting fat mass from total body weight.

Pubertal status was self-reported and classified according to the method of Tanner and Whitehouse.[17] A good concordance has been demonstrated between self-reported sexual maturation status and when assessed it by a trained researcher through brief observation.[18, 19]

Other factors studied

Some factors potentially related to birth weight, physical fitness or body composition, were also studied:

Breast feeding: The parents were asked to answer the following question concerning breast feeding: *How long was your child breastfed?* The possible answers were: only baby-bottle, baby-bottle + breast, <1 month, ≥1 and <2 months, ≥2 and <3 months, ≥3 and <4 months, ≥4 and <5 months, or ≥5 months.

Leisure-time sporting activity: It was determined from the adolescent's answers to a question designed specifically for the AVENA study:[9] *Do you undertake any physical-sporting activity after school?* The answer was classified as no physical-sporting activity or as one or more physical-sporting activities.

Television (TV) viewing: The time spent in TV viewing was also self-reported by the adolescents and divided into two categories: ≤ 2 h/day and > 2 h/day.

Statistical analysis

Physical characteristics of the study sample by sex are presented as means and standard deviations (SD), unless otherwise stated. Variables with skewed distribution were log transformed to obtain a more symmetrical distribution. Given that in previous work conducted in this same sample,[20] we found interaction factors for sex×birth weight with adolescent body composition, all analyses were performed separately for males and females.

After bivariate correlation analysis (Pearson correlation) among the main study variables, the relationships between birth weight, handgrip strength and cardiovascular fitness (VO_{2max}) were analyzed by linear regression in an extended-model approach. Model I included only the predictor (birth weight) and the dependent variable (either handgrip strength or cardiovascular fitness). Model II: a set of confounders, i.e. current age, gestational age and breast feeding, was entered into the model. Model III: height was additionally entered into the model (confounders + height). Model IV: BMI was entered into the model instead of height (confounders + BMI). Model V: fat free mass was entered into the model instead of BMI (confounders + FFM). Model VI: percentage body fat was entered into the model instead of previous indexes (confounders + BF%). Model VII: waist circumference was entered into the model instead of previous indexes (confounders + WC). Separate models were built for each body size and body composition variable in order to determine how each of them influences or does not influence the associations between birth weight and physical fitness variables.

Finally, differences in physical fitness among birth weight groups were analyzed by one-way analysis of the covariance (ANCOVA). For this purpose, the birth weight was categorized into three groups according to the top and bottom sex-specific deciles (10^{th} and 90^{th} centiles): low birth weight, <10^{th} centile; normal birth weight, 10^{th} to 90^{th} centile; and high birth weight, >90^{th} centile. The set of confounders together with body size and body composition indexes were entered into consecutive models as covariates. We also examined how different cut-off values could affect the results. For this purpose, the analysis was redone using the 5^{th} and 95^{th} sex-specific centiles, and the widely used birth weight thresholds of 2,500g and 4,000g, as cut-off values for categorizing the adolescents into birth weight groups.

The statistical models used all subjects with available covariate information in order to make maximum use of the data; therefore sample sizes vary between models. Restriction of the analysis to a subset of individuals with complete data on all covariates did not substantially alter the results from either regression analysis or ANCOVA.

All calculations were performed using SPSS v.15.0 software for Windows. For all analyses, the significance level was 5%.

RESULTS

Physical characteristics of the study sample by sex are shown in table 1. Bivariate correlations among birth weight, physical fitness, body size and body composition variables are shown in table 2. Positive correlations between birth weight and handgrip strength was observed in females (P<0.001) and males (borderline significance, P=0.063). No significant correlation was found between birth weight and cardiovascular fitness either in females or males.

Associations between birth weight and handgrip strength

Linear regression statistics, showing estimated change in mean handgrip strength and cardiovascular fitness scores per kilogram increase in birth weight in male and female adolescents are shown in table 3.

In females, birth weight was positively associated with handgrip strength (P<0.001). This association remained significant after controlling for age, gestational age and breast feeding (P=0.001), and after additional controlling for BMI (P=0.002), percentage body fat (P<0.001) and waist circumference (P=0.005). The significance of the association disappeared when fat free mass or height was entered into the model. In males, birth weight was also positively associated with handgrip strength, after controlling for age, gestational age and breast feeding (P=0.010), and after additional controlling for percentage body fat (P=0.039). The results were not substantially altered when sexual maturation status was entered into the models instead of age, or when the analyses were additionally controlled for leisure-time sporting activity and TV viewing (data not shown).

Handgrip strength according to birth weight groups

Handgrip strength levels by birth weight groups (<10^{th}, 10^{th} to 90^{th} and >90^{th} centiles) were analyzed by ANCOVA (Figure 1). In female adolescents, handgrip strength levels were higher in the high birth weight group compared to either the normal (P=0.004) or low birth weight (P=0.006) groups, after adjustment for the set of confounders and percentage body fat. When height was entered into the model, these differences become weaker and non-significant, and when fat free mass was entered into the model instead of height, no differences were observed. Similar patterns, but non-significant, were found in male adolescents. No differences were found between low birth weight and normal birth weight groups either in females or males.

The results were not substantially altered when different cut-off values for classing the adolescents into birth weight groups (i.e. 10^{th} and 90^{th} centiles, 5^{th} and 95^{th} centiles, or 2,500g and 4,000g thresholds) were used (data not shown).

Associations between birth weight and cardiovascular fitness

No association was found between birth weight and cardiovascular fitness level in either male or female adolescents, except for males when the analysis was controlled for the set of confounders and waist circumference (positive borderline association, P=0.047).

DISCUSSION

Associations between birth weight and handgrip strength

Birth weight was positively associated with handgrip strength in adolescents, especially in females. These associations were not substantially affected by different adiposity indexes, such as BMI, percentage body fat and waist circumference, but were highly explained by height and mainly fat free mass. As far as we are aware, no previous data based on large-scale studies have examined the associations between birth weight and handgrip strength, accounting for body size and body composition parameters, in young people born at term. Some literature is however available in adults.[21-23] The results reported in these studies support the positive associations between birth weight and handgrip strength observed in this study. By contrast, this association was not observed in another study, which used other strength tests, such as the static arm pull and the high jump tests.[24] In tests involving jumps or in those that require holding the body weight with hands/arms (also called weight-bearing exercises), the performance is highly affected by the individual's body weight, a problem that is not easily handled in the statistical analysis, even when controlling for body weight. This can explain the discrepancies.

The genetic contribution to muscle strength, as assessed by heritability studies, may be up to 65%,[25] but this still leaves scope for the influence of lifestyle factors. A major lifestyle correlate of muscle strength is sporting activities, and hence, also the lack of activity. In this regard, our data suggest that the association between birth weight and handgrip strength in female adolescents is independent of their sporting activity level and the time spent in TV viewing.

The physiological rationale of the associations between birth weight and adolescent handgrip strength can be hypothesized. The programming effect of birth weight on adolescent grip strength may be due to the fact that, although most muscle growth and fibre-type transformations occurs postnatally, the number of muscle fibers is also partially fixed by the time of birth.[26, 27] This hypothesis is supported by animal studies showing that the number of muscle fibers can be modified by intrauterine nutrition.[28]

The association of birth weight with handgrip strength was stronger in females than in males. During adolescence, muscle development is greater in boys than in girls because of the influence of sex hormones[29] or synergism between growth hormones and androgens.[30] The higher "confounding" effect of hormonal activity in males at this age might have partially masked the actual effect of birth weight on adolescent handgrip strength.

Several authors have used a scored birth weight for gestational age, computed as the individual birth weight observations minus the expected birth weight for each gestational age and sex, according to population-specific reference values. We have also calculated the scored birth weight according to reference values for our population,[31] and the results remained unchanged.

Handgrip strength according to birth weight groups

Based on the positive linear association observed between birth weight and handgrip strength, it could be concluded that individuals with a low birth weight could have lower handgrip strength later in life. However, our analysis across different birth weight groups suggests that a low birth weight is not associated with a decreased handgrip strength level at adolescence, when comparing with a normal birth weight. The results showed that it is a high birth weight that is associated with increased handgrip strength in adolescents, especially in females. Future studies concerning birth weight should consider the possibility of a non-linear association between birth weight and outcome variables.

The analysis by birth weight groups confirms the regression-derived results above discussed. The associations between birth weight and handgrip strength are independent of adiposity, but highly explained by height and mainly fat free mass. Muscle strength depends on morphological factors, such as size and number of muscle fibres, and neurological factors (motor units synchronization and recruitment). Since lean mass, a main component of fat free mass, is essentially a surrogate index of these morphological factors, it is reasonable, from a physiological point of view, that the associations between birth weight and handgrip strength are explained by fat free mass. This study has shown, for first time, to what extent fat free mass modifies these associations in young people.

Associations between birth weight and cardiovascular fitness

Overall, birth weight was not associated with cardiovascular fitness in the studied adolescents. To our knowledge, only one large-scale study has previously examined early life origins of adolescent cardiovascular fitness in Irish males and females born at term.[32] The authors observed a positive association between birth weight and cardiovascular fitness in children aged 12 years, but not in adolescents aged 15 years. This finding is in accordance with our results.

Running tests, such as the 20m shuttle run test, require the individuals' body weight to be transported when they are being performed. It is well known that body weight is negatively associated with endurance performance in running events; therefore, body weight might also mask a potential association between birth weight and cardiovascular fitness, as measured in this study. More studies involving direct measures of oxygen uptake and using non-weight-bearing test protocols (e.g. cycling) are needed for a better understanding of the association between birth weight and cardiovascular fitness in adolescents.

Study limitations and strengths

Other interesting data, such as length at birth and body composition or physical fitness levels during childhood, were not available in our subjects. Similarly, maternal nutrition and exercise habits,[1, 33] as well as parental body composition indexes,[34] that may influence birth weight and the associations studied here, were not registered in the AVENA study. The biological explanation for the sex differences found in this study is not clear, but it is generally accepted that sex hormones play a key role in these relationships. Unfortunately, we did not measure sex hormones; further studies are required on this topic. On the other hand, the range of potential confounders that have been controlled for and the substantial number of subjects included are notable strengths of this study.

In conclusion, the results suggest that a high birth weight is associated with higher handgrip strength in adolescents, especially in females, yet these associations seem to be highly explained by fat free mass. The findings also suggested that low birth weight adolescents do not show poorer handgrip strength than their peers born with a normal weight. Finally, body weight at birth was not associated with cardiovascular fitness in this study, though further research involving direct measurements of VO_{2max} and non-weight-bearing testing protocols is required for a better understanding of these associations in adolescence.

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Table 1: Descriptive characteristics of the study sample stratified by sex.

	Males (n=818)	Females (n=983)
Neonatal data		
Birth weight (kg)	3.5 ± 0.5	3.3 ± 0.5
Adolescent data		
Age (y)	15.3 ± 1.3	15.4 ± 1.3
Sexual maturation status:		
Tanner stages I/II/III/IV/V (%)	0/4.4/13.7/ 38.2/43.7	0/0.6/11.4/ 49.7/38.4
Weight (kg)	63.9 ± 12.8	56.4 ± 9.6
Height (cm)	171 ± 8.2	162 ± 6.1
Body mass index (kg/m^2)	21.7 ± 3.6	21.5 ± 3.3
Fat free mass (kg)	50.7 ± 7.7	41.6 ± 4.6
Body fat (%) [1]	17.5 ± 1.6	24.8 ± 1.3
Waist circumference (cm) [1]	76.1 ± 1.1	70.6 ± 1.1
Handgrip strength (kg) [2]	35.0 ± 8.0	25.5 ± 4.1
20 m shuttle run (stages)	7.0 ± 2.5	4.2 ± 1.7
Cardiovascular fitness (mL·kg^{-1}·min^{-1})	47.8 ± 6.9	39.8 ± 5.1

All values are mean ± SD, unless otherwise stated. [1] Geometric means. [2] The average of left and right hand scores is shown.

Table 2: Bivariate correlations (Pearson correlation coefficients = r) among birth weight, handgrip strength, cardiovascular fitness and adolescent body size and body composition variables in males and females.

	Birth weight r (*P*)	Height r (*P*)	Body mass index r (*P*)	Fat free mass r (*P*)	Body fat (%) [2] r (*P*)	Waist circumference [2] r (*P*)
Males						
Birth weight	- -	**0.170** (<0.001)	**0.089** (0.012)	**0.140** (<0.001)	**0.090** (0.011)	**0.156** (<0.001)
Handgrip strength	0.065 (0.063)	**0.569** (<0.001)	**0.344** (<0.001)	**0.713** (<0.001)	0.034 (0.334)	**0.328** (<0.001)
Cardiovascular fitness	0.009 (0.810)	0.014 (0.708)	**-0.351** (<0.001)	0.070 (0.060)	**-0.467** (<0.001)	**-0.339** (<0.001)
Females						
Birth weight	- -	**0.226** (<0.001)	**0.077** (0.017)	**0.233** (<0.001)	0.031 (0.335)	**0.091** (<0.001)
Handgrip strength	**0.132** (<0.001)	**0.346** (<0.001)	**0.289** (<0.001)	**0.503** (<0.001)	**0.141** (<0.001)	**0.301** (<0.001)
Cardiovascular fitness	-0.013 (0.700)	0.018 (0.604)	**-0.245** (<0.001)	-0.055 (0.121)	**-0.305** (<0.001)	**-0.207** (<0.001)

[1] The average value between the left and right hand was used in the analysis. [2] Log transformed variables were used in the analysis.

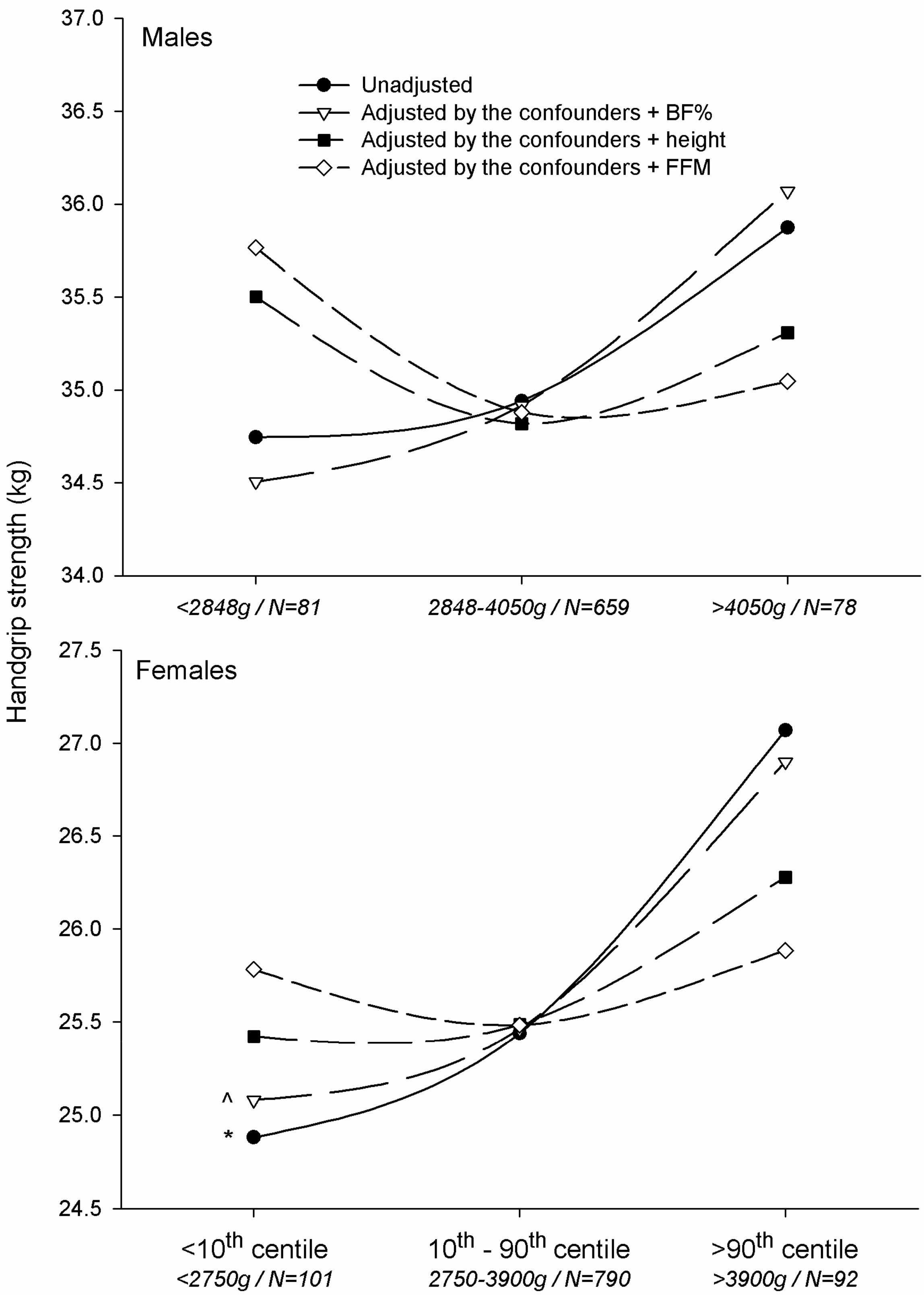
Table 3: Linear regression statistics showing estimated change in mean handgrip strength and cardiovascular fitness (VO_{2max}) scores per kilogram increase in birth weight for male and female adolescents.

		Birth weight (kg)									
		Males					Females				
		N	*β*	*95% CI*		*P*	*N*	*β*	*95% CI*		*P*
Handgrip strength (kg) [1]	No confounder	818	0.954	-0.052	1.960	0.063	983	1.079	0.571	1.587	**<0.001**
	Confounders	811	1.152	0.278	2.025	**0.010**	975	1.018	0.505	1.532	**0.001**
	Confounders + Height	794	-0.163	-0.993	0.666	0.699	937	0.392	-0.115	0.899	0.130
	Confounders + BMI	794	0.640	-0.211	1.490	0.140	936	0.783	0.281	1.284	**0.002**
	Confounders + FFM	791	-0.427	-1.148	0.294	0.245	933	0.027	-0.443	0.497	0.909
	Confounders + BF% [2]	791	0.945	0.047	1.843	**0.039**	934	0.925	0.407	1.444	**<0.001**
	Confounders + WC [2]	792	0.446	-0.426	1.317	0.316	935	0.725	0.223	1.227	**0.005**
Cardiovascular fitness: (VO_{2max}, $mL\cdot kg^{-1}\cdot min^{-1}$)	No confounder	734	0.114	-0.813	1.040	0.810	828	-0.134	-0.817	0.549	0.700
	Confounders	727	0.064	-0.869	0.997	0.893	822	-0.058	-0.728	0.612	0.864
	Confounders + Height	713	0.002	-0.981	0.984	0.997	792	-0.138	-0.833	0.557	0.697
	Confounders + BMI	713	0.644	-0.260	1.547	0.163	792	0.160	-0.498	0.818	0.634
	Confounders + FFM	710	-0.217	-1.186	0.752	0.660	789	0.032	-0.665	0.729	0.928
	Confounders + BF% [2]	710	0.745	-0.102	1.592	0.084	789	0.072	-0.573	0.716	0.827
	Confounders + WC [2]	712	0.930	0.014	1.846	**0.047**	790	0.172	-0.495	0.838	0.613

[1] The average value between the left and right hand was used in the analysis. [2] Log transformed variables were used in the analysis.
The confounders entered into the model were: current age, gestational age and breast feeding. CI, confidence intervals; BMI, body mass index; FFM, fat free mass; BF%, percentage body fat; WC, waist circumference.

FIGURE CAPTIONS

Figure 1: Handgrip strength according to birth weight groups in male and female adolescents: influence of several confounders, body size and body composition indexes.
The symbols show mean values (unadjusted or adjusted) and lines connecting them are just shown as a visual help for observing differences among the means. Data were analyzed by one-way ANCOVA for males and females separately. The set of confounders entered into the model was: current age, gestational age and breast feeding. Percentage body fat (BF%), height or fat free mass (FFM) were consecutively entered into the models.
* $P<0.001$, between >90th centile and 10th – 90th centile or <10th centile groups; otherwise not significant.
^ $P=0.004$, between >90th centile and 10th – 90th centile groups; $P=0.006$, between >90th centile and <10th centile groups; otherwise not significant.


Handgrip strength (kg)
Males
Unadjusted
Adjusted by the confounders + BF%
Adjusted by the confounders + height
Adjusted by the confounders + FFM
37.0
36.5
36.0
35.5
35.0
34.5
34.0
<2848g / N=81
2848-4050g / N=659
>4050g / N=78
Females
27.5
27.0
26.5
26.0
25.5
25.0
24.5
^
*
<10th centile
<2750g / N=101
10th - 90th centile
2750-3900g / N=790
>90th centile
>3900g / N=92

Physical fitness modify the associations between birth weight and adolescent body composition

Ortega FB, Ruiz JR, Labayen I, Redondo C, Breidenassel C, Moreno LA, Castillo MJ

submitted

VI

Physical fitness modify the associations between birth weight and adolescent body composition

Running title: Fitness, body composition and birth weight

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Abstract

The programming effect of birth weight on later body composition has become of increasing interest in recent years. It has been shown that this programming effect may be affected by gender. Physical fitness level could be another factor of influence. This study aimed to examine whether handgrip strength or cardiovascular fitness modify the associations between birth weight and body composition in healthy adolescents. A sample of 1740 adolescents aged 13 to 18.5y, born at more than 35 weeks of gestation, from the AVENA study (942 females) was studied. Weight, height and waist circumference were measured. Percentage body fat was calculated from skinfold thicknesses using Slaughter's equations and fat free mass was derived by subtracting fat mass from total body weight. Handgrip strength and cardiovascular fitness were assessed using the handgrip test and the 20m shuttle run test, respectively. Birth weight was positively associated with later fat free mass in those female adolescents with high cardiovascular fitness (above the median), and with total and central adiposity in those male adolescents with low handgrip strength (below the median). The programming effect of birth weight on fat free mass in females, and on total and central adiposity in males, seems to be dependent on gender, weight status and physical fitness level.

Keywords: Aerobic exercise, childhood obesity, fat distribution, fetal programming, lean body mass

Introduction

The programming effect of birth weight, a surrogate of the intrauterine conditions, on body composition at childhood and adolescence has become of increasing interest in pediatrics and epidemiology in recent years (1-3). It is hypothesized that intrauterine under- or over-nutrition can alter the gene expression of the fetus, causing developmental adaptations that may lead to permanent changes in physiology and metabolism that may have consequences later in life (4). We have previously shown that this programming effect may be affected by gender (5). Body weight at birth is associated with fat free mass in female adolescents, while in male adolescents is more associated to both total and abdominal adiposity (5). Physical fitness level could be another factor of influence.

Both muscular strength and cardiovascular fitness are emerging risk factors and powerful health markers for cardiovascular disease already at childhood and adolescence (6). In addition, there is evidence indicating that physical fitness interacts with fatness in relation to several health outcomes (6). Whether the association between birth weight and later body composition is influenced by physical fitness remains to be elucidated. This study aimed to examine whether handgrip strength or cardiovascular fitness modify the associations between birth weight and body composition in healthy female and male adolescents.

Research Methods and Procedures

Study design

A sample of 1740 adolescents (942 females and 798 males aged 13–18.5 y) from the AVENA study (7, 8), had complete and valid data for birth weight and body composition variables, and were included in this study. The fact to be born at 35 weeks of gestation or more was an additional inclusion criteria. Written consent to participate was obtained from both parents and adolescents. The study protocol was performed in accordance with the ethical standards laid down in the 1975 Declaration of Helsinki (as revised in Hong-Kong in 1989 and in Edinburgh in 2000), and approved by the Review Committee for Research Involving Human Subjects of the Hospital Universitario Marqués de Valdecilla (Santander, Spain).

Measurements

Birth weight and gestational age at birth were obtained from health records. The parents were asked to answer the question of how many months the child was breastfed.(5) The harmonization and standardization of anthropometric measurements used in the AVENA study was strictly controlled and has been published elsewhere (8). Weight, height and waist circumference were measured. Body mass index was calculated as weight divided by height squared (kg/m^2), and used to classify the adolescents as overweight (including obesity) and non-overweight (9). Percentage body fat was calculated from skinfold thicknesses using Slaughter's equations (10), and fat free mass (kg) was derived by subtracting fat mass from total body weight. Sexual maturation status was assessed according to Tanner and Whitehouse (11). Handgrip strength and cardiovascular fitness were measured using the handgrip test and the 20m shuttle run test, respectively, as previously described (12).

Statistical analysis

In order to determine whether the associations between birth weight and body composition indexes were independent of the physical fitness level, the following linear regression models were performed. Model I: composed by birth weight and one of the body composition variables. Model II: model I plus a set of confounders, i.e. gestational age, breast feeding, and current age and height. Model III: model II plus handgrip strength (confounders + HG). Model IV: model II plus cardiovascular fitness (confounders + CVF). Variables with skewed distribution were log transformed to obtain a more symmetrical distribution.

Interaction factors between the main exposures (i.e. birth weight×handgrip strength and birth weight×cardiovascular fitness) with body composition variables were analyzed. Finally, the associations between birth weight and body composition variables were separately analyzed according to handgrip strength (low/high HG) or cardiovascular fitness (low/high CVF), in those cases in which interactions were found. Handgrip strength and cardiovascular fitness levels were dichotomized (low/high) when being below/above the sex-specific median.

All calculations were performed using SPSS v.15.0 software for Windows. For all analyses, the significance level was 5 %.

Results and Discussion

A positive association was observed between birth weight and fat free mass ($P\leq0.001$) in female adolescents, and birth weight and adiposity (percentage body fat and waist circumference, for both $P\leq0.001$) in male adolescents, after controlling for gestational age, breast feeding, and current age and height (Table 1). These associations remained unchanged after additional controlling for handgrip strength or cardiovascular fitness (Table 1). The results were not substantially altered when sexual maturation status was entered into the models instead of age (data not shown).

Interestingly, significant interactions were found for birth weight×cardiovascular fitness in relation to fat free mass in females (P=0.003), and for birth weight×handgrip strength in relation to percentage body fat and waist circumference in males (P=0.025 and P=0.042, respectively). The different behaviour of the regression slopes in females with low or high cardiovascular fitness and in males with low or high handgrip strength levels are shown in Figure 1 and Figure 2, respectively. Birth weight was positively associated with fat free mass in females with high cardiovascular fitness (P<0.001), while no association was observed in females with low cardiovascular fitness (Figure 1). In males with low handgrip strength, birth weight was positively associated with percentage body fat and waist circumference (both P=0.002), while no association was observed in males with high handgrip strength (Figure 2).

In order to find a possible explanation by which the programming effect of birth weight on adolescent body composition differ by physical fitness levels, we calculated the percentage of overweight (including obese) people that fell into each handgrip strength and cardiovascular fitness group. The results showed that the proportion of overweight individuals in the group of low cardiovascular fitness and high handgrip strength was significantly greater than in the group of high cardiovascular fitness (low *vs* high, 25.2 *vs* 12.5; P<0.001) and low handgrip strength group (high *vs* low, 30.0 *vs* 21.3; P=0.006), respectively. We hypothesized then, that the differences in the programming could be actually due to differences between overweight and non-overweight, rather than due to differences between high fit and low fit individuals. In order to test this hypothesis we repeated the analyses shown in Table 1, stratifying by weight status (overweight and non-overweight). The patterns and effect size of the associations did not change in the non-overweight group, but no association was found between birth weight and body composition in the overweight group (data not shown). This finding suggests that in addition to the previously reported gender-effect (5), may be a weight status-related effect on the programming of later body composition. No significant association between birth weight and waist circumference was found in a study conducted in obese Japanese children (13). This result supports our findings, though no comparisons with non-overweight individuals were made. The associations between birth weight and body composition by weight status categories have not been previously examined in children and adolescents. Further studies comparing the programming effect of birth weight on later body composition in overweight and non-overweight young people are needed to confirm our findings.

Finally, we examined whether physical fitness modified the associations between birth weight and body composition also within weight status categories. Similar associations to those shown in Figures 1 and 2 were observed in non-overweight female and male adolescents (P=0.029 for fat free mass, and P=0.001 for both adiposity indexes; data not shown), suggesting that the effect of the studied physical fitness components on the programming of body composition in adolescents is beyond that observed for weight status. Similar handgrip strength and cardiovascular fitness effects were observed in the overweight group, yet significant associations were only found for percentage body fat in males (P=0.019; data not shown).

In conclusion, birth weight seems to be positively associated with later fat free mass in those female adolescents with high cardiovascular fitness, and with total and central adiposity in those male adolescents with low handgrip strength. The programming effect of birth weight on fat free mass in females, and on total and central adiposity in males, is dependent on gender, weight status and physical fitness level.

Acknowledgments

This study was supported by the Spanish Ministry of Health (FIS nº 00/0015); the Consejo Superior de Deportes grants (05/UPB32/01, 109/UPB31/03 and 13/UPB20/04); the Spanish Ministry of Education (AP2003-2128 and AP-2004-2745), and grants from Panrico S.A., Madaus S.A., and Procter and Gamble S.A.

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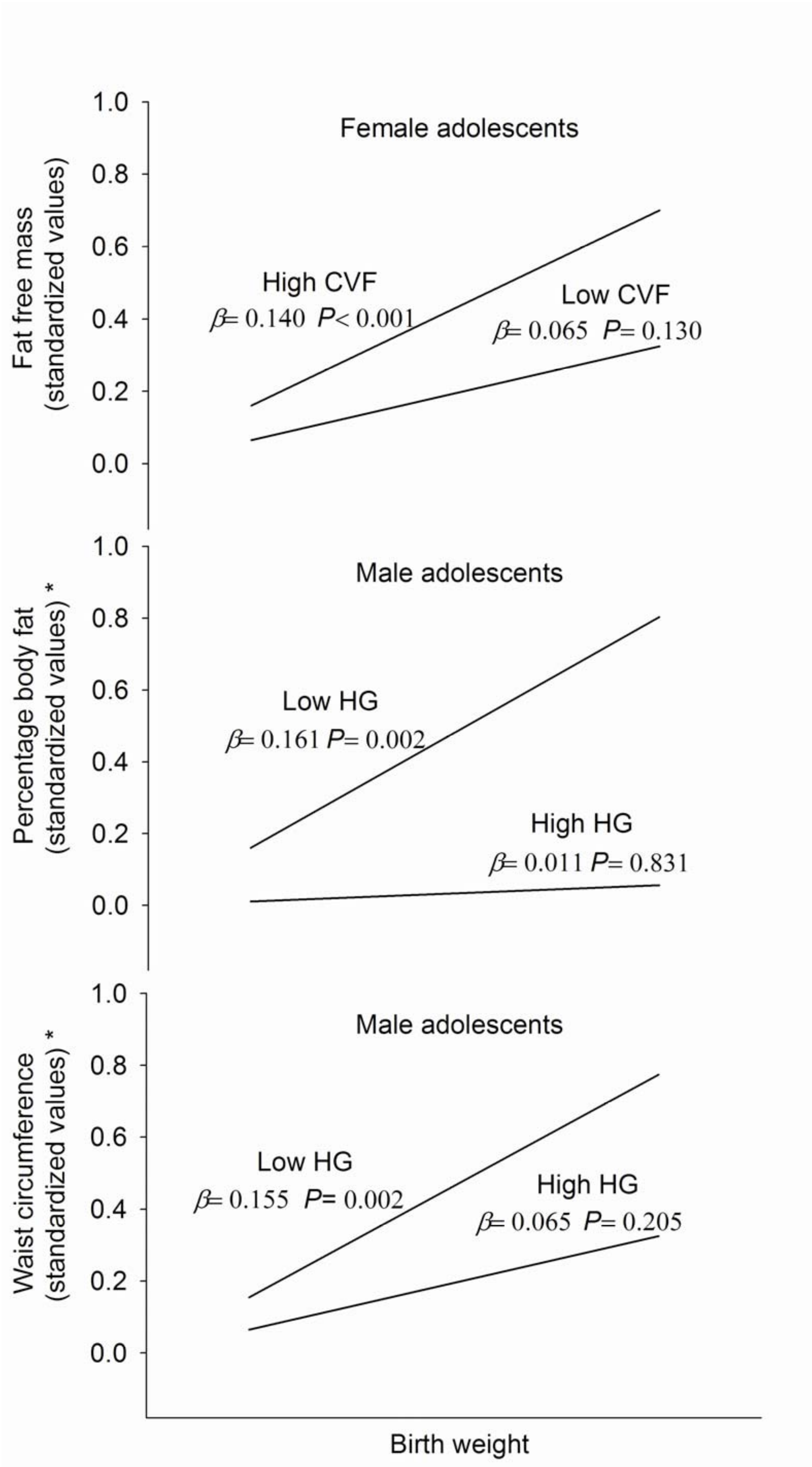
Table 1: Linear regression statistics showing estimated change in mean fat free mass, percentage body fat and waist circumference per kilogram increase in birth weight for female and male adolescents.

		Birth weight (kg)									
		Females					Males				
		N	*β*	*95% CI*		*P*	*N*	*β*	*95% CI*		*P*
Fat free mass (kg)	No confounder	942	2.152	1.576	2.727	**<0.001**	798	2.006	1.018	2.995	**<0.001**
	Confounders	932	0.948	0.462	1.433	**<0.001**	791	0.349	-0.252	0.950	0.255
	Confounders + HG	932	0.805	0.358	1.252	**<0.001**	791	0.403	-0.123	0.929	0.133
	Confounders + CVF ‡	788	0.895	0.386	1.404	**0.001**	710	0.369	-0.263	1.002	0.252
Percentage body fat *	No confounder	942	1.47%	-1.52%	4.45%	0.335	798	7.48%	1.74%	13.22%	**0.011**
	Confounders	932	1.67%	-1.45%	4.79%	0.293	791	7.34%	1.41%	13.27%	**0.015**
	Confounders + HG †	932	1.33%	-1.76%	4.42%	0.399	791	7.42%	1.50%	13.35%	**0.014**
	Confounders + CVF	788	1.42%	-1.75%	4.60%	0.380	710	9.45%	3.90%	14.99%	**0.001**
Waist circumference (cm) *	No confounder	942	1.95%	0.59%	3.31%	**0.005**	798	3.37%	1.89%	4.86%	**<0.001**
	Confounders	933	1.21%	-0.17%	2.59%	0.086	792	2.38%	0.92%	3.85%	**0.001**
	Confounders + HG †	933	0.95%	-0.39%	2.29%	0.165	792	2.44%	1.00%	3.87%	**0.001**
	Confounders + CVF	789	1.06%	-0.38%	2.49%	0.148	712	2.74%	1.29%	4.18%	**<0.001**

The confounders entered into the model were: gestational age, breast feeding, and current age and height. CI, confidence intervals; HG, handgrip strength; CVF, cardiovascular fitness. * Log transformed variables were used in the analysis and the regression coefficients are shown as the relative change (%) per kg increase in birth weight (*i.e.* 100 x β_{Ln}.). † Interactions were found in males (i.e. birth weight×handgrip strength; *P*=0.025 and *P*=0.042 for percentage body fat and waist circumference, respectively). ‡ An interaction was found in females (i.e. birth weight×cardiovascular fitness, *P*=0.003).



1.0
0.8
0.6
0.4
0.2
0.0
Female adolescents
Fat free mass (standardized values)
High CVF
β= 0.140 P< 0.001
Low CVF
β= 0.065 P= 0.130
Male adolescents
Percentage body fat (standardized values) *
Low HG
β= 0.161 P= 0.002
High HG
β= 0.011 P= 0.831
Male adolescents
Waist circumference (standardized values) *
Low HG
β= 0.155 P= 0.002
High HG
β= 0.065 P= 0.205
Birth weight

Figure 1.

LEGENDS TO FIGURES

Figure 1. Graphical representation of the interactions found in females between birth weight and cardiovascular fitness (CVF) in their association with fat free mass, and in males between birth weight and handgrip strength (HG) in their association with total and central adiposity (percentage body fat and waist circumference, respectively). The lines show the standardised regression coefficients (regression slopes) after controlling for gestational age, breast feeding, and current age and height. * Log transformed data were used in the analysis.

Physical fitness assessment in adolescence

(Papers VII and VIII)

Health-related fitness assessment in childhood and adolescence; An European approach based on the AVENA, EYHS and HELENA studies

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VII

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REVIEW ARTICLE

Health-related fitness assessment in childhood and adolescence: a European approach based on the AVENA, EYHS and HELENA studies

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Abstract Results from cross-sectional and longitudinal studies such as Alimentación y Valoración del Estado Nutricional en Adolescentes: Food and Assessment of the Nutritional Status of Spanish Adolescents (AVENA) and the European Youth Heart Study (EYHS) respectively, highlight physical fitness as a key health marker in childhood and adolescence. Moderate and vigourous levels of physical activity stimulate functional adaptation of all tissues and organs in the body (i.e. improve fitness), thereby also making them less vulnerable to lifestyle-related degenerative and chronic diseases. To identify children and adolescents at risk for these major public health diseases and to be able to evaluate the effects of alternative intervention strategies in European countries and internationally, comparable testing methodology across Europe has to be developed, tested, agreed upon and included in the health monitoring systems currently under development by the European Commission (EC): the Directorate General for Health and Consumer Affairs (DG SANCO); the Statistical Office of the European Communities (EUROSTAT), etc. The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study group plans, among other things, to describe the health-related fitness of adolescents in a number of European countries. Experiences from AVENA and EYHS will be taken advantage of. This review summarises results and experiences from the developmental work so far and suggests a set of health-related fitness tests for possible use in future health information systems.

Keywords Cardiorespiratory fitness · Muscular fitness · Physical activity · Non-communicable diseases · Young adults · Health-related fitness

On behalf of the HELENA Study Group

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Introduction

The public health burden of lifestyle-related diseases in the European countries is high. The most common causes of morbidity and mortality are coronary heart disease, stroke, obesity, hypertension, type-2 diabetes, allergies and several cancers. A sedentary lifestyle is a major risk factor for these diseases and is close to overtaking tobacco as the leading cause of preventable death (Mokdad et al. 2004). The protective effect of intentional physical activity on the above mentioned non-communicable diseases has been widely reported in people of all ages (Strong et al. 2005; Jonker et al. 2006). Regular participation in moderate and vigorous levels of exercise increases physical fitness, which can lead to many health benefits (Ruiz et al. 2006a).

Physical fitness is also determined by constitutional factors, and it has been suggested that up to ~40% of variation in fitness may be attributable to genetic factors (Bouchard 1986). In adults, low physical fitness (mainly low cardiorespiratory fitness and low muscular strength) seems to be a stronger predictor of both cardiovascular and all-cause mortality than any other well established risk factors (Myers et al. 2002). In Spanish adolescents, results from the Alimentación y Valoración del Estado Nutritional en Adolescentes: Food and Assessment of the Nutritional Status of Spanish Adolescents (AVENA) study; (http://www.estudioavena.com), suggest significant associations between cardiorespiratory fitness and plasma lipid profile (Mesa et al. 2006a) inflammatory status (Wärnberg 2006) and abdominal adiposity (Ortega et al. in press). Similar results have been achieved in Swedish and Estonian children aged 9–10 years from the European Youth Hearth Study (EYHS), as well as in other cross-sectional and longitudinal studies across Europe (Ruiz et al. 2006a,b). Taken together, these results may have important implications for public-health-oriented lifestyle intervention programs.

Physical fitness refers to the full range of physical qualities, i.e. cardiorespiratory fitness, muscular strength, speed of movement, agility, coordination, and flexibility. It can be understood as an integrated measurement of all functions (skeletomuscular, cardiorespiratory, haematocirculatory, psychoneurological and endocrine–metabolic) and structures involved in the performance of physical activity and/or physical exercise (Castillo Garzon et al. 2005). There are several well-known, health-related fitness batteries to assess fitness in all its dimensions in young people. A good example in Europe is the EUROFIT battery (Committee of Experts on Sports Research EUROFIT, 1993) and in the USA is the FITNESSGRAM battery (Cooper Institute for Aerobics Research 1999). A number of studies have followed most of the indications given in these and other fitness batteries. Some of the suggested health-related fitness tests have been performed in American (Baquet et al. 2006), Finnish (Mikkelsson et al. 2006), Russian (Izaak and Panasiuk 2005), Greek (Koutedakis and Bouziotas 2003), Flemish (Deforche et al. 2003), African (Monyeki et al. 2005), Spanish (Ortega et al. 2005), Dutch (Kemper et al. 2000) and Swedish and Estonian (Ruiz et al. 2006a,b) adolescents. However, in most studies, an adaptation of the tests has been made according to local/national social, cultural or environmental considerations and instrument or budget issues at the time the study was done.

To identify children and adolescents at risk for the major public health diseases and to be able to evaluate effects of alternative intervention strategies in European countries and internationally, comparable testing methodology across Europe has to be developed, tested, agreed upon and included in the health monitoring systems currently under development by the European Commission (EC) (DG SANCO; EUROSTAT, etc.). In this work, experiences from previous projects across Europe (AVENA and EYHS) will be taken advantage of. The Healthy Lifestyle by Nutrition in Adolescence (HELENA) study; (http://www.helenastudy.com) is a European-Union (EU)-funded project on lifestyle and obesity among European adolescents. The HELENA study will provide, for the first time in Europe, harmonised and comparable data about health-related fitness and other health-related outcomes among male and female adolescents from ten European countries (Athens in Greece, Dortmund in Germany, Gent in Belgium, Heraklion in Crete, Lille in France, Pecs in Hungary, Rome in Italy, Stockholm in Sweden, Vienna in Austria and Zaragoza in Spain). The health-related fitness test battery suggested for the HELENA study is summarised in Table 1. Methods for

Table 1 Summary of health-related fitness tests included in the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study

Fitness dimensions	Fitness quality	Test	Included in the EUROFIT battery	Included in the FITNESSGRAM battery
Cardiorespiratory fitness	Aerobic capacity	20-m shuttle run	✓	✓
Flexibility	Flexibility	Back-saver sit and reach		✓
Muscular fitness	Maximal isometric muscle strength	Handgrip strength	✓	
	Muscular endurance	Curl up		✓
	Explosive strength	Standing broad jump	✓	✓
	Explosive strength, elastic energy, coordination	Squat jump, counter movement jump, Abalakov		
	Muscular endurance	Bent-arm hang	✓	✓
Speed of movement–agility	Speed, agility and coordination[a]	Shuttle run 4×10-m	✓	

[a] Modified from the EUROFIT battery

health-related fitness assessment have already been tested for feasibility and reliability.

This review summarises results and experiences from the developmental work so far in AVENA, EYHS and HELENA studies and suggests a set of health-related fitness tests for possible use in future health information systems.

Assessment of cardiorespiratory fitness

What is cardiorespiratory fitness?

Cardiorespiratory fitness is one of the most important components of health-related fitness. Cardiorespiratory fitness reflects the overall capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged strenuous exercise. Hence, cardiorespiratory fitness has been considered a direct measure of the physiological status of the person. Cardiorespiratory fitness, cardiovascular fitness, cardiorespiratory endurance, aerobic fitness, aerobic capacity, aerobic power, maximal aerobic power, aerobic work capacity, physical work capacity and maximal oxygen consumption (VO_{2max}) all refer to the same concept and are used interchangeably in the literature. In this manuscript, only the term cardiorespiratory fitness is used.

Why is cardiorespiratory fitness important in the young population?

High cardiorespiratory fitness during childhood and adolescence has been associated with a healthier cardiovascular profile during these years (Mesa et al. 2006a,b) and later in life (for review see Ruiz et al. 2006a,b). Results from the Swedish and Estonian part of the EYHS revealed negative associations between cardiorespiratory fitness and body fat (expressed as the sum of five skin folds) (Ruiz et al. 2006a). The same relationship was noted between cardiorespiratory fitness and other features of the metabolic syndrome [insulin resistance, raised triglycerides and total cholesterol to high-density lipoprotein (HDL) cholesterol ratio] in children (Ruiz et al. 2006b). Similar results have been found in Spanish counterparts from the AVENA study (Gonzalez-Gross et al. 2003; Mesa et al. 2006a) (Fig. 1). In the same study, we have shown associations between increased cardiorespiratory fitness and a favourable metabolic profile in both overweight and non-overweight adolescents [normal-weight category was categorised fol-

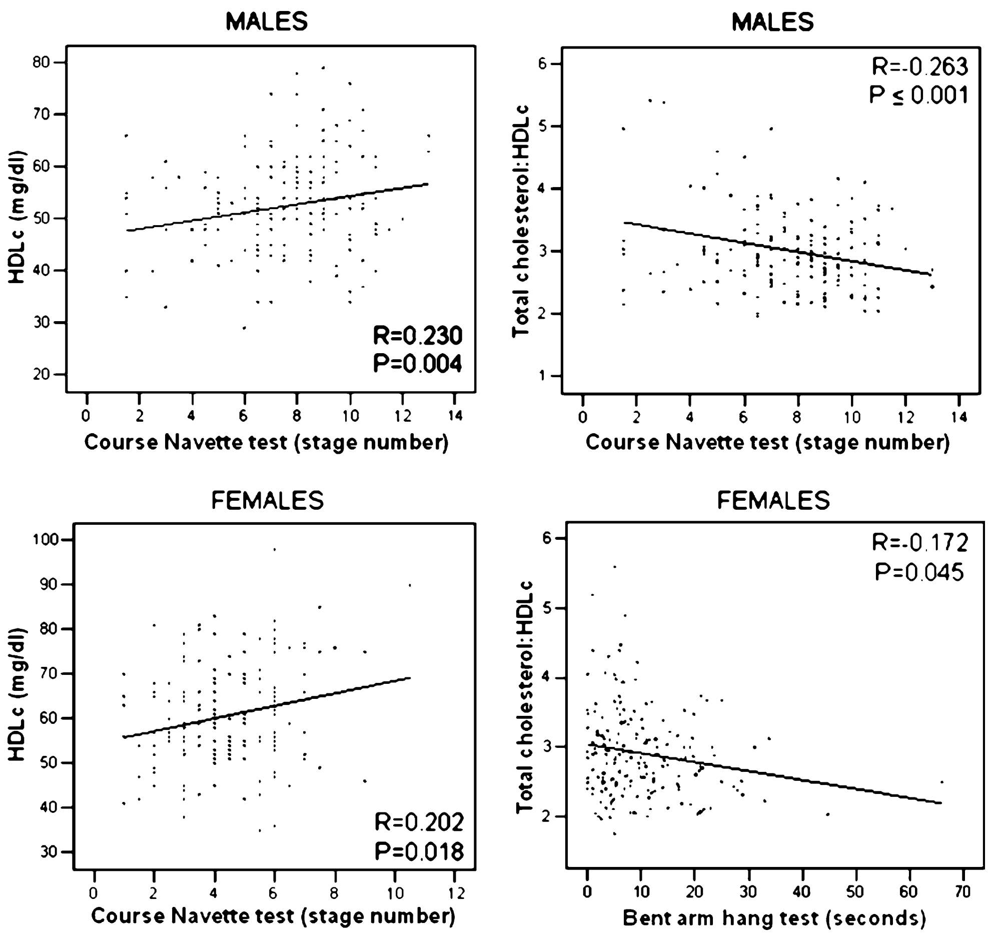

Fig. 1 Physical fitness variables associated with cardiovascular risk factors among normal-weight Spanish adolescents. Normal-weight category was categorised following the International Obesity Task Force (IOTF)-proposed gender- and age-adjusted body mass index (BMI) cutoff points

lowing the International Obesity Task Force (IOTF)-proposed gender- and age-adjusted body mass index (BMI) cutoff points (Cole et al. 2000)], and the main outcome was that cardiorespiratory fitness was an indicator of a favourable metabolic profile in male adolescents (Mesa et al. 2006a). Results are similar in other European children and adolescents (Klasson-Heggebo et al. 2006).

A number of longitudinal studies have suggested that low cardiorespiratory fitness during childhood and adolescence is associated with later cardiovascular risk factors, such as hyperlipidemia, hypertension and obesity (for review, see Ruiz et al. 2006b).

Cardiorespiratory fitness test methodology in young people

One of the most widely used tests to assess cardiorespiratory fitness among children and adolescents is the 20-m shuttle run test, also called "Course Navette" test (Léger et al. 1984). The initial speed is 8.5 km/h, which is increased by 0.5 km/h per min (1 min equal to one stage). Subjects are instructed to run in a straight line, to pivot upon completing a shuttle, and to pace themselves in accordance with audio signals given. The test is finished when the subject failed to reach the end lines concurrent with the audio signals on two consecutive occasions. A more detailed methodology and reference values of ~3,000 Spanish adolescents participating in the AVENA study can be found elsewhere (Ortega et al. 2005). The equations of Leger et al. (1984) are used to estimate the VO_{2max} from the result of the 20-m shuttle run test: VO_{2max}=31.025+3.238S−3.248A+0.1536SA, where A is the age and S the final speed (S=8+0.5 x last stage completed). Reliability and validity of this test for determining the VO_{2max} in children and adolescents has been widely documented. The test has many advantages as a fitness test because a large number of subjects can be tested at the same time, which enhances participant motivation and, because of its objectivity, standardisation, reliability, validity and availability of reference data. The 20-m shuttle run test has been included in several fitness batteries, such as the EUROFIT (Committee of Experts on Sports Research EUROFIT 1993), the Australian Coaching Council (Australian Sports Commission 1999), the British National Coaching Foundation (Brewer et al. 1988), the American Progressive Aerobic Cardiovascular Endurance Run (Cooper Institute for Aerobics Research 1999), and the Queen's University (Riddoch 1990), among others.

Previous cross-sectional and longitudinal European studies (e.g. EYHS) have used a maximum cycle ergometer test (Hansen et al. 1989). This test is probably one of the most objective, reliable and valid indicator of cardiorespiratory fitness, but it is demanding on resources, especially when large groups of subjects are tested. Moreover, a major limitation to cycle ergometer testing is the discomfort and fatigue of the muscle quadriceps. In inexperienced subjects, leg fatigue may cause him/her to stop before reaching a true VO_{2max}. There are some studies showing that VO_{2max}, the ventilatory threshold, and minute ventilation are generally 10–20% higher with treadmill testing (Working Group on Cardiac Rehabilitation and Exercise Physiology 2001).

Assessment of flexibility

What is flexibility?

Flexibility is the ability of a specific muscle or muscle group to move freely through a full range of motion. It is of importance in a variety of athletic performances but also in the capacity to carry out the activities of daily living, which is very important from a public health perspective.

"Back-saver sit-and-reach"

What is "back-saver sit-and-reach?"

Back-saver sit and reach assesses flexibility by means of reaching forward as far as possible from a seated position with one leg bent at knee. The test requires a standardised box with a ruler, which has to be pushed by the subject.

Why is performing "back-saver sit-and-reach" important in the young population?

There is growing evidence about the associated benefits of flexibility, including range of motion and function, improved athletic performance, reduced injury risk, prevention or reduction of postexercise soreness and improved coordination (Pope et al. 2000). Some studies have shown that decreased hamstring flexibility is a risk factor for the development of patella tendinopathy and patellofemoral pain (Witvrouw et al. 2000, 2001), hamstring strain injury (Witvrouw et al. 2001) and symptoms of muscle damage following eccentric exercise (McHugh et al. 1999). Similarly, poor flexibility and subsequent injury has been established in several musculotendinous units, including the Achilles tendon (Leach et al. 1981) and plantar fascia (Kibler et al. 1991). Results from a recent longitudinal Finnish study suggest that hamstring flexibility (measured by the sit-and-reach test) was one of the best explanatory factors for adult health-related fitness for men (Mikkelsson et al. 2006).

Back-saver sit-and-reach test methodology in the young

One of the tests to assess lower body flexibility is the back-saver sit-and-reach test. The back-saver sit-and-reach test is part of the FITNESSGRAM battery (Cooper Institute for Aerobics Research 1999), and is a modification of the more traditional sit-and-reach test included in the EUROFIT battery (Committee of Experts on Sports Research EUROFIT 1993). The back-saver sit-and-reach test differs from the sit-and-reach test in that the subject performs the test with one leg bent at the knee; therefore, it may be safer on the back by restricting flexion. The traditional sit-and-reach test (both legs are stretched simultaneously) may result in overstretching of the lower back, especially in terms of excessive disc compression and posterior ligament and erector spinae muscle strain. It also involves a forward rotation of the pelvis and sacrum which elongates the hamstrings. The back-saver sit-and-reach allows the legs to be evaluated separately and therefore also the determination of symmetry (or asymmetry) in hamstring flexibility. In addition, testing one leg at a time eliminates the possibility of hyperextension of both knees. The reliability and validity of the back-saver sit-and-reach tests has been widely reported (Cooper Institute for Aerobics Research 1999). The sit-and-reach test has been usually performed in the background of school physical education classes, suggesting its feasibility and applicability in this context. Therefore, the possibility of preforming the back-saver sit-and-reach test instead of sit-and-reach test would not be a problem.

Assessment of muscular fitness

Balanced, healthy functioning of the musculoskeletal system requires that a specific muscle or muscle group be able to generate force or torque (measured as strength), resist repeated contractions over time or maintain a maximal voluntary contraction for a prolonged period of time (measured as muscular endurance) and to carry out a maximal, dynamic contraction of a muscle or muscle group (measured as explosive strength).

Handgrip strength

What is handgrip strength?

Handgrip strength refers to the maximal isometric force that can be mainly generated by the hand and forehand muscles involved in the handgrip performance.

Why is handgrip strength important in the young population?

The handgrip strength test is a simple and economical test that gives practical information on muscle, nerve, bone or joint disorders. In adults, handgrip strength has been proposed as a possible predictor of mortality and the expectancy of being able to live independently (Metter et al. 2002). Results from the AVENA study revealed a negative association between handgrip strength and total cholesterol/HDL cholesterol lipoprotein-related risk factors (Ortega et al. 2004).

Handgrip strength test methodology in young people

The handgrip strength test is a widely used test in experimental and epidemiological studies. The measure of handgrip strength is influenced by several factors, including age, gender, different angle of shoulder, elbow, forearm, and wrist (Richards et al. 1996), posture (Watanabe et al. 2005) and grip span (Ruiz-Ruiz et al. 2002). Another important factor affecting handgrip strength is hand size (Ruiz-Ruiz et al. 2002; Ruiz et al. in press). The handgrip test was measured in ~3,000 Spanish adolescents in the framework of the AVENA study. Detailed test methodology and reference values have been properly described elsewhere (Ortega et al. 2005; Ruiz et al. in press). Briefly, subjects performed the test in a standard bipedal position and with the arm in complete extension without touching any part of the body with the dynamometer except the hand being measured.

We made an attempt to find the optimal grip span that resulted in maximum handgrip strength and that increased reliable and reproducible handgrip strength in adult population (Ruiz-Ruiz et al. 2002). Recently, we have shown a standard procedure to evaluate the maximum handgrip strength in adolescents (Ruiz et al. in press). The results of our study suggest that there is an optimal grip span to which the dynamometer should be adjusted when measuring handgrip strength in young subjects. For males, the optimal grip span can be derived from the equation $y=x/7.2+3.1$ cm and for females $y=x/4+1.1$ cm, where y is optimal grip span and x is hand size measured from the tip of the thumb to the tip of the little finger with the hand open widely. These equations may improve the validity and accuracy of results and may guide clinicians and researchers in selecting the optimal grip span on the hand dynamometer when measuring handgrip strength in young, healthy subjects.

"Curl-up"

What is the "curl-up" test?

The curl-up test assesses trunk strength, i.e. abdominal muscular endurance. Muscular endurance is the ability of a muscle group to execute repeated contractions over time or to maintain a maximal voluntary contraction for a prolonged period of time.

Why is performing curl-up important in the young population?

The strength of abdominal muscles has been shown to have a significant association with lower back pain in adults

(Nourbakhsh and Arab 2002). Improvements in abdominal muscle strength have been shown to not only reduce low back pain but also to prevent injury recurrence in athletes (Trainor and Trainor 2004), and young adults (Arokoski et al. 2001). Low back pain is a common and costly complaint in society. Its multifactorial aetiology is not well understood, but it is assumed to involve biomechanical loading of the spine and psychosocial influences (Keyserling 2000). Also, overweight (Leboeuf-Yde 2000), smoking (Goldberg et al. 2000) and lack of physical exercise (Hildebrandt et al. 2000) may contribute to low back pain. To prospectively evaluate the influence of low abdominal strength in young people with the likelihood of developing low back pain later in life would be of special interest from a public health perspective.

"Curl-up" test methodology in young people

The cadence-based curl-up test is the recommended test for abdominal strength/endurance testing in the FITNESSGRAM battery (Cooper Institute for Aerobics Research 1999). The curl-up test is a modification of the traditional sit-up test included in the EUROFIT battery (Committee of Experts on Sports Research EUROFIT 1993). The differences between the former and the full sit up are arm placement, leg position and range of motion of movement. Moreover, the reduced action of the psoas iliac muscle in the curl-up test may prevent back pain when performing the test. The use of a cadence (25 reps per minute) with the curl up also seems to eliminate many concerns about the ballistic nature of 30-s (or 1-min) all-out speed tests. In addition, the use of a cadence allows students to focus on their own performance and avoid competitive speeding up.

Standing broad jump and Bosco jumps

What are standing broad jumps and Bosco jumps?

The standing broad jump assesses lower-limb explosive strength. Explosive strength is the ability to carry out a maximal, dynamic contraction of a muscle or muscle group. It is the maximum rate of working of a muscle or muscle group. In the HELENA study, a more detailed assessment of muscle performance of the lower limbs has been proposed. Different jump tests will be measured according to the Bosco protocol. The Bosco jump protocol includes, among other things, the following type of jumps: squat jump, countermovement jump and Abalakov jump. Performance in squat jump indicates explosive strength of the lower limbs; the countermovement jump assesses explosive strength plus the use of elastic energy; the Abalakov jump assesses explosive strength, plus the use of elastic energy, plus the coordinative capacity using trunk and upper limbs. These are usually performed by young subjects (Vicente-Rodriguez et al. 2003, 2004a).

Why is standing broad jump important in the young population?

Jump performance together with speed has been shown to be highly strongly correlated with mean hip and lumbar bone mass accretion (Vicente-Rodriguez et al. 2003, 2004a). Results from the AVENA study revealed a negative association between standing broad jump and total cholesterol in overweight/obese male adolescents (Fig. 2) (Ortega et al. 2004).

From a public health perspective, these observations are of greater interest mainly because the standing broad jump test is an easy and feasible test to be used in schools; in fact, it is preformed as a part of the curriculum in many European countries.

Standing broad jump test methodology in young people

The standing broad jump test is a simple and cost- and time-effective test and is part of the EUROFIT battery (Committee of Experts on Sports Research EUROFIT 1993). The subject is instructed to push off vigorously and jump as far as possible trying to land with both feet together. The score is the distance from the take-off line to the point where the back of the heel nearest to the take-off line lands on the mat. Reference values of a population

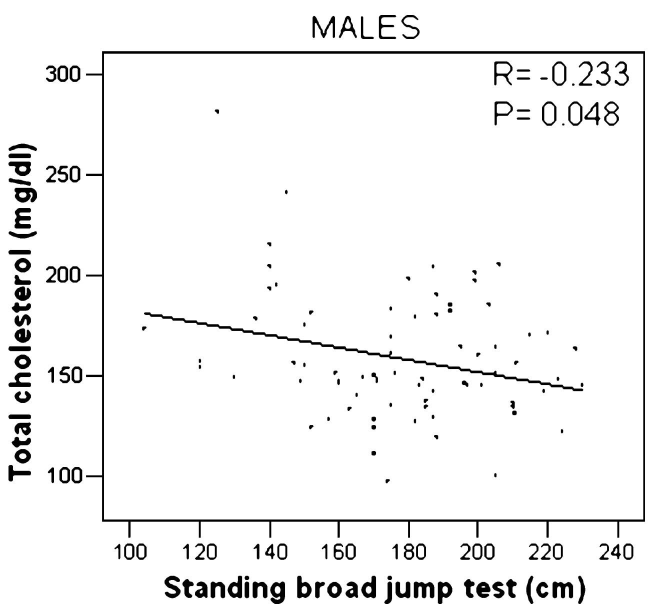

Fig. 2 Associations between standing broad jump and total cholesterol in overweight/obese Spanish adolescents. Overweight/obese category was categorised following the International Obesity Task Force (IOTF)-proposed gender- and age-adjusted body mass index (BMI) cutoff points

sample of Spanish adolescents participating in the AVENA study and a detailed description of the test can be found elsewhere (Ortega et al. 2005).

Bosco jump protocol

A more detailed and accurate information about muscle performance of the lower limbs can be obtained by use of the Bosco system (ERGOJUMP Plus, BOSCO SYSTEM, Byomedic, S.C.P., Barcelona, Spain). Briefly, the Ergojump Bosco system measures flight time during the vertical jump. This apparatus consists of a digital timer (±0.001 s) connected by a cable to two infrared bars. The timer is triggered by the feet of the subject at the moment of release from the platform and stops at the moment of contact coming down. As mentioned, the Bosco jump protocol includes three types of jumps (squat, countermovement and Abalakov) measuring different muscle characteristics. Briefly, the tests are performed as follows: in the squat jump, the subject performs a vertical jump starting from a half-squat position, with trunk straight and both hands on hips and without doing a previous countermovement; the countermovement jump is similar to the previous one, but the legs are extended in the start position, and a flexion–extension of the legs must be performed as fast as possible; finally, the Abalakov jump is a natural vertical jump. The results from these tests allow the calculation of relevant muscle-strength-related indexes, such as the elasticity index [measures elastic energy = ({counter movement jump − squat jump}/counter movement jump)x100] and the upper limbs coordination index [({Abalakov − countermovement jump})/Abalakov)×100]. Moreover, the software allows estimation of the percentage of fast-twitch fibres (Bosco et al. 1983).

"Bent-arm hang"

What is the "bent-arm hang" test?

The bent-arm hang assess upper-limb endurance strength. This test evaluates the ability to maintain a maximal voluntary contraction (hanging from a bar) for a prolonged period of time, i.e. assesses mainly the arm, shoulder and dorsal muscular endurance. It is proposed as a marker of functional strength.

Why is performing "bent-arm" hang important in the young population?

Results from the AVENA study suggest that the bent-arm hang test is positively associated with HDL cholesterol and with total cholesterol to HDL cholesterol ratio (Fig. 1), as well as with body fat, expressed as the sum of six skinfolds, and/or percentage of body fat estimated by the Slaughter equation (FB Ortega, JR Ruiz, MJ Castillo, A Gutierrez, unpublished data, 2006). Deforche et al. (2003) showed that obese subjects had significantly lower performances on bent-arm hang and other weight-bearing tasks compared with their non-obese counterparts; however, the obese had better results in handgrip strength test. These results support findings from the AVENA study. The bent-arm hang test has been shown to be a significant explanatory factor for adult health-related fitness in Finnish female pupils studied from 9 to 21 years of age (Mikkelsson et al. 2006).

"Bent-arm hang" test methodology in young people

The bent-arm hang test (also called flexed arm hang) is one of the recommended tests for upper-limb endurance strength in both the FITNESSGRAM battery (Cooper Institute for Aerobics Research 1999) and the EUROFIT battery (Committee of Experts on Sports Research EUROFIT 1993). Reference values of a population sample of Spanish adolescents participating in the AVENA study and detailed methodology of the test can be found elsewhere (Ortega et al. 2005).

Speed of movement/agility

This is the ability of a specific muscle or muscle group be able to move as quickly as possible over a distance.

Shuttle run (4×10-m)

What is the shuttle run (4×10-m)?

The shuttle run test (4×10-m) assesses the subjects' speed of movement, agility and coordination in an integrated fashion.

Why is performing shuttle run (4×10-m) important in the young population?

Preliminary results from the AVENA study have shown a strong independent relationship between speed (assessed by means of 4×10-m shuttle-run test) and bone mineral content in both male and female adolescents, regardless of the stage of maturation (G Vicente-Rodriguez, MI Mesana, LA Moreno, JR Ruiz, FB Ortega, M Bueno, unpublished data, 2006). Recently, it has been shown that some physical-fitness-related variables, specifically those related with speed and dynamic strength, had a high predictive value for both bone mineral content and density and also for the accumulation of bone mass during early puberty (Vicente-Rodriguez et al. 2003, 2004a,b).

Shuttle run test (4x10-m) methodology in young people

The shuttle run (4×10-m) test is a modification of the shuttle run (10×5-m) test included in the EUROFIT battery

(Committee of Experts on Sports Research EUROFIT 1993). The present test also includes four sponges that are carried one by one to the different lines. The subjects run back and forth four times along a 10-m track at the highest speed possible. At the end of each track section, the subjects deposit or pick up a sponge from a line on the floor. Therefore, it allows measurement not only speed of displacement but also agility and coordination. Validation studies have been done in our university, and results will soon be published. Detailed methodology and reference values from the AVENA study have been reported elsewhere (Ortega et al. 2005).

Concluding comment

Results and experiences obtained from pan-European research suggest that physical fitness is a key health marker in children and adolescents. The fitness tests to be included in the assessment of health-related fitness in the HELENA study seem to give relevant information regarding the health status of the young people and are feasible and objective. Validation studies of most tests are already done (Ruiz et al. in press) and others are under the validation process. Future health information systems should include monitoring of health-related fitness among adults as well as among young individuals, and results and experiences from recent and ongoing research projects on young people across Europe, such as AVENA, EYHS and HELENA studies, should be taken advantage of. Some of these experiences have been summarised in this review. Relevant methodology seems to be available. Development of efficient systems for large-scale collection of health-related fitness data and transfer of data to centrally located databases will be the next step. The working party "Lifestyle" within the Health Information Strand of the Public Health Programme 2003–2008 of the EC (DG SANCO) has developed an implementation and dissemination strategy to put into operation and ensure rapid transfer of data and experiences to the units within the commission, national health authorities and other stakeholders involved in the development and implementation of health information systems.

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Reliability of health-related physical fitness tests in European adolescents. The HELENA study

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VIII

Reliability of health-related physical fitness tests in European adolescents. The HELENA study.

Running head: Reliability of fitness assessment in adolescents

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ABSTRACT

Objective: To examine the reliability of a set of health-related physical fitness tests used in the EU-funded HELENA study on lifestyle and nutrition among adolescents.

Design: A set of physical fitness tests was performed twice in a study sample, two weeks apart, by the same researchers.

Subjects: A total of 123 adolescents (69 males and 54 females, aged 13.6 ± 0.8 y) from ten European cities participated in the study.

Measurements: Flexibility, muscular fitness, speed/agility and aerobic capacity were tested using the back-saver sit and reach, handgrip, standing broad jump, Bosco jumps (squat jump, counter movement jump and Abalakov jump), bent arm hang, 4x10m shuttle run, and 20m shuttle run tests.

Results: The ANOVA analysis showed that neither systematic bias nor sex differences were found for any of the studied tests, except for the back-saver sit and reach test, in which a borderline significant sex-difference was observed (P=0.044). The Bland-Altman plots showed that the reliability patterns, in terms of systematic errors (bias) and random error (95% limits of agreement), for the physical fitness tests assessed were acceptable.

Conclusions: Neither a learning nor a fatigue effect was found for any of the physical fitness tests when repeated. The results also suggest that the reliability did not differ between male and female adolescents. Collectively, it can be stated that the set of physical fitness tests examined in this study is acceptably reliable. The data provided contribute to a better understanding of physical fitness assessment in young people.

Keywords: Fitness, reliability, Bland-Altman, adolescents

INTRODUCTION

Health-related physical fitness includes the characteristics of functional capacity and is affected by physical activity level and other lifestyle factors. Maintaining an appropriate level of health-related physical fitness allows a person to meet emergencies, reduce the risk of disease and injury, work efficiently, participate and enjoy physical activity (sports, recreation, leisure) and look one's physical best. A high health-related physical fitness level focuses on optimum health and prevents the onset of disease and problems associated with inactivity in all ages [1-4].

The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study [5] includes a thorough assessment of health-related physical fitness. For this purpose, a set of standardized tests has been chosen, and the scientific rationale for their selection has been published elsewhere [6].

Reliability can be defined as the consistency of measurements. Terms that have been used inter-changeably with reliability in the literature, are “repeatability”, “reproducibility”, “consistency”, “agreement”, “concordance” and “stability”. Another related, but different concept, is validity. Validity is the ability of the measurement tool to measure what it is designed to measure. The validity of a tool is judged by comparison with a “gold standard” method. Definitions and detailed discussions about reliability issues in sport sciences-related research and general science can be found in the reviews published by Atkinson and Nevill [7], Rothwell [8] and Bruton et al. [9].

Realistically, some amount of error is always present when collecting data. The main components of measurement error are systematic bias (e.g. general learning on the tests), and random error due to biological or mechanical variation. Several statistical methods have been used to evaluate certain aspects of reliability. Correlation analysis has been commonly used, but this has limitations will be discussed further in this paper. The study of the agreement between two measurements by means of the Bland-Altman approach seems a more proper and useful method for reliability analyses [7-9].

In this paper, we report the outcome of the reliability testing, on a test-retest basis, of the set of health-related physical fitness tests used on the HELENA study [6]. The outcome is discussed and compared with the outcome of an extensive overview of published data on reliability testing.

METHODS

Study design

The HELENA study (http://www.helenastudy.com) is a European Union-funded project on lifestyle and nutrition among adolescents from 10 European cities: Athens and Heraklion in Greece, Dortmund in Germany, Gent in Belgium, Lille in France, Pecs in Hungary, Rome in Italy, Stockholm in Sweden, Vienna in Austria, and Zaragoza in Spain. The study was approved by the Research Ethics Committees of each city involved. Written informed consent was obtained from the parents of the adolescents and the adolescents themselves.

From a total sample of 204 adolescents who participated in the HELENA Pilot study and performed all the physical fitness tests, a sub-sample of 123 adolescents (69 males and 54 females, aged 13.6 ± 0.8 years), were asked to undergo the tests again two weeks later. The same inter-trial period has been previously used in similar reliability studies carried out in healthy young people [10]. The two physical fitness measurements were performed at the same time of the day by the same researchers. Those adolescents who took part in the retest study did not differ in age, height, weight or body mass index (BMI) ($P>0.05$) to those adolescents who did not.

Anthropometric measurements

Anthropometric measurements were made with the subjects barefoot and in their underwear. Weight was measured using an electronic scale (Type SECA 861) and recorded to the nearest 100 g. Height was measured using a telescopic height measuring instrument (Type SECA 225). The instrument was calibrated prior to the measurements with a metal calibrating rod. Height was recorded to the last complete 1 mm.

Physical fitness assessment

An extended and detailed manual of operations was designed for and thoroughly read by every researcher involved in field work before the data collection started. In addition, a workshop training week was carried out in Zaragoza (Spain) in January 2006, in order to standardize and harmonize the measurement of physical fitness. The field workers were asked to always perform the same fitness tests so that they would become specialized in a single fitness measurement, in order to minimize the potential inter-rater variability within each center. The instructions given to the subjects in every test were standardized for all the cities and were translated into the local language. In this way, the same verbal information was given to all participants in the HELENA study.

The health-related physical fitness components, *i.e.* flexibility, muscular strength, speed/agility and aerobic capacity (hereafter called cardiorespiratory fitness), were assessed by the physical fitness tests described below. The scientific rationale for the selection of all of these tests has been previously published [6].

1) *Back-saver sit and reach test* (Flexibility assessment): A standard box with a small bar, which has to be pushed by the subject, was used to perform the test. The adolescent bends his/her trunk and reaches forward as far as possible from a seated position, with one leg straight and the other one bent at the knee. The test is performed once again with the opposite leg. The farthest position of the bar reached by each leg was scored in centimetres and the average of the distances reached by both legs was used in the analysis.

2) *Handgrip test* (Maximum handgrip strength assessment): A hand dynamometer with adjustable grip was used (TKK 5101 Grip D; Takey, Tokio Japan). The subject squeezes gradually and continuously for at least two seconds, performing the test with the right and left hand in turn, using the optimal grip-span. The hand grip-span was adjusted according to hand size using the equation that we have developed specifically for adolescents [11]. The maximum score in kilograms for each hand was recorded. The average of the scores achieved in both handgrip tests was used in the analysis..

3) *Standing broad jump test* (Lower limb explosive-strength assessment): From a starting position immediately behind a line, standing with feet approximately shoulder's width apart, the adolescent jumps as far as possible with feet together. The result was recorded in centimetres. A non-slip hard surface, chalk and a tape measure were used to perform the test.

4) *The Bosco protocol* is composed of three different jumps: 4.1) *Squat jump* (Lower limb explosive-strength assessment): The adolescent performs a vertical jump without rebound movements starting from a half-squat position, keeping both knees bent at 90°, the trunk straight and both hands on hips. Previous counter movements are not allowed. 4.2) *Counter movement jump* (Lower limb explosive-strength and elastic component assessment): In a standing position, with legs straight and both hands on hips, the adolescent performs a vertical jump with a prior fast counter movement. 4.3) *Abalakov jump* (Lower limb explosive-strength, elastic component and inter-muscular coordination capacity assessment): The Abalakov jump is similar to the counter movement jump, but now the adolescent is allowed to freely coordinate the arms and trunk movements in order to reach the maximum height.

The jump height is recorded in centimetres. The Infrared Platform ERGO JUMP Plus – BOSCO SYSTEM (Byomedic, S.C.P., Barcelona, Spain) was used for the jump assessment.

5) *Bent arm hang test* (Upper limb endurance-strength assessment): The adolescent hangs from a bar for as long as possible, with arms bent at 90 degrees. The palms face forward and the chin must be over the bar's plane. The time spent in this postion in to the nearest tenth of a second is recorded. A cylindrical horizontal bar and a stopwatch were used to perform the test.

6) *4x10m shuttle run test* (Speed of movement, agility and coordination assessment): Two parallel lines are drawn on the floor 10m apart. The adolescent runs as fast as possible from the starting line to the other line and returns to the starting line, crossing each line with both feet every time. This is performed twice, covering a distance of 40m (4x10m). Every time the adolescent crosses any of the lines, he/she should pick up (the first time) or exchange (second and third time) a sponge, which has previously been placed behind the lines. The stopwatch is stopped when the adolescent crosses the end line with one foot. The time taken to complete the test is recorded to the nearest tenth of a second. A slip-proof floor, four cones, a stopwatch and three sponges were used to perform the test.

7) *20m shuttle run test* (Cardiorespiratory fitness assessment): The adolescents perform the test as previously described by Léger et al. [12]. Participants are required to run between two lines 20m apart, while keeping pace with audio signals emitted from a pre-recorded CD. The initial speed is 8.5 km/h, which is increased by 0.5 km/h per minute (one minute equals one stage). Participants are instructed to run in a straight line, to pivot on completing a shuttle, and to pace themselves in accordance with the audio signals. The test is finished when the participant fails to reach the end lines concurrent with the audio signals on two consecutive occasions. Otherwise, the test ends when the subject stops because of fatigue. All measurements were carried out under standardized conditions on an indoor rubber-floored gymnasium. The participants were encouraged to keep running as long as possible throughout the course of the test. The last completed stage or half-stage at which the subject drops out was scored. A gymnasium or space large enough to mark out a 20 m track, a 20 m tape measure, a CD player and a CD with the audio signals recorded were used to perform the test.

All the tests were performed twice and the best score was retained, except the bent arm hang and the 20m shuttle run test, which were performed only once.

Review of fitness reliability studies

The search strategy for identifying the fitness reliability studies was based on combinations of the following terms: fitness, reliability, repeatability, reproducibility, measurement error. The databases used were Medline, PubMed and SportDiscus. The electronic search identified 112 publications that concerned reliability of fitness assessment. The inclusion criteria were: studies involving healthy children and/or adolescents aged 18 years or younger, and published since 1990. In the end, 22 studies met the inclusion criteria and were selected. An additional search was done in order to find fitness reliability studies that used the Bland-Altman approach, including healthy or unhealthy people at any age.

Statistical Analysis

The data are presented as means ± standard deviation (SD), unless otherwise stated. Both the potential systematic bias (H_0; mean inter-trial difference = 0; H_1; mean inter-trial difference ≠ 0) and sex differences on the studied physical fitness tests were analysed by one-way analysis of variance (ANOVA) on inter-trial difference (test 2-test 1, hereafter called T2-T1) with sex as fixed factor. Since no sex-specific effect on reliability of the studied physical fitness tests was found, the analyses were performed for both males and females together. The agreement between the corresponding fitness variables obtained during the two successive measurements was also examined graphically by plotting the difference between each pair of measurements against their mean, according to the Bland and Altman approach [13, 14]. The 95% limits of agreement for all the physical fitness variables were calculated as inter-trial mean difference ± 1.96 SD (of the inter-trial differences).

Since the SD for a sample of two observations can be written as $|T2-T1| / \sqrt{2}$, the presence of heteroscedasticity can then be analysed in line with the Bland-Altman approach by using the Kruskal-Wallis test, a nonparametric one-way ANOVA. A significant *P* value would confirm heteroscedasticity, which means that the inter-trial variability, $|T2-T1|$, of a physical fitness test would differ with the physical fitness level groups. Sex-specific quartiles were estimated for every test performed and used to class the adolescents into different fitness levels. The distribution of the residuals for the inter-trial difference variables (T2-T1), but not for the absolute difference variables $|T2-T1|$, showed a satisfactory pattern. Therefore, parametric (ANOVA) and non-parametric (Kruskal-Wallis) approaches were used in this paper.

All calculations were performed using SPSS v.15.0 software for Windows. For all analyses, the significance level was 5 %.

RESULTS

The physical characteristics of the study sample are shown in Table 1. Mean values and SD for the two trials and the mean inter-trial difference for the physical fitness tests in the studied male and female adolescents are also shown in Table 1. Neither systematic bias nor sex differences were found for any of the studied tests, except for the back-saver sit and reach test, in which a borderline significant sex-difference was observed (P=0.044). The Bland-Altman plots (Figures 1-3) graphically showed that the reliability patterns, in terms of systematic errors (bias) and random error (95% limits of agreement), for the physical fitness tests assessed were acceptable.

The heteroscedasticity analysis showed that the higher the bent arm hang score (quartiles), the higher the inter-trial difference (P<0.001) was. Moreover, it was observed that those adolescents who scored high in the back-saver sit and reach test had a better inter-trial agreement compared to the adolescents who scored lower (P<0.01).

DISCUSSION

Review of fitness reliability studies and methodological discussion

Table 2 summarizes the fitness reliability studies carried out in healthy young people since 1990. The most frequently used statistical approaches to assess overall agreement between measurements were correlation methods (used in 95 % of the reviewed studies). However, correlation is a measure of the strength of association between two variables but not necessarily a measure of agreement. Its use is considered inappropriate for that purpose, firstly because it is not possible to assess systematic bias, and secondly, because it depends on the range of the values in the sample [7, 14]. For example, if an observer always overestimates (a positive systematic bias) the 4x10m shuttle run test score by twenty percent compared with another observer, the correlation between the measurements would be perfect, but they would never agree. Moreover, the more heterogeneous the study sample is, the greater the correlation. The Intraclass correlation coefficient is an appropriate overall summary measure of agreement between measurements, which reflects both systematic bias and random error in test scores [8]. However, it does not give any information on any variation in agreement with the size of the measurement, and it is also affected by the sample range [7].

Several reviews have proposed the Bland-Altman approach as an appropriate descriptive method for a meaningful and useful interpretation of reliability [7-9]. According to the review performed, only two (9 %) of the physical fitness reliability studies carried out in healthy young people used the Bland-Altman approach [10, 15].

When the search was extended to healthy or unhealthy people of any age, only eight additional studies using the Bland-Altman approach were found [16-23]. Given that physical fitness can be considered a marker of health already in this period of life [3, 6, 24], information about the reliability of health-related physical fitness tests in young people is of interest. Additionally, the review also shows that both cardiorespiratory fitness and muscular strength were the most studied physical fitness qualities (in 41% and 50%, respectively, of the reviewed studies), whereas data about speed-agility, coordination and flexibility in young people are lacking (used in 4% to 14% of the reviewed studies).

Collectively, the review and the methodological discussion performed above suggest that methods such as correlation or regression have important limitations and are not useful enough for studying reliability. In addition, the decision about what is “acceptable” agreement is a scientific judgement; statistics alone can not answer this question since measurements, which may be considered to agree well enough for one purpose, may not agree well enough for another [25]. For instance, if blood glucose concentration is measured twice, minutes apart, the acceptable error will be much lower than if hand-grip strength is measured two weeks apart.

Physical fitness reliability analysis

One of the main hypotheses tested in this study was whether a learning effect (positive systematic bias) existed among the physical fitness tests studied when repeated measurements are performed. Li et al. [10] examined the reliability of a 6 min walk test in adolescents. They found a bias of 15 m (95% limits of agreement: -35 to 65), whereas no significant difference was found between both measurements. Johnston et al. [15] studied the test-retest reliability of several physiological variables during a maximal cardiopulmonary exercise test in children. The peak oxygen consumption showed a bias of 1.4 $mL·kg^{-1}·min^{-1}$ (95% limits of agreement: -3 to 5 $mL·kg^{-1}·min^{-1}$), but no significant difference was found between test and retest scores. In our study, the bias for the physical fitness variables studied in the study sample was close to 0 in most of the tests. The results suggest that neither learning nor fatigue (negative systematic bias) effects occurred when physical fitness is assessed with the tests used in this study, on a test-retest basis, in adolescents.

Results from the heteroscedasticity analyses and Bland-Altman plots indicate that the better (longer time) the performance in the bent arm hang test, the worse the degree of the agreement, whereas the better the performance in the back-saver sit and reach tests (further reach), the better the degree of the agreement.

In addition, the reliability of the physical fitness tests analysed is similar between male and female adolescents. This result is in accordance with data reported in men and women who performed a cardiopulmonary test in laboratory conditions [19].

The wide variety of physical fitness tests examined in this study, the relatively large number of participants involved in the study and the use of adolescents from 10 European cities are notable strengths of this study.

In conclusion, our study provides reference values for reliability of a wide set of physical fitness tests in European adolescents. Neither a learning nor a fatigue effect was found for any of the physical fitness tests when repeated. The results also suggest that the reliability did not differ between male and female adolescents. Collectively, it can be stated that the set of physical fitness tests examined in this study is acceptably reliable. The data provided contribute to a better understanding of physical fitness assessment in young people

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Table 1. Reliability of physical fitness tests (mean ± standard deviation) in male (n=69) and female (n=54) adolescents.

	1st Trial (T1)		2nd Trial (T2)		Inter-trial difference (T2-T1)	
	Males	Females	Males	Females	Males	Females
Age (y)	13.7 ± 0.8	13.6 ± 0.8	-	-		
Weight (kg)	56.4 ± 12.5	53.0 ± 8.9	-	-		
Height (cm)	164 ± 9.7	161 ± 6.2	-	-		
Body mass index (kg/m^2)	21.0 ± 3.8	20.5 ± 2.9	-	-		
Back-saver sit and reach (cm) [1]	19.1 ± 7.2	24.8 ± 9.1	18.8 ± 7.4	26.2 ± 8.4	-0.3 ± 3.6	1.4 ± 4.9*
Handgrip (kg) [1]	31.2 ± 6.4	26.1 ± 5.1	31.5 ± 6.9	26.1 ± 4.9	0.3 ± 2.5	0.0 ± 1.8
Standing broad jump (cm)	172 ± 29.3	147 ± 23.3	172 ± 27.0	147 ± 25.2	-0.3 ± 12.9	0.3 ± 9.0
Squat jump (cm)	24.8 ± 5.1	22.7 ± 5.0	24.3 ± 5.2	21.8 ± 3.9	-0.5 ± 3.3	-0.8 ± 3.0
Counter movement jump (cm)	26.2 ± 5.2	23.8 ± 5.0	26.1 ± 4.8	23.3 ± 4.5	0.0 ± 3.4	-0.4 ± 3.3
Abalakov jump (cm)	32.0 ± 6.3	26.8 ± 6.1	32.0 ± 6.4	26.5 ± 5.7	0.0 ± 4.0	-0.4 ± 3.6
Bent arm hang (s)	24.2 ± 36.3	9.5 ± 10.7	21.0 ± 29.8	10.5 ± 14.8	-0.7 ± 13.9	0.0 ± 16.3
4x10m shuttle run (s)	11.7 ± 1.1	12.5 ± 1.1	11.8 ± 1.2	12.5 ± 1.0	0.1 ± 0.7	0.1 ± 0.8
20m shuttle run (stages)	6.4 ± 2.3	4.1 ± 1.9	6.2 ± 2.5	4.0 ± 2.0	-0.1 ± 1.5	0.0 ± 1.1

[1] The average of right and left side scores is shown in the table and was used for the analyses.

Both the potential systematic bias (†) and sex differences (*) on the studied physical fitness tests were analysed by one-way ANOVA, with sex as a fixed factor and inter-trial difference as the dependent variable.

Table 2. Review of fitness reliability studies (n=22) published since 1990 in healthy young people.

Author	Subjects	Age (y)	Design	Fitness quality	Test	Statistical methods
Erbaugh 1990 [26]	boys = 13 girls = 13	8.3 ± 1	test-retest	cardiorespiratory fitness, muscular endurance and flexibility	9-min run test, sit-up, modified pull-up, sit-and-reach	ANOVA, interclass correlation, ICC
Cotten 1990 [27]	boys = 171 girls = 192	5 - 12	test-retest	muscular endurance	modified pull-up	ANOVA, ICC
Atwater et al. 1990 [28]	boys and girls = 24	4 - 9	inter-rater and test-retest	balance	one-leg balance and balance on a tiltboard	Wilcoxon matched pairs signed-rank tests, Spearman rank-order correlation coefficients, magnitude of difference
Engelman and Morrow 1991 [29]	boys = 242 girls = 228	7 - 11	test-retest	muscular endurance	pull-up (traditional and modified)	two-way (alpha) reliability model
Kollath et al. 1991 [30]	boys and girls = 105	14 - 15	test-retest	muscular endurance	modified pull-up	ANOVA, ICC, proportion of agreement, kappa statistic
Rikkli et al. 1992 [31]	boys = 177 girls = 185	5 - 9	test-retest	cardiorespiratory fitness	1-mile run test	ANOVA, ICC
Liu et al. 1992 [32]	boys = 12 girls = 8	12 - 15	test-retest	cardiorespiratory fitness	20-m shuttle run test	ANOVA, ICC
Pate et al. 1993 [33]	boys = 38 girls = 56	9 - 10	test-retest	muscular endurance	pull-up (original and two modified versions), flexed arm hang, push-up	ANOVA, ICC
Mc Manis and Wuest 1994 [34]	boys = 57 girls = 43	9 and 15	test-retest	muscular endurance	modified push-up	ANOVA, ICC
Patterson et al. 1996 [35]	boys = 42 girls = 46	11 - 15	test-retest	flexibility	back-saver sit-and-reach	ANOVA, ICC
Mahar et al. 1997 [36]	boys = 137 girls = 104	10 - 11	test-retest	cardiorespiratory fitness	PACER (adapted from 20-m shuttle run test)	ANOVA, ICC

Table 2. (cont.)

Author	Subjects	Age (y)	Design	Fitness quality	Test	Statistical methods
Anderson et al. 1997 [37]	boys = 107 girls = 129	6 - 10	test-retest	muscular endurance	curl-up	ANOVA, ICC
Patterson et al. 1997 [38]	boys = 43 girls = 45	11 - 15	test-retest	muscular strength, flexibility	trunk lift	ANOVA, ICC, proportion of agreement, kappa statistic
McSwegin et al. 1998 [39]	boys and girls = 21	14 - 18	test-retest	cardiorespiratory fitness	1-mile walk test	intraclass stability reliability coefficient
McManis et al. 2000 [40]	boys and girls = 310	elementary and high school age	test-retest	muscular endurance	push-up	stability reliability coefficient
Figueroa-Colon et al. 2000 [41]	girls = 61	7.3 ± 1.3	test-retest	cardiorespiratory fitness	treadmill submaximal and maximal protocols	CV
Patterson et al. 2001 [42]	boys = 36 girls = 48	10 - 12	inter-rater	muscular endurance	curl-up	ANOVA, ICC, proportion of agreement, kappa statistic
Tong et al. 2001 [43]	boys = 14 girls = 31	17	test-retest	cardiorespiratory fitness	5-minutes running field test	ANOVA, Pearson correlation coefficient (r), intraclass reliability coefficient, CV
Romain and Mahar 2001 [44]	boys = 30 girls = 32	11.4 ± 0.9	test-retest	muscular endurance	90º push-up, modified pull-up	ANOVA, ICC, proportion of agreement, kappa statistic
Alricsson et al. 2001 [45]	boys = 8 girls = 3	11	test-retest	speed and agility	slalom test (speed) and hurdle test (agility)	ANOVA, ICC, CV
Li et al. 2005 [10]	boys = 23 girls = 29	14.2 ± 1.2	test-retest	cardiorespiratory fitness	6-minute walk test	ICC, Bland-Altman limits of agreement
Johnston et al. 2005 [15]	boys = 6 girls = 3	8 - 11	test-retest	cardiorespiratory fitness	treadmill continuous, incremental protocol	Wilcoxon matched pairs signed-rank tests, ICC, CV, Bland-Altman limits of agreement

ANOVA: analysis of variance; CV: coefficient of variation; ICC: intraclass correlation coefficient

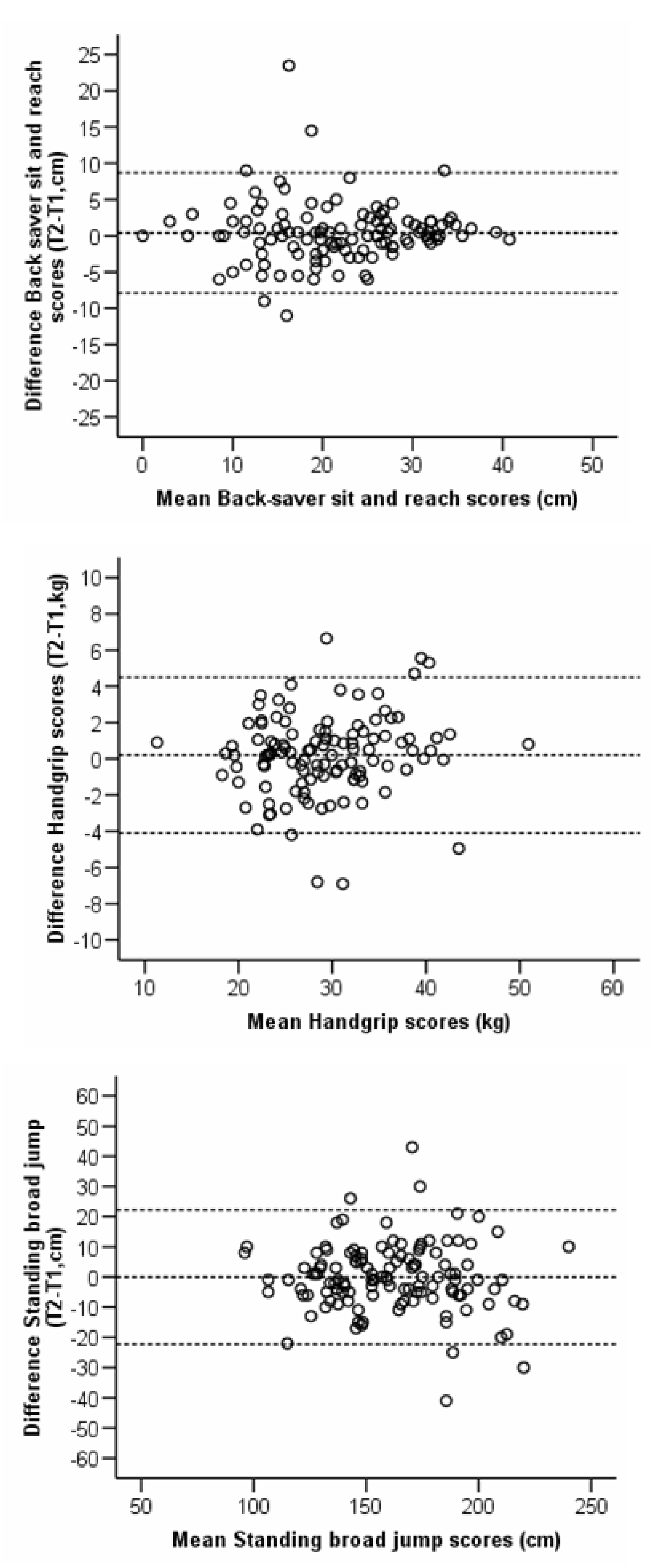

Figure 1.

Figure 1: Bland-Altman plot of the back-saver sit and reach, handgrip and standing broad jump tests, in adolescents. The central dotted line represents the mean differences between the second trial (T2) and the first trial (T1); the upper and lower dotted lines represent the upper and lower 95% limits of agreement (mean differences ± 1.96 standard deviations of the differences), respectively.

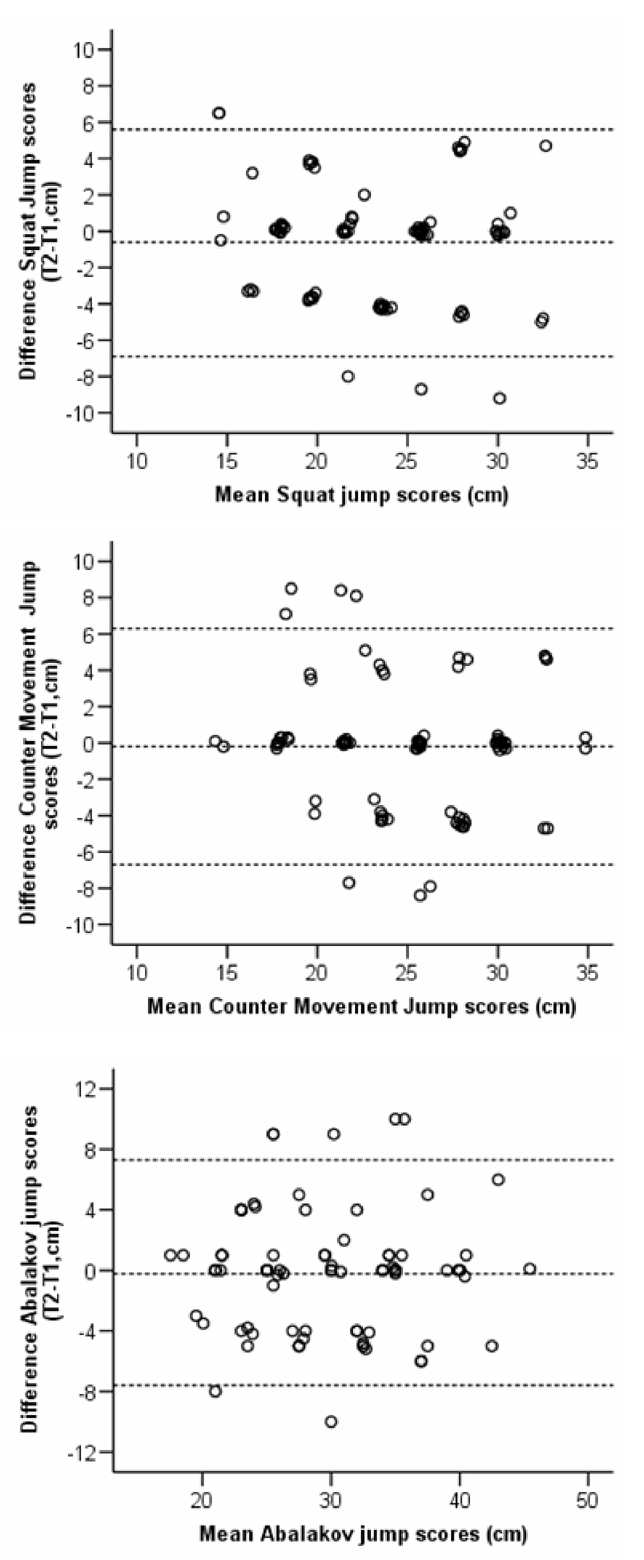

Figure 2.

Figure 2: Bland-Altman plot of the Bosco jumps, *i.e.* squat jump, counter movement jump and Abalakov jump, in adolescents. The central dotted line represents the mean differences between the second trial (T2) and the first trial (T1); the upper and lower dotted lines represent the upper and lower 95% limits of agreement (mean differences ± 1.96 standard deviations of the differences), respectively.

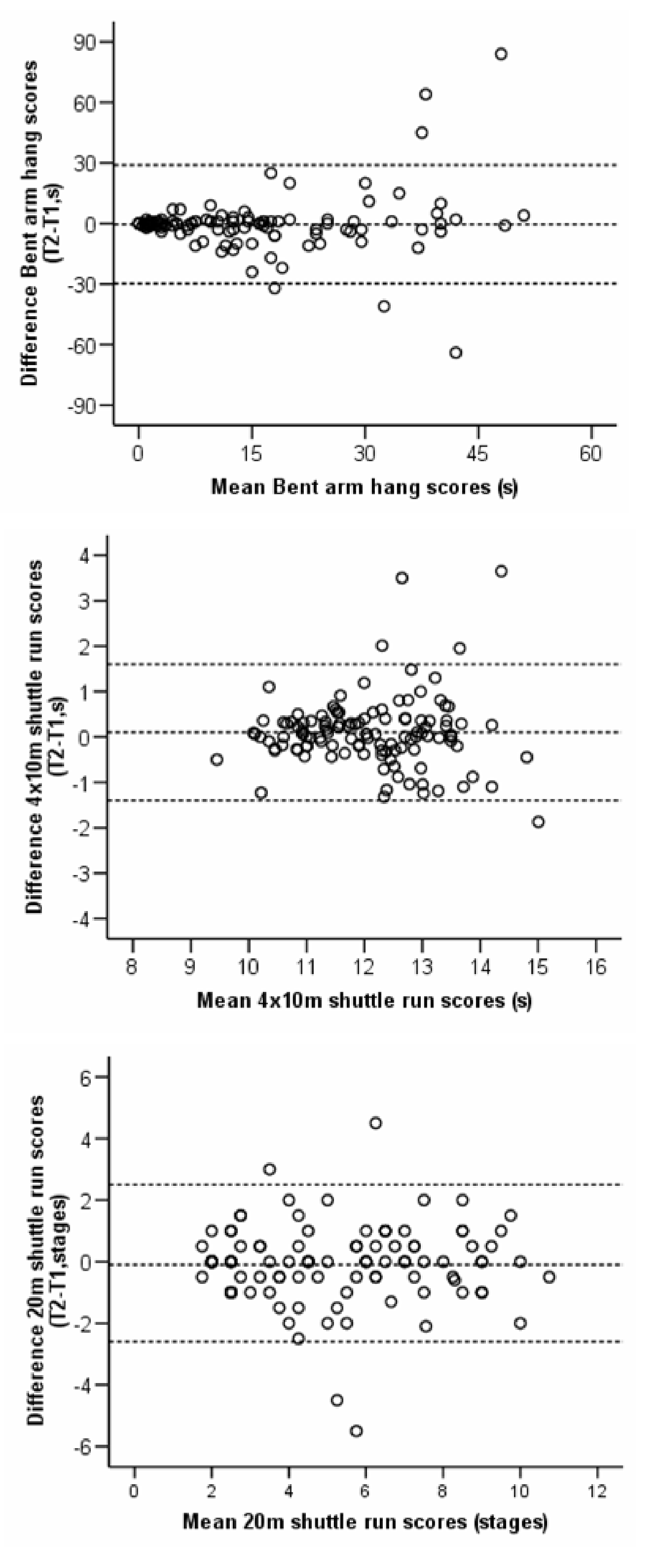

Figure 3.

Figure 3: Bland-Altman plot of the bent arm hang, 4x10 shuttle run and 20m shuttle run tests, in adolescents. The central dotted line represents the mean differences between the second trial (T2) and the first trial (T1); the upper and lower dotted lines represent the upper and lower 95% limits of agreement (mean differences ± 1.96 standard deviations of the differences), respectively.

Fitness and health in young people: state of the art

(Paper IX)

Physical fitness in childhood and adolescence:

a powerful marker of health

Ortega FB, Ruiz JR, Castillo MJ, Sjöström M.

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PEDIATRIC REVIEW

Physical fitness in childhood and adolescence: a powerful marker of health

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This review aims to summarize the latest developments with regard to physical fitness and several health outcomes in young people. The literature reviewed suggests that (1) cardiorespiratory fitness levels are associated with total and abdominal adiposity; (2) both cardiorespiratory and muscular fitness are shown to be associated with established and emerging cardiovascular disease risk factors; (3) improvements in muscular fitness and speed/agility, rather than cardiorespiratory fitness, seem to have a positive effect on skeletal health; (4) both cardiorespiratory and muscular fitness enhancements are recommended in pediatric cancer patients/survivors in order to attenuate fatigue and improve their quality of life; and (5) improvements in cardiorespiratory fitness have positive effects on depression, anxiety, mood status and self-esteem, and seem also to be associated with a higher academic performance. In conclusion, health promotion policies and physical activity programs should be designed to improve cardiorespiratory fitness, but also two other physical fitness components such us muscular fitness and speed/agility. Schools may play an important role by identifying children with low physical fitness and by promoting positive health behaviors such as encouraging children to be active, with special emphasis on the intensity of the activity.
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Keywords: fitness; health; adiposity; cardiovascular disease risk factors; bone; children

Introduction

Physical fitness can be thought of as an integrated measure of most, if not all, the body functions (skeletomuscular, cardiorespiratory, hematocirculatory, psychoneurological and endocrine–metabolic) involved in the performance of daily physical activity and/or physical exercise. Hence, when physical fitness is tested, the functional status of all these systems is actually being checked. This is the reason why physical fitness is nowadays considered one of the most important health markers, as well as a predictor of morbidity and mortality for cardiovascular disease (CVD) and for all causes.[1–4] Physical fitness is in part genetically determined, but it can also be greatly influenced by environmental factors. Physical exercise is one of the main determinants.

Childhood and adolescence are crucial periods of life, since dramatic physiological and psychological changes take place at these ages. Likewise, lifestyle and healthy/unhealthy behaviors are established during these years, which may influence adult behavior and health status. Thorough reviews have recently discussed the associations between physical activity at young ages and its short/long-term consequences on health.[5–10] However, less is known about physical fitness and health outcomes in young people.[9] In the last years, an increasing amount of research on physical fitness and health in childhood and adolescence has been published.

This review aims to summarize the latest developments with regard to physical fitness and health outcomes such as adiposity, CVD risk factors, skeletal health, cancer and mental health, in young people.

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Definitions and basic methodological issues

Physical fitness, physical exercise and physical activity are sometimes used as interchangeable concepts in the literature, which is not always appropriate.[11,12]

Physical fitness is the capacity to perform physical activity, and makes reference to a full range of physiological and psychological qualities. *Physical activity* is any body movement produced by muscle action that increases energy expenditure, whereas *physical exercise* refers to planned, structured, systematic and purposeful physical activity. In this review we will discuss the three main health-related physical fitness components: cardiorespiratory fitness, muscular fitness and speed/agility.

Cardiorespiratory fitness, also called cardiovascular fitness or maximal aerobic power, is the overall capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged strenuous exercise. The maximal oxygen consumption (VO_{2max}) attained during a graded maximal exercise to voluntary exhaustion has long since been considered by the World Health Organization as the single best indicator of cardiorespiratory fitness.[13] Although different ways have been used to express VO_{2max}, the most common way is as the volume of oxygen consumed per unit of time relative to body mass ($ml\,min^{-1}\,kg^{-1}$ of body mass). However, researchers aiming to compare cardiorespiratory fitness level between groups of young people should care the way in which the VO_{2max} is expressed (that is, $ml\,min^{-1}\,kg^{-1}$ of body mass or $ml\,min^{-1}\,kg^{-1}$ of fat-free mass or $l\,min^{-1}$), since it can influence the results and interpretation, leading to misleading conclusions (Figure 1).[14]

The VO_{2max} can be estimated using maximal or submaximal tests, by direct or indirect methods. The most commonly used tests are walking/running tests followed by cycling and step tests. In epidemiological studies involving young people, the most common test for assessing cardiorespiratory fitness has been the 20-m shuttle run test, or adaptations/modifications of this test.[15,16] The VO_{2max} can then be estimated from the score obtained in this test from equations.[17]

Muscular fitness is the capacity to carry out work against a resistance. Since the maximum force that can be generated depends on several factors (for example, the size and number of muscles involved, the proportion of muscle fibres called into action, the coordination of the muscle groups, etc.) there is no single test for measuring muscle strength. The main health-related muscular fitness components are maximal strength (isometric and dynamic), explosive strength, endurance strength and isokinetic strength.

The handgrip test is one of the most used tests for assessing muscular fitness in epidemiological studies. In adults, handgrip strength has been reported to be a strong predictor of morbidity and life expectancy.[4] Due to its importance for health, we have carried out methodological investigations in order to increase the accuracy of measurement in both adults[18] and young people.[19] There is an optimal grip span to which the standard dynamometer should be adjusted when measuring handgrip strength in both male and female adolescents. In both genders, the optimal grip span is influenced by the hand size, which implies the need for adjustment of the grip span of the dynamometer to the hand size of the individual. For this reason, sex-specific equations are proposed to determine the appropriate grip span:[19]

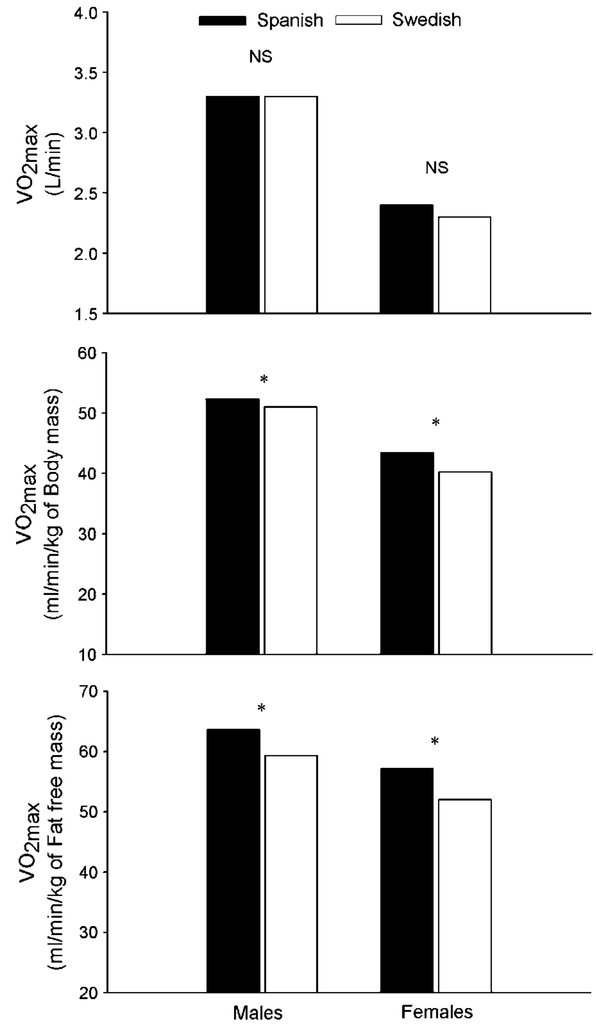

Figure 1 The choice of expression of VO_{2max} may affect the results and interpretation when comparing groups of adolescent people (data from the EYHS and AVENA studies; Ortega *et al.*[14]). * Indicates significant differences. AVENA, Alimentación y Valoración del Estado Nutricional de los Adolescents [Food and Assessment of the Nutritional Status of Spanish Adolescents]; EYHS, European Youth Heart Study; NS, not significant; VO_{2max}, maximal oxygen consumption.

$$\text{Males}: y = x/7.2 + 3.1 (r = 0.92; P = 0.01)$$

$$\text{Females}: y = x/4 + 1.1 (r = 0.93; P = 0.02)$$

where x is the hand size (maximal width between the thumb and small finger, with 0.5-cm precision), and y is the optimal grip span in cm.

Finally, jump tests, either a vertical jump test or a standing broad jump test, and the bent-arm hang test, have been widely used in young people for assessing explosive strength and endurance strength, respectively.[16,20]

Speed/agility: Speed is the ability to move the body (or some parts of the body) as fast as possible. Agility is the ability to move quickly and change direction while maintaining control and balance. Consequently, agility is a combination of speed, balance, power and coordination. The 30-m sprint test and the 4×10-m shuttle run test are useful tests for assessing speed and/or agility, respectively, in young people.[16,20] Several other tests have been proposed, but sufficient supporting literature for them is still lacking. Further methodological research is still needed for a better understanding of the accuracy, validity and reliability of the available fitness tests.

Physical fitness and health outcomes

Physical fitness and adiposity

The number of investigations into overall obesity and abdominal obesity (also called central obesity) and physical fitness has increased substantially in the last years.

Physical fitness and total adiposity. Data from the Swedish part of the European Youth Heart Study (EYHS), a school-based, cross-sectional study of risk factors for future CVD in a random sample of children (9–10 years old) and of adolescents (15–16 years old),[21] indicate that those individuals having a high cardiorespiratory fitness level also have significantly lower total adiposity, as measured by skinfold thicknesses (Figure 2).[22] When total fatness was assessed by a reference method, that is, Dual Energy X-ray Absorptiometry, a similar inverse association was found in Spanish[24] and North American[25] children. Cardiorespiratory fitness has shown a stronger association with total adiposity, as measured by skinfold thicknesses, than other physical fitness components such as muscular fitness, speed/agility, flexibility or motor coordination.[26] Even in overweight or obese children, those children who had a higher cardiorespiratory fitness have shown a lower overall adiposity.[27] Longitudinal data have shown a significant relationship between adolescent cardiorespiratory fitness and later body fatness.[28,29]

Physical fitness and abdominal adiposity. Abdominal obesity seems to be a better predictor than overall obesity for the risk of CVD and type II diabetes, as well as being a strong predictor of morbidity and mortality in adults, independently of body mass index.[30] In population studies, waist circumference has shown to be an accurate measurement for intra-abdominal and subcutaneous fat, measured by magnetic resonance imaging, in children and adolescents.[31]

Data from the Alimentación y Valoración del Estado Nutricional de los Adolescents [Food and Assessment of the Nutritional Status of Spanish Adolescents] (AVENA) study, a multicenter cross-sectional study carried out in 2859 Spanish adolescents,[32,33] show that both moderate to high levels of cardiorespiratory fitness are associated with lower abdominal

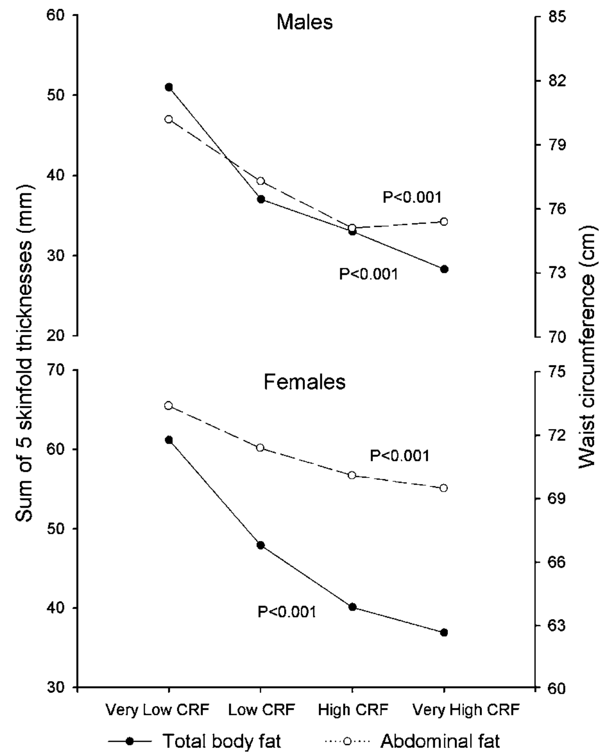

Figure 2 Association between cardiorespiratory fitness (CRF) and either total or abdominal adiposity in children and adolescents, after adjustment for age (data from the Swedish part of the EYHS and AVENA studies; Ruiz *et al.*[22] and Ortega *et al.*[23], respectively). AVENA, Alimentación y Valoración del Estado Nutricional de los Adolescents [Food and Assessment of the Nutritional Status of Spanish Adolescents]; EYHS, European Youth Heart Study.

adiposity (Figure 2).[23] These results are in accordance with those found in Irish children.[34] Similar associations have also been reported when physical fitness was measured as lower limb explosive strength, abdominal endurance strength or speed/agility instead of cardiorespiratory fitness.[35] In the previously mentioned studies, abdominal adiposity was assessed by measuring waist circumference. The same inverse association with cardiorespiratory fitness was observed when visceral and abdominal subcutaneous adipose tissue were measured using computed tomography or magnetic imaging resonance instead of waist circumference.[25,36] Further longitudinal investigations are needed for a better understanding of the specific associations of physical fitness with later abdominal adiposity and related diseases.

Physical fitness and CVD risk factors

Cardiovascular disease events occur most frequently during or after the fifth decade of life; however, there is evidence to indicate that the precursors of CVD have their origin in childhood and adolescence.[37] CVD risk factors such as total and high-density lipoprotein cholesterol (HDLc), low-density lipoprotein cholesterol (LDLc), triglycerides, insulin resistance, inflammatory proteins, blood pressure and body

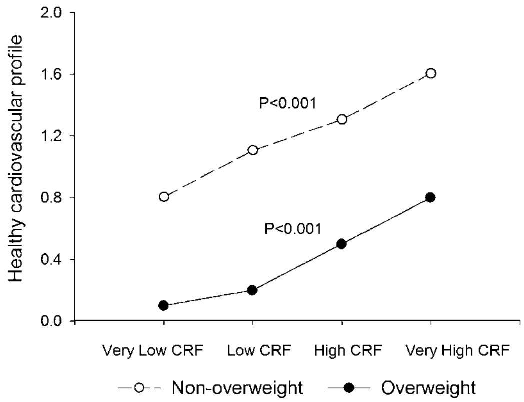

Figure 3 Association between cardiovascular profile (calculated from age- and gender-specific standardized values of triglycerides, LDLc, HDLc and fasting glycemia) and CRF quartiles in non-overweight and overweight Spanish adolescents. A higher score implies a healthier profile (data from the AVENA study; Castillo *et al.*[40]). AVENA, Alimentación y Valoración del Estado Nutricional de los Adolescents [Food and Assessment of the Nutritional Status of Spanish Adolescents]; CRF, cardiorespiratory fitness; HDLc, high-density lipoprotein cholesterol; LDLc, low-density lipoprotein cholesterol.

fat during childhood have been shown to track into adulthood.[38,39]

Cardiorespiratory fitness and CVD risk factors. We have shown that higher levels of cardiorespiratory fitness are inversely associated with a healthier cardiovascular profile in children and adolescents.[16,23,40–54] Results from the AVENA study indicate that high levels of cardiorespiratory fitness are associated with a more favorable metabolic profile (computed from age- and sex-specific standardized values of triglycerides, LDLc, HDLc and fasting glycemia) in both overweight and non-overweight Spanish adolescents (Figure 3).[52] The same association was also found between cardiorespiratory fitness and the clustering of metabolic risk factors and individual CVD risk factors in Swedish and Estonian children and adolescents participating in the EYHS.[43,47,51] Sex-specific cardiorespiratory fitness cut-off values associated with a healthier cardiovascular profile (below the 75th percentile of a computed risk score) were determined in school-aged children.[47] The cardiorespiratory fitness level associated with a low metabolic risk score was 37.0 and 42.1 $ml\,kg^{-1}\,min^{-1}$ in girls and boys, respectively. Therefore, low (high) cardiorespiratory fitness was defined when the cardiorespiratory fitness levels were <37.0 and 42.1 ($\geqslant 37.0$ and 42.1) $ml\,kg^{-1}\,min^{-1}$, in girls and boys, respectively. These cut-off values require further testing in other populations as well as in longitudinal and/or interventional studies.

There are reasons to believe that there might be potential interactions between cardiorespiratory fitness and fatness in relation to CVD risk.[44,49,51,55] Regarding cardiorespiratory fitness and traits of pediatric type II diabetes, data from the Swedish and Estonian part of the EYHS indicate that cardiorespiratory fitness explains a significant proportion of the homeostasis model assessment, a surrogate of insulin resistance, and fasting insulin variance in those children with relatively high levels (that is, the highest tertile) of body fat and waist circumference.[49] Data from the same study population show that markers of total and abdominal adiposity are related to blood pressure in girls with low levels of cardiorespiratory fitness.[44] Further analysis revealed that girls with hypertension had higher fatness and lower fitness compared with girls with normal blood pressure. Taken together, these findings suggest that the deleterious consequences ascribed to high fatness could be counteracted by having high levels of cardiorespiratory fitness. If so, it would imply that interventions to prevent states of unfavorable cardiovascular profile should focus not only on weight reduction but also on enhancing cardiorespiratory fitness.

Cardiorespiratory fitness has also been inversely associated with other CVD risk factors such as low-grade inflammatory markers and homocysteine in young people.[48,56,57] The levels of C-reactive protein and C3 were inversely associated with cardiorespiratory fitness in prepubertal children,[48] which is consistent with other studies of young people.[58–60] Halle *et al*.[59] reported that interleukin-6 levels were as low for obese and fit as for lean and unfit children, while the highest serum interleukin-6 concentrations were found in the obese and unfit group. Similarly, data from the AVENA study show that overweight and unfit adolescents are more likely to have high levels of C-reactive protein, C3 and C4 compared with non-overweight and fit peers.[57]

In adults, cardiorespiratory fitness has been inversely associated with relatively novel CVD risk factors such as homocysteine.[61] Studies examining the association between cardiorespiratory fitness and homocysteine levels in young people are scarce. We have found conflicting results in Spanish adolescents[50] and Swedish children and adolescents[62] after controlling for different potential confounders including age, puberty, birth weight, smoking, socioeconomic status, skinfold thickness and methylenetetrahydrofolate reductase 677C>T genotype. Cardiorespiratory fitness was inversely and significantly associated with homocysteine in female Spanish adolescents,[50] whereas no association was found in Swedish children and adolescents.[62] These results should encourage discussion on whether the metabolism of homocysteine could be one way in which the benefits of high cardiorespiratory fitness are exerted.

Muscular fitness and CVD risk factors. The role of muscular fitness in the performance of exercise and activities of daily living, as well as in preventing disease has become increasingly recognized.[63,64]

Data from the AVENA study show that there is an inverse association between muscular fitness, as defined by an index computed from the standardized scores of maximal handgrip strength, explosive strength and endurance strength, and a CVD risk score (an average value from the standardized triglycerides, LDLc, HDLc and glucose) in female adolescents.[54] In addition, it was reported that for a given

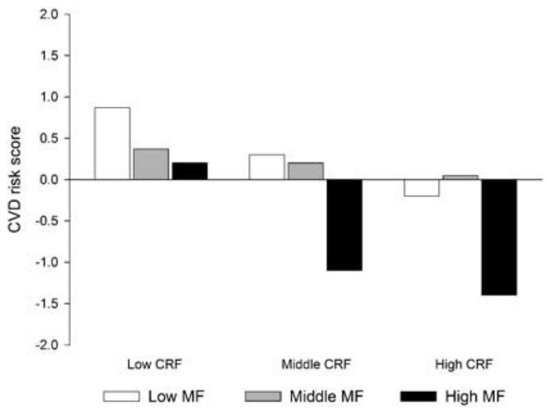

Figure 4 Associations between CVD risk score (an average value from the standardized triglycerides, LDLc, HDLc and glucose) and muscular fitness for a given level of CRF in adolescents. A higher score implies greater CVD risk. Data from the AVENA study, García-Artero *et al.*[54]. AVENA, Alimentación y Valoración del Estado Nutricional de los Adolescents [Food and Assessment of the Nutritional Status of Spanish Adolescents]; CRF, cardiorespiratory fitness CVD, cardiovascular disease; HDLc, high-density lipoprotein cholesterol; LDLc, low-density lipoprotein cholesterol; MF, muscular fitness.

cardiorespiratory fitness level, an increased level of muscular fitness was associated with a lower CVD risk score (Figure 4). These findings suggest that both cardiorespiratory and muscular fitness may have a combined and accumulative effect on the improvement of cardiovascular health in young people. Findings from the same cohort also indicate that muscular fitness is inversely associated with C-reactive protein, C3 and ceruloplasmin.[65] Further analysis revealed that C-reactive protein and transthyretin are also inversely associated with muscular fitness in overweight adolescents after controlling for different confounders, including cardiorespiratory fitness.[65]

Collectively, these findings support the concept that cardiorespiratory and muscular fitness may exert a positive effect on the cardiovascular system from an early age. In fact, due to this interest as a health marker for cardiovascular health status, we have suggested the inclusion of physical fitness testing in health monitoring systems.[45] Prospective studies are needed to examine the independent and joint effects of cardiorespiratory and muscular fitness in preventing the development of CVD risk factors among young people.

Physical fitness and skeletal health

Osteoporosis and related fractures are a current health concern worldwide and senile osteoporosis has been described as a ‘pediatric disease’,[66] as the accumulation of bone mass during childhood and adolescence may contribute more than half of the variability of bone mass with age.[67] Extra gains in bone mass during growth could be crucial to achieving a high peak bone mass and to preventing osteoporotic fractures later in life. In this regard, a systematic review focused on the associations between adolescent physical activity and several health outcomes concludes that there is a strong evidence indicating that adolescent physical activity is related to bone health at that age and also in later life.[5] However, the short-term and long-term relationships between physical fitness and skeletal health have not been specifically reviewed yet. Is physical fitness in young people associated with bone health at these ages and later in life? Which are the main physical fitness components that are related to bone health?

A cross-sectional study showed a positive association between total and site-specific bone mineral status and both cardiorespiratory and muscular fitness, in male adolescents.[68] In male and female adolescents from the AVENA study, the bone mineral content of the whole body was directly associated with physical fitness (that is, cardiorespiratory fitness, muscular fitness and speed/agility), and seemed to be mediated by the association between fitness and lean mass.[44] In fact, the results suggested that the bone mass differences between males and females could probably be explained by differences in physical fitness and lean mass.

A 3-year follow-up study carried out in Spanish prepubertal boys revealed that improvements in running speed (30-m sprint test) and explosive strength (vertical jump test), but not cardiorespiratory fitness, were associated with the enhancement of bone mass.[69] A 2-year longitudinal study reported that improvements in cardiorespiratory fitness predicted increased bone formation and bone resorption in female adolescents.[70] However, data from a 15-year follow-up study showed that during adolescence and young adulthood, only neuromotor fitness, as defined by muscular fitness and speed, and not cardiorespiratory fitness, was related to the bone mineral density at adulthood.[71] Similarly, a 20-year follow-up study showed that the main physical fitness component at adolescence related to adult bone mineral content was muscular fitness, although a significant correlation was also found between cardiorespiratory fitness and lumbar spinal bone mineral density.[72]

The physiological explanation of the findings mentioned above can be hypothesized. It has been reported that an increase in lean mass is the most important predictor of bone mineral mass accrual during prepubertal growth.[10] Since skeletal muscle is the primary component of lean mass, and improvements of muscular fitness accompanying muscular development would increase the generation of forces on bone attachment, indirectly stimulating bone growth.[73–75] Taking together the literature reviewed and the physiological rationale of the association between fitness and bone mass, seems more plausible that muscular fitness and speed/agility, rather than cardiorespiratory fitness, are independent predictors of bone mineral density. Finally, from a health promotion point of view it seems important to highlight that participation in sport and exercise should start before the pubertal growth spurt in order to achieve the maximum development of both bone mass and skeletal muscle development.[10]

Physical fitness and cancer

Cancer remains an important public health problem worldwide.[76] Leukemia is the most common childhood cancer and the leading cause of cancer death among children and adolescents. Since 75% of children with leukemia cancer have acute lymphoblastic leukemia, this section will describe the available literature on physical fitness and cancer, with special focus on acute lymphoblastic leukemia.

Poor physical fitness is largely responsible for the disrupting symptoms of fatigue that cancer patients/survivors experience during normal activities of daily living, with subsequent impairment in quality of life.[77] Cardiorespiratory fitness tends to be reduced in survivors of acute lymphoblastic leukemia.[78,79] This suggests the need for this population group to engage in regular physical activities, with the purpose of increasing their functional capacity or physical fitness. More recent data show that even 5–6 years after cessation of childhood leukemia treatment, there are still clear negative effects on motor performance and physical fitness.[80] Both chemotherapy-induced neuropathy and muscle atrophies are probably the prominent causes for this reduced physical fitness status.[80] Improvements in cardiorespiratory and muscular fitness through physical exercise have been indicated for patients surviving leukemia.[77] The effects of a 16-week intrahospital supervised conditioning program including both resistance and aerobic training on several fitness components in children receiving treatment for acute lymphoblastic leukemia were examined.[81] Young children in the maintenance phase of treatment against acute lymphoblastic leukemia can safely perform both aerobic and resistance training, attaining significant increases in cardiorespiratory fitness, muscular fitness and functional mobility. In addition, after 20 weeks without any training, strength and functional mobility were well maintained, whereas cardiorespiratory fitness measurements were only partially maintained. Even a period of time as short as 8 weeks seems to be enough to produce clinically relevant early-phase adaptations (that is, improved functional mobility and muscular fitness) and improvements in quality of life in children receiving treatment against acute lymphoblastic leukemia and children who have undergone bone marrow transplantation.[82,83] The experts highlight the potential health benefits of an enhanced physical fitness and well-being in survivors of cancer.[77,82,84] In this regard, Lucia *et al*.[85] have indicated that even although exercise training most likely will not improve survival rates, supervised exercise has the potential to considerably improve children's quality of life and overall health status during treatment periods.

Physical fitness and mental health

Mental health is how people think, feel and act as they face life's situations. Like adults, children and adolescents can have mental health disorders such as depression, anxiety or self-esteem. There is strong evidence suggesting that physical activity improves mental health in young people,[5] but the literature focused on the relationship between fitness and mental health is scarce.

Physical activity sessions of intensity sufficient to promote improvement in cardiorespiratory fitness seem to positively affect depression status and self-esteem, compared with a control group that worked at a lower intensity.[86] This suggests that the improvement of cardiorespiratory fitness is required for an enhanced psychological well-being. In this regard, the literature about young people is rather scarce, whereas some evidence has been shown in adults. DiLorenzo *et al*.[87] designed a thorough randomized controlled trial in order to examine the effects of increasing cardiorespiratory fitness, by means of an aerobic exercise program, on psychological outcomes (that is, depression, anxiety, mood status and self-concept). The study concluded that exercise-induced increases in cardiorespiratory fitness have beneficial short-term and long-term effects on all the psychological outcomes studied.

Possible explanations for the positive effects of physical fitness on psychological well-being are as follows:

(a) Increasing physical fitness via aerobic and resistance training is usually associated with a decrease in fat mass and an increase in lean mass. This is quite visible to individuals, leading to enhancement body image, which may explain some of the other improvements in psychological outcomes.
(b) Increased fitness may have a direct effect on neurochemicals in the brain such as serotonin or endorphins that function to elevate mood.

An interesting concept related to mental status is mental fitness or brain fitness, which refers to the cognitive performance of the individuals. Many studies have been conducted in adults to test the potentially beneficial effects of increases in cardiorespiratory fitness on cognition.[88] However, similar information in young people is lacking. Recently, it has been reported that physical fitness, especially cardiorespiratory fitness, seems to be positively related to academic performance (that is, mathematics, reading and overall performance) in youths.[89] Improvements in mental fitness at young ages could have many positive consequences for daily life activities in childhood and adolescence, as well as later in life. However, further research is still required in this emerging field.

Effects of physical activity and exercise on physical fitness

Cross-sectional studies using objectively measured physical activity

The apparently obvious association between cardiorespiratory fitness and physical activity still requires further research, mainly due to the complexity of assessing physical activity.[90,91] Efforts are being made in order to standardize and improve the assessment of physical activity and physical fitness in Europe (for example, the ALPHA study, Instruments for Assessing Levels of PHysical Activity and related health determinants).

Physical activity may have different effects on physical fitness depending on its intensity. We have observed that increased levels of vigorous physical activity (>6 metabolic equivalents), rather than light/moderate physical activity, are associated with a higher cardiorespiratory fitness level in children and adolescents.[22] Similar results have been reported by others.[34,92] This was also the case when cardiorespiratory fitness level was assessed by direct oxygen consumption.[93] In this context, we examined whether the adolescents who meet the current physical activity recommendations are more likely to have a high cardiorespiratory fitness level.[94] The results suggested that achieving 60 min or more of moderate–vigorous physical activity daily is associated with a healthier cardiorespiratory fitness level in adolescents, independently of their adiposity status.[95] The health level of cardiorespiratory fitness was established according to the cut-off values proposed by the Cooper Institute (for adolescent boys, this corresponds to a VO_{2max} of $42\,ml\,min^{-1}/kg^{-1}$, and for girls 14 years or older, to $35\,ml\,min^{-1}\,kg^{-1}$).[96,97]

Randomized controlled trials

Several randomized or clinical controlled trials have been conducted to study the effects of physical exercise programs on cardiorespiratory fitness and/or other physical fitness components, such as muscular fitness and speed/agility. In school-aged children, the results are consistent and show that different types of physical exercise programs (including or not diet intervention) are successful in improving cardiorespiratory fitness, as well as muscular fitness and speed/agility.[98–101] Although less studies have been conducted in preschool children ($\leqslant$6 years old), similar findings have been reported already at these ages.[99,102–104] Baquet *et al.*[105] have reviewed the available literature on endurance training and cardiorespiratory fitness in young people. They concluded that after rejection of all those studies that did not meet the high quality criteria (that is, the lack of a control group, an unclear training protocol, inappropriate statistical procedures, small sample size, studies with trained or special populations), endurance training leads to improvements of cardiorespiratory fitness in children at different ages, specially when high intensities ($\geqslant$80% of maximal heart rate) are achieved.

Regarding maturity development, to our knowledge no exercise training studies have comprehensively examined the 'trainability' (that is, the extent to which the physiologic markers of cardiorespiratory fitness change as a result of regular participation in endurance exercise) in children and adolescents in the three developmental stages (pre-pubescence, pubescence or circumpubertal stage and post-pubescence or adolescence). This is because most of the relevant studies have used chronologic age, and not developmental status, as the basis for categorizing the individuals. The available data from these studies do not indicate periods of enhanced aerobic trainability during childhood and/or youth.[105,106]

Moreover, the results have consistently shown no sex differences between the usefulness of physical training for improving cardiorespiratory fitness in boys and girls.[106]

To sum up, the available information from large-scale epidemiological studies using objective methods for assessing physical activity, and findings from randomized controlled trials, support that high-intensity physical activity is associated with physical fitness, and that properly designed and controlled physical exercise programs improve physical fitness in children and adolescents, independent of chronological age, maturation development and sex. High-intensity physical activity seems to be a key element for physical fitness enhancement.

Summary

The relationships between physical fitness and the health outcomes discussed here, indicating the main fitness components involved in these associations, are illustrated in Figure 5. There is strong evidence indicating that cardiorespiratory fitness levels are associated with *total and abdominal adiposity*, when adiposity is assessed either by anthropometric indexes or by reference methods such as Dual Energy X-ray Absorptiometry, computed tomography or magnetic resonance imaging.

Both cardiorespiratory and muscular fitness have shown to be associated with *traditional and emerging CVD risk factors*. The available information suggests that the deleterious consequences ascribed to high fatness could be counteracted by having high levels of cardiorespiratory fitness. In addition, both cardiorespiratory and muscular fitness seem to have a combined and accumulative effect on cardiovascular profile in young people.

Improvements in muscular fitness and speed/agility, rather than cardiorespiratory fitness, seem to have a positive effect on *skeletal health*. It is highly recommended to start participation in sports and exercise at prepubertal ages and to be maintained through the pubertal development in order to obtain the maximum benefit on bone mass.

Both cardiorespiratory and muscular fitness enhancements are recommended in pediatric *cancer* patients/survivors in order to compensate for the chemotherapy-induced neuropathy and muscle atrophies, to attenuate fatigue and to improve their quality of life.

The literature on the association between physical fitness and *mental health* in young people is still scarce. To date, the available information suggests that improvements in cardiorespiratory fitness have short-term and long-term positive effects on depression, anxiety, mood status and self-esteem in young people, being also associated with a higher academic performance.

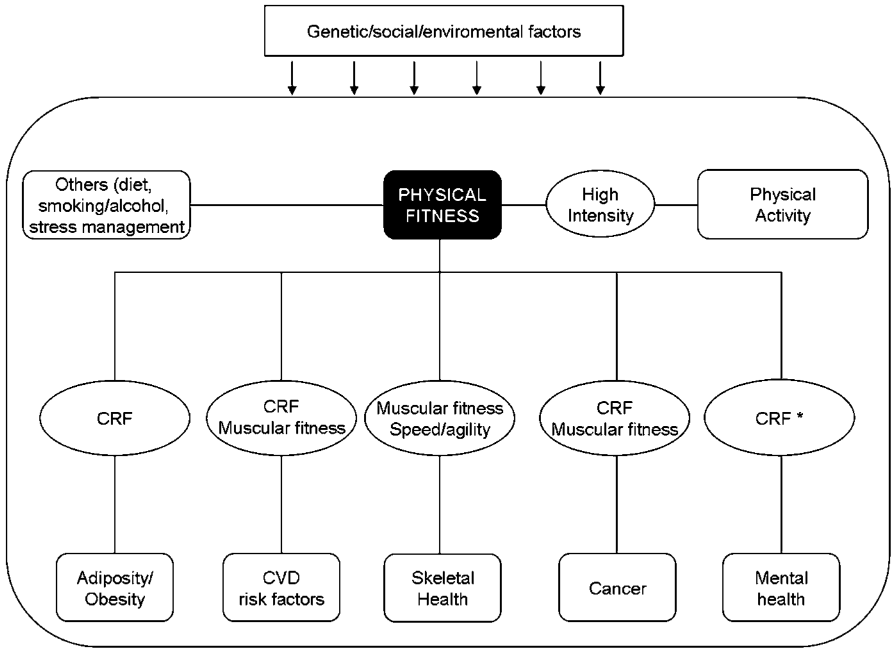

Figure 5 Associations between physical fitness and several health outcomes, showing the main health-related physical fitness components involved in those associations. * No information has been found about the other fitness components.

Conclusions

We conclude that:

(1) Physical fitness should be considered as a useful health marker already in childhood and adolescence, reinforcing the need to include physical fitness testing in health monitoring systems.
(2) Physical fitness enhancement, through increases in the time spent in vigorous physical activity and high-intensity training, should be a major goal in current and future public health promotion policies.
(3) Given that physical fitness components relate in different ways to the different health outcomes, physical activity programs should be designed to improve not only the levels of cardiorespiratory fitness but also muscular fitness and speed/agility. School may play an important role by helping to identify children with low physical fitness, and by promoting positive health behaviors such as encouraging children to be active, with special emphasis on the intensity of the activity. Longitudinal studies and randomized control trials are still needed in this field to understand the nature and relative importance of alternative determinants of physical fitness during growth and maturation, and to verify the usefulness of alternative promotion strategies and recommendations. Care must be taken not to base unrealistic aims for public health on tentative results and unattainable recommendations.

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CONCLUSIONES

I. Un programa educativo de intervención nutricional y de actividad física de 6 meses en adolescentes, tuvo un efecto positivo sobre la composición corporal, reduciendo la grasa corporal en los niños y evitando su aumento en las niñas.

II. Los valores de referencia mostrados en el presente estudio permiten evaluar e interpretar correctamente el nivel de forma física del adolescente tanto en términos individuales como poblacionales. Uno de cada cinco adolescentes españoles posee una capacidad cardiorespiratoria indicativa de riesgo cardiovascular futuro. Este dato, junto con el hecho de que los niveles de condición física en los adolescentes estudiados fueron inferiores a los observados en adolescentes de otros países, sugiere la necesidad de mejorar el nivel de condición física en la población adolescente española.

III. La condición física se interpreta de manera diferente según se valore en base a la edad cronológica o en base a la edad biológica del sujeto. Las diferencias parecen ser mayores para la capacidad cardiorespiratoria que para la fuerza muscular. La edad biológica de los adolescentes se asocia positivamente con la fuerza muscular en niños y niñas, y con la capacidad cardiorespiratoria en niñas.

IV. Una moderada/alta capacidad cardiorespiratoria y una baja tasa de actividades sedentarias, pero no la práctica de actividad físico-deportiva, se asocian con un menor nivel de grasa abdominal (perímetro de cintura).

V. Un peso al nacer elevado se asocia con una mayor fuerza de prensión manual en adolescentes, especialmente en niñas, aunque dicha asociación parece estar explicada por el propio nivel de masa libre de grasa del individuo. Los resultados también sugieren que aquellos adolescentes que nacieron con bajo peso no muestran una peor fuerza muscular en la adolescencia que sus compañeros nacidos con un peso apropiado. El peso al nacer no se asoció con la capacidad cardiorespiratoria en los adolescentes estudiados.

VI. El peso al nacer parece asociarse positivamente con la masa libre de grasa en niñas adolescentes que poseen una alta capacidad cardiorespiratoria, y con la grasa total y central en niños con una baja fuerza de prensión manual. El efecto "programming" del peso al nacer sobre la composición corporal en la adolescencia, parece ser dependiente del género, estado de sobrepeso y nivel de condición física.

VII. Los tests de condición física incluidos en el estudio HELENA ofrecen una información relevante acerca del estado de salud en personas jóvenes, y se muestran viables y objetivos. Los sistemas de información sanitaria deberían incluir la monitorización de la condición física tanto en personas adultas como jóvenes.

VIII. Cuando la evaluación de la condición física es repetida en dos ocasiones, no parece existir ningún "efecto de aprendizaje" ni de "fatiga". Del mismo modo, no se encontraron diferencias significativas en la fiabilidad de los tests entre niños y niñas adolescentes. En conjunto, se puede afirmar que la fiabilidad de la batería de tests de condición física incluida en el estudio HELENA es aceptable.

IX. Los últimos avances en relación con la condición física y diversos parámetros de salud, tales como la cantidad de grasa total y abdominal, factores de riesgo cardiovascular, salud ósea, cáncer y salud mental, han sido revisados en profundidad en esta tesis. La evidencia científica sugiere que la condición física es un potente indicador del estado de salud también en personas jóvenes. Las políticas de promoción de la salud y programas de actividad física deberían estar centrados no sólo en la mejora de la capacidad cardiorespiratoria, sino también en otros componentes de la condición física como son la fuerza muscular y la velocidad-agilidad.

CONCLUSIONS

I. A 6-month school-based intervention program focused on nutritional and physical activity had a positive effect on body composition in adolescents, reducing body fat in boys and avoiding body fat increases in girls.

II. The reference values for physical fitness depicted in this thesis enable better assessment and interpretation of the physical fitness level in adolescence, both in an individual and a population level. Our results show that one in five Spanish adolescents present a suboptimal level of cardiorespiratory fitness indicative of future cardiovascular risk. This finding together with the fact that the physical fitness levels observed in the studied adolescents were lower than in other countries, suggests that the physical fitness of Spanish adolescents requires specific attention and should be improved.

III. Discrepancies between biological and chronological age determinants on several health-related physical fitness components might be greater for cardiorespiratory fitness than for muscular fitness. Biological age, as measured by sexual maturation status, seems to be positively associated with muscular fitness in male and female adolescents, and with cardiorespiratory fitness in female adolescents, after accounting for percentage body fat, fat free mass and physical-sporting activity.

IV. Both moderate to high levels of cardiorespiratory fitness and low levels of sedentary activities, but not self-reported physical-sporting activity, seem to be associated with lower abdominal adiposity, as measured by waist circumference.

V. High birth weight seems to be associated with higher handgrip strength in adolescents, especially in females, yet these associations are highly explained by current fat free mass. The findings also suggest that low birth weight adolescents do not show poorer handgrip strength than their peers born with a normal weight. Body weight at birth was not associated with cardiorespiratory fitness in the adolescents studied.

VI. Birth weight seems to be positively associated with later fat free mass in those female adolescents with high cardiorespiratory fitness, and with total and central adiposity in those male adolescents with low handgrip strength. The programming effect of birth weight on body composition is dependent on gender, weight status and physical fitness level.

VII. The fitness tests included in the HELENA study seem to provide relevant information regarding the health status of the young people and are feasible and objective. Future health information systems should include monitoring of health-related fitness among adults as well as among young individuals.

VIII. When repeated, neither a “learning” nor a “fatigue effect” was found for any of the physical fitness tests. The results also suggest that the reliability of fitness testing does not differ between male and female adolescents. Collectively, it can be stated that the reliability of the set of physical fitness tests included in the HELENA study is acceptable.

IX. The latest developments in regard to physical fitness and several health outcomes, such as total and abdominal adiposity, traditional and emerging cardiovascular disease risk factors, skeletal health, cancer and mental health, in young people, have been thoroughly reviewed. There is evidence indicating that physical fitness is an important maker of health in young people. Health promotion policies and physical activity programs should be designed to improve cardiorespiratory fitness, but also other physical fitness components such as muscular fitness and speed/agility.

INFORMACIÓN COMPLEMENTARIA [COMPLEMENTARY INFORMATION]

Annex I: Editorial asociado al Artículo II de esta tesis [Editorial associated to Paper II]

Physical Activity. An Efficient and Underused Way of Preventing Cardiovascular Disease From Childhood to Old Age

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In 1994, the World Health Organization recognized that a sedentary lifestyle was an independent risk factor for ischemic heart disease.[1] Persons with a sedentary lifestyle are estimated to have about twice the risk for ischemic heart disease, or of dying from it, as compared with active persons.[1] The regular practice of physical exercise has also been shown to be associated with a reduced risk for cerebrovascular disease.[2] Ischemic heart disease, together with cerebrovascular disease and other cardiovascular diseases, represent the largest cause of death in industrialized countries. Prevention of these diseases, therefore, is an important element in public health care programs in these countries. To this end, the encouragement of physical activity should form an important part in disease prevention and the promotion of health.

Physical Activity, Yes, But How Much? What Sort?, and How Often?

Although most of us agree that the promotion of physical activity is important, discussion remains about how much to do, what type of exercise is best, and how often to do it.[3] Reasons accounting for this lack of agreement include variation in the methods used to measure physical activity in different studies, and that different indicators of health probably have a different pattern of association with physical activity[4]:

1. The type of dose-response association between the amount of physical activity and health has still not been established (Figure). In the case of ischemic heart disease, it appears that small amounts of physical activity produce large benefits in health, and as the amount of physical activity increases the resulting benefit is gradually reduced (Figure, C).[5] Beneficial effects on the heart are evident with an energy expenditure >1000 kcal/week; higher expenditures have a greater benefit, but of a lower magnitude. However, other health indicators, such as obesity or cancer, may have a different association with physical activity.

2. The type of physical activity can be defined by means of different criteria: according to the type of muscle contraction (dynamic-isotonic or static-isometric), or the type of metabolism employed to obtain the energy (aerobic or anaerobic). From the viewpoint of health, however, the most interesting type of physical activity depends on its intensity. For instance, does expending 1000 kcal walking (light-intensity physical activity) have the same effect on health as expending 1000 kcal running (vigorous-intensity physical activity)?[3] This question still remains to be answered. Moderate physical activity (4-5.5 metabolic equivalents [MET]) and intense physical activity (6 MET) are accepted to have a beneficial effect on cardiovascular health, but no agreement exists concerning the effect of light physical activity (<4 MET), such as walking. Nevertheless, several studies have shown that for persons older than 65 years of age, walking is associated with a reduced risk for ischemic heart disease.[6] Thus, at least in this subgroup of persons, which has the highest incidence of ischemic heart disease in the general population, data support the recommendation to walk, as an activity with a beneficial effect on the heart.[6]

3. Regarding the frequency of physical activity, most studies have analyzed the regular practice of physical activity divided into 3 or more sessions per week and studied its effects on health. However, it is becoming more and more common to find persons who do not normally undertake any physical activity during the week but who, at weekends, play a game of indoor soccer, or go for a bicycle ride with friends, either in the hills or on the road. As far as we are

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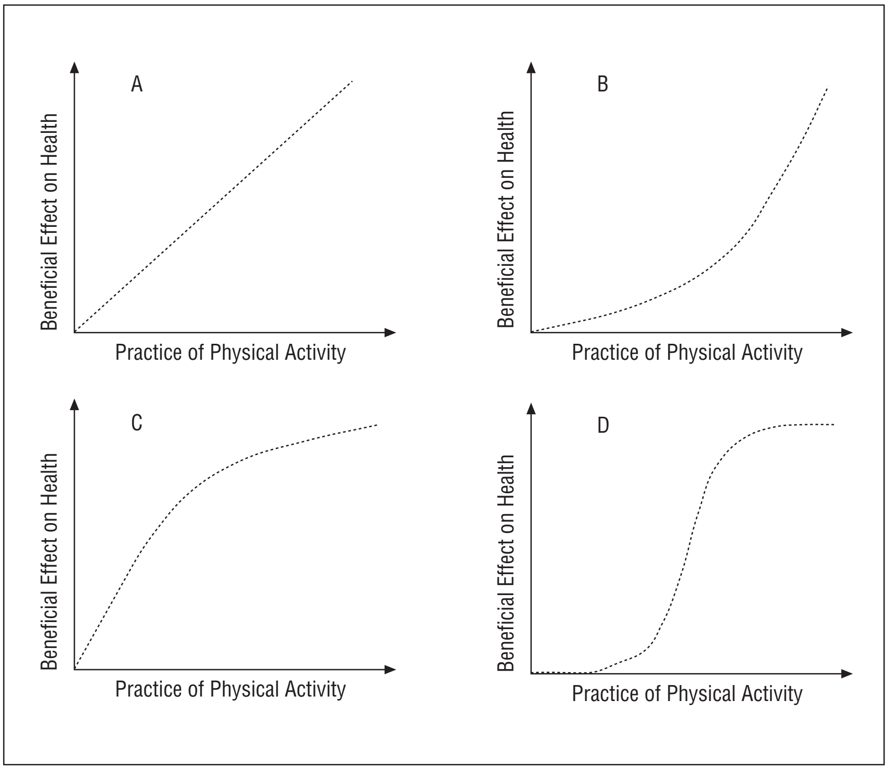

Figure. Representation of some of the possible kinds of dose-response association between the amount of physical activity undertaken and its effect on health.

aware, only one study has examined the effect of this once-a-week activity on health, concluding that in persons without risk factors this activity has beneficial results on mortality, but it has no benefit in persons with risk factors.[7] It should also be recalled that during intense physical activity there is an increase in the risk of having an acute cardiovascular event (acute myocardial infarction, sudden death), especially in persons who do not regularly undertake physical activity.[8] These data suggest that the wisest and recommended attitude is to undertake regular physical activity, at least three days per week, and, if possible, every day.

Physical Activity Versus Physical Fitness

In this issue of the REVISTA ESPAÑOLA DE CARDIOLOGÍA, Ortega et al[9] present data on the level of physical fitness of Spanish adolescents, and establish reference values that can be used in both the health care and the educational setting.[9] First and foremost, we should like to congratulate the authors on their effort, the quality of the study, and for its relevance and multidisciplinary approach. In their study, the authors provide normative values of the physical condition or fitness of Spanish adolescents, data that were previously lacking for our population, and show how this fitness can be evaluated by means of a set of standardized, valid, and objective tests (the EUROFIT battery).

At one point in the discussion, the authors state that increasing the level of physical activity is not sufficient, because the cardiovascular risk is related more with the level of physical fitness than with the particular physical activity undertaken. This statement requires qualification, since the debate about which is more important for health, physical activity or physical fitness, is controversial and still open.[10] Physical fitness is closely associated with the practice of physical activity, such that persons who are more active are fitter, thereby hindering separate analysis of their independent effects. What is well established, however, is that, as with energy expenditure, intense physical activity is associated with improved physical fitness more than is moderate or light physical activity; i.e., expending 1000 kcal/week running results in a greater improvement in physical fitness than expending 1000 kcal/week walking. Thus, physical fitness mainly reflects the practice of intense physical activity; it is less influenced by moderate physical activity and even less so by light physical activity. There is no doubt that intense physical activity is associated with a lower rate of disease and death, but, as mentioned above, there are also signs that moderate and light physical activity are associated with beneficial effects on health.[6] Physical fitness, therefore, is important, but light physical activity, even though it is not accompanied by important changes in physical fitness, is also relevant for improving health.

Recommendations About the Practice of Physical Activity

In December 1999, a European Working Group, which included the Spanish Heart Foundation, published certain recommendations in the European Union for the prevention of cardiovascular diseases by means of the practice of physical activity.[5] These recommendations were summarized in the message that every European adult should accumulate 30 minutes of moderate-intensity physical activity, such as brisk walking, most days of the week and, if possible, every day. These recommendations agree with those for United States citizens, and equate to a weekly energy expenditure of about 1000 kcal. Greater energy expenditure is associated with greater benefit in cardiovascular health, but the magnitude of the benefit obtained is reduced (Figure, C).[5] The European recommendations, however, include a special additional section aimed at children and adolescents, which establishes that this group of the population should undertake one hour of at least moderate physical activity daily.[5] This recommendation, for children and adolescents, is very important for the following reasons:

1. The undertaking of physical activity at an early age has been shown to be associated with the practice of physical activity as an adult.[11] It is therefore important to encourage physical activity in young persons, so that when they become adults they remain active. Children and adolescents spend long hours at school each day and it is important that they undertake physical activity regularly at school. However, this is not solely the responsibility of the school. Public organisms, such as governments and city halls, should facilitate adolescents with access to areas where they can regularly play sports, as well as providing suitable installations and equipment. Parents also have their responsibility in encouraging, by example and stimulus, their children to exercise. Finally, each individual person, after being duly informed and with the means available, is also partly responsible when choosing a healthy lifestyle.

2. Studies have shown that young persons with a low level of physical fitness have a greater incidence of cardiovascular risk factors at follow-up,[12] and they probably also have a greater risk of future cardiovascular events.

Thanks to the researchers involved in the AVENA study, we now have available the normative values of physical fitness in a group of Spanish adolescents.[9] These normative values will be very useful, in both the health care and educational settings, to provide an objective evaluation of the level of physical fitness of a particular adolescent, identify adolescents who have a low level of physical fitness and intervene in this subgroup of persons in order to improve the level, thereby reducing any potential future cardiovascular risk. One possibility would be to set up this series of tests in Spanish schools, with the aim of determining the level of physical fitness of each student. These results could be very useful for the pediatrician or family doctor, who would then have valid and objective data for future use, just like normograms for weight and height, with a view to controlling the individuals' evolution and intervening by encouraging the practice of physical activity.

Practice, Promoting Physical Activity in the Spanish Population, and its Potential Impact on Health

One of the most important results of this study is that the level of physical fitness of Spanish adolescents is lower than that seen in other studies undertaken in nearby countries.[9] The results also coincide with those of other studies concluding that Spanish adults undertake less physical activity than persons in other countries.[5] These data, together with the increase in the prevalence of childhood obesity in Spain,[13] should sound the alarm in political, health care, and educational leaders, as well as in families, with a view to improving the situation.

At a time when cardiovascular prevention depends increasingly on drugs,[14] we should recognize the importance, efficacy and effectiveness of a healthy lifestyle in the prevention of cardiovascular diseases.[15] We know that a sedentary lifestyle and adult obesity account for one third of premature deaths and almost 60% of cardiovascular deaths.[15] In the United States, it has been calculated that the risk of ischemic heart disease attributable to a sedentary lifestyle is about 33% in the overall population; that is, if everybody in the United States was active, the number of coronary events in that country would fall by 33%.[16] Furthermore, 80% of this reduction would be achieved if persons with a totally sedentary lifestyle did just a little physical activity.[16]

All these data concerning the benefits of physical activity, not only for cardiovascular health, but also for other indicators of health, should be made known to the general population. It is important that the whole Spanish population walk at least 30 minutes a day, every day of the week. To achieve this, those responsible for policies and health care should undertake national campaigns promoting physical activity,[17] and health care professionals should recommend physical activity in their daily clinical practice.[18] We now have physical fitness normograms for Spanish adolescents and these normograms can and must become important elements in promoting health in this group of persons, with one final aim: to increase the practice of physical activity from childhood to old age, in order to improve the health of the Spanish population.

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Annex II: Premio otorgado por la Sociedad Española de Cardiología al Artículo II de esta tesis, como uno de los tres mejores artículos publicados en Revista Española de Cardiología en el año 2005 [Award granted by the Spanish Society of Cardiology to Paper II, as one of the three best papers published in Rev Esp Cardiol in 2005]

La Sociedad Española de Cardiología

Comprometida en la salud cardiovascular

HA CONCEDIDO UN

ACCÉSIT DEL PREMIO AL MEJOR TRABAJO PUBLICADO EN REVISTA ESPAÑOLA DE CARDIOLOGÍA 2006

Al trabajo:

"BAJO NIVEL DE FORMA FÍSICA EN LOS ADOLESCENTES ESPAÑOLES. IMPORTANCIA PARA LA SALUD CARDIOVASCULAR FUTURA (ESTUDIO AVENA)"

De los Autores:

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Por la Sociedad Española de Cardiología:

El Presidente, El Secretario,

Málaga, 18 de Octubre de 2006

Annex III: Book chapter (in Italian). Migliorare la forma fisica: non è mai troppo presto per cominciare [Fitness enhancement for a graceful aging: when should we start?]

Migliorare la forma fisica: non è mai troppo presto per cominciare

Francisco B. Ortega Jonathan R. Ruiz***
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Attività fisica, esercizio fisico e forma fisica

È IMPORTANTE chiarire tre concetti differenti, ma strettamente correlati tra loro: l'attività fisica, l'esercizio fisico e la forma fisica. L'attività regolare stimola l'adattamento funzionale di tutti gli organi e i tessuti dell'organismo, rendendoli anche meno vulnerabili allo stile di vita correlato alle malattie croniche e degenerative; si riferisce a tutti i movimenti, prodotti dall'azione muscolare, che provocano un aumento del dispendio energetico.

L'esercizio fisico consiste invece in un'attività pianificata, strutturata, ripetitiva e finalizzata a un determinato scopo.

La forma fa riferimento a tutte le qualità fisiche (come la forma cardiorespiratoria, la forza muscolare, la velocità, l'agilità, il coordinamento e la flessibilità) e prevede la misurazione integrata (se non di tutte) della maggior parte delle strutture e funzioni corporee (muscoloscheletriche, cardiorespiratorie, emodinamiche, psiconeurologiche ed endocrino-metaboliche) coinvolte nell'esecuzione di un'attività fisica e/o di un esercizio fisico.

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La forma cardiorespiratoria come indice dello stato di salute

La forma cardiorespiratoria è una delle componenti più importanti della forma fisica. Si tratta infatti di un indice diretto dello stato fisiologico e riflette l'efficienza globale dei sistemi cardiovascolare e respiratorio. La capacità aerobica massima viene espressa in termini di consumo massimo di ossigeno (VO_2max).

Questo parametro si può esprimere in base al peso corporeo (ml/kg/min), in termini assoluti (L/min) o in equivalenti metabolici (MET, dove 1 MET rappresenta il consumo di energia a riposo e corrisponde circa a 3,5 ml/kg/min). Quindi, se un soggetto ha un VO_2max di 42 ml/kg/min, ciò significa che ha un consumo di energia pari a 12 MET: ovvero, è in grado di aumentare di 12 volte la sua spesa energetica a riposo.

Diversi studi prospettici hanno dimostrato che il VO_2max è il fattore predittivo più importante di mortalità dovuta a qualunque causa e, in particolare, a causa cardiovascolare. Questo è vero tanto per le persone sane quanto per i soggetti affetti da malattie cardiovascolari, sia per gli uomini sia per le donne di qualunque età. A mano a mano che la forma cardiorespiratoria aumenta, si osserva una riduzione, quasi lineare, della mortalità.

A ogni aumento di 1 MET corrisponde un aumento del 12% dell'aspettativa di vita negli uomini e del 17% per le donne. Una buona forma cardiorespiratoria riduce inoltre le perdite neuronali associate all'invecchiamento e protegge dalle alterazioni cognitive.

La forza muscolare come indice dello stato di salute

La forza muscolare consiste nel salutare e bilanciato funzionamento dell'apparato muscolo-scheletrico e richiede che un muscolo specifico oppure un gruppo di muscoli sia in grado di produrre forza o torsione. La forza con cui si stringe la mano, determinata tramite il test del dinamometro manuale, viene normalmente considerato un parametro attendibile per valutare lo stato di salute e il benessere e permette di prevedere con buona approssimazione la capacità di condurre una vita indipendente e anche la mortalità. Data la sua importanza, sono stati fatti molti sforzi per ridurre gli errori di misurazione nella popolazione adulta.

Un recente studio condotto su pazienti affetti da cardiopatie ha dimostrato che la forza isocinetica dei muscoli estensori (quadricipiti) e soprattutto dei flessori del ginocchio (muscoli ischiotibiali) è fortemente associata alla mortalità e rappresenta anche un migliore potere predittivo rispetto a variabili quali il VO_2max. Il mantenimento di un buon tono muscolare a livello delle gambe è stato anche correlato a una drastica riduzione del numero di cadute (e quindi di fratture ossee).

La forma cardiorespiratoria e i fattori di rischio cardiovascolari

Negli adolescenti spagnoli è stato riscontrato un profilo metabolico più favorevole (valutato sulla base di valori standardizzati, in base all'età e al sesso, di trigliceridi, colesterolo LDL, colesterolo HDL e glicemia a digiuno) con livelli più elevati di forma cardiorespiratoria. Questi risultati indicano che per prevenire negli adolescenti i rischi cardiovascolari correlati a un eccesso di lipidi nel sangue sono necessari sia una corretta forma fisica sia il controllo del peso corporeo.

La forma cardiorespiratoria è stata anche associata a fattori di rischio cardiovascolari di recente individuazione, come un basso livello di marker infiammatori e un elevato livello di omocisteina.

La forza muscolare e i fattori di rischio cardiovascolari

È attualmente riconosciuta l'importanza degli esercizi di resistenza per promuovere la salute e prevenire le malattie. Questi esercizi potenziano la forza e la potenza muscoloscheletrica. È stato ipotizzato che, indipendentemente dalla forma cardiorespiratoria, esista negli adulti una relazione inversamente proporzionale tra la forza muscolare e la mortalità, di qualunque causa. Si sa comunque ancora poco riguardo alla forza muscolare e ai citati fattori di rischio nei giovani. Un lieve stato infiammatorio sembra svolgere un ruolo significativo nella patogenesi dell'aterosclerosi a partire dai primi anni di vita, indicando che bisognerebbe adottare delle misure preventive in tal senso fin dalla fanciullezza.

Queste scoperte sostengono il concetto che la forma cardiorespiratoria e la forza muscolare possono svolgere un effetto protettivo sul sistema cardiovascolare anche in giovane età.

Attività fisica, forma fisica e grasso corporeo totale

L'obesità tra i bambini e gli adolescenti rappresenta un problema epidemico incontrollato e in aumento a livello mondiale. Ne sono tra i principali responsabili lo stile di vita sedentario e la riduzione dell'attività fisica, ma anche il cattivo stato di forma cardiorespiratoria ne è una causa importante. A scopo preventivo, è interessante capire quale sia nei giovani l'influenza relativa della quantità e intensità dell'attività fisica sul grasso corporeo totale, così come l'influenza della forma fisica. Recenti risultati dimostrano che aumentando l'attività fisica, soprattutto intensa (maggiore di 6 MET), migliora la forma cardiorespiratoria (Figura 1) mentre, al contrario, diminuendo l'attività fisica intensa aumenta il sovrappeso nei bambini e negli adolescenti (Figura 2).

Tutto ciò indica che non tutti i tipi di attività fisica sono in grado di migliorare la forma fisica e l'accumulo di grasso corporeo, sul quale solo l'attività intensa sembra infatti poter incidere, tra i giovani. Recenti studi condotti sugli adolescenti spagnoli indicano che moderati o alti livelli di forma cardiorespiratoria, ma non di attività fisica, sono associati a una minore adiposità addominale, misurata come circonferenza del giro vita.

La prescrizione di esercizi fisici come terapia antinvecchiamento

La prescrizione di specifici esercizi allo scopo di ridurre le conseguenze fisiologiche dell'invecchiamento dovrebbe essere orientata ad aumentare l'attività fisica giornaliera e a migliorare la forma. L'obiettivo deve essere quello di allenarsi al massimo, ma senza strafare. È molto

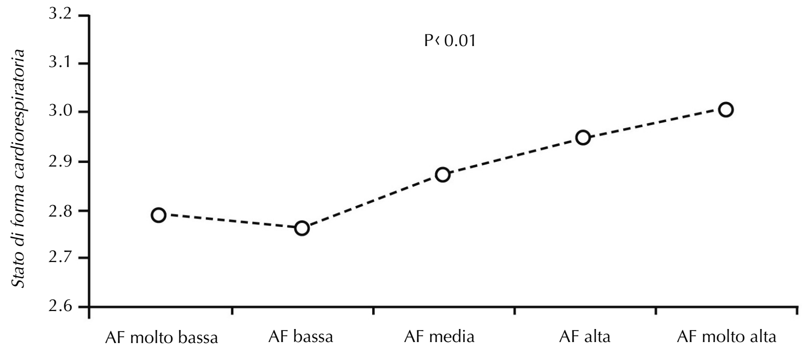

Figura 1. Relazione tra attività fisica (AF) intensa [> 6 equivalenti metabolici (MET)] e stato di forma cardiorespiratoria. (Tratto da Ruiz et al. 47.)

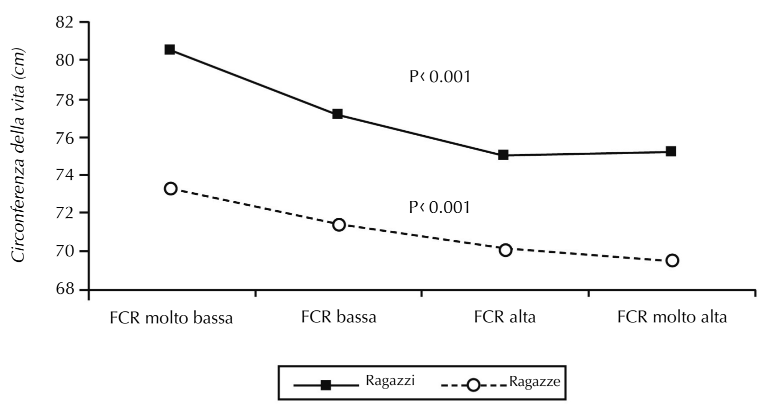

Figura 2. Relazione tra stato di forma cardiorespiratoria (FCR) e la circonferenza della vita negli adolescenti. (Tratto da Ortega et al. 51.)

importante quindi studiare esercizi personalizzati e monitorare l'adattamento alla diversa funzionalità. Questo permetterà di modulare in ogni momento gli esercizi in base alle condizioni fisiologiche del soggetto e ai consigli del medico. In linea generale, gli esercizi dovranno essere prescritti in base alla frequenza, intensità e durata dell'allenamento, al tipo di attività svolta e al livello iniziale di forma fisica (che costituisce il principale fattore da tenere in considerazione).

Gli esercizi fisici per l'allenamento aerobico

Le attività utili alla forma cardiorespiratoria devono essere la base di ogni programma di allenamento. Esse hanno lo scopo di migliorare la capacità e l'efficienza dei sistemi metabolico e cardiovascolare e aiutano inoltre a controllare e ridurre il grasso corporeo.

I risultati ottenuti con l'esercizio aerobico, come camminare, sono molto positivi, in particolare per la salute dell'apparato cardiovascolare. Un programma di esercizi aerobici regolari per 3-6 mesi può migliorare la forma cardiorespiratoria del 15-30%. Sottoponendo uomini e donne ipertesi tutte le settimane a 60-90 minuti di esercizi aerobici, si ottiene una significativa riduzione della pressione sanguigna sia sistolica sia diastolica. Questa è una prova evidente che l'allenamento aerobico esercita a tutte le età un'influenza favorevole sul profilo dei lipidi e delle lipoproteine nel sangue. Un altro importante beneficio dell'esercizio aerobico è la sua capacità di ridurre la resistenza all'insulina. Analoghi risultati sono stati ottenuti durante il trattamento di pazienti affetti da diabete e sindrome metabolica. Gli esercizi aerobici, infine, eseguiti per 30 minuti almeno tre volte alla settimana, dimostrano avere un potente effetto terapeutico su certe malattie mentali, come la depressione, e le sindromi di panico.

È raccomandabile una frequenza di allenamento pari a 3-5 vo settimana, mentre è consigliabile evitare un'unica seduta di allenamento intenso alla settimana. L'intensità dell'allenamento dovrebbe portare dal 55-65% al 90% della frequenza cardiaca massima, o della frequenza cardiaca di riserva massima (la differenza tra la frequenza cardiaca massima e la frequenza cardiaca a riposo). Intensità minori, per esempio 40-49% della frequenza cardiaca di riserva massima e 55-64% della frequenza cardiaca massima, sono invece consigliabili se il soggetto è fuori forma. La durata dell'allenamento dovrebbe essere di almeno 30-60 minuti di esercizio aerobico continuo o intermittente (aumentare di 10 minuti al giorno). Tale durata dipende dall'intensità dell'attività svolta: quelle di bassa intensità dovrebbero essere prolungate per 30 minuti o più, mentre l'allenamento individuale a più alto livello d'intensità dovrebbe durare almeno 20 minuti.

Gli esercizi fisici per migliorare la forza muscolare

Un allenamento di resistenza (di potenziamento, basato su esercizi con i pesi) è una componente fondamentale di molti programmi sportivi atti a garantire la forma fisica e deve includere l'utilizzo di pesi, macchine, elastici e altri attrezzi. Gli esercizi di resistenza rappresentano il metodo più efficace per sviluppare la forza muscolo-scheletrica e vengono prescritti normalmente per migliorare la salute e la forma. L'allenamento di resistenza riduce i fattori di rischio associati alle malattie cardiache, al diabete non insulino-dipendente e al cancro del colon, previene l'osteoporosi, favorisce la perdita di peso o il mantenimento del peso forma, migliora la stabilità dinamica, conserva la capacità funzionale e aumenta il benessere psicologico. Questi benefici vengono ottenuti se viene prescritto un programma individualizzato. Diversi studi, condotti su uomini e donne di età compresa tra i 45 e i 65 anni sottoposti a un programma di allenamento di sei mesi, hanno dimostrato che un adeguato allenamento di resistenza provoca un significativo aumento della forza muscolare in un tempo relativamente breve (risultati non pubblicati.

La forza e la resistenza muscolari possono essere potenziate tramite esercizi statici (isometrici) o dinamici (isotonici o isocinetici). Sebbene qualunque tipo di allenamento presenti vantaggi e limiti, nel caso di adulti sani gli esercizi di resistenza dinamici sono particolarmente indicati in quanto mimano meglio le attività quotidiane. Per un soggetto medio, l'allenamento di resistenza dovrebbe essere ritmico, eseguito a una velocità controllata lenta o moderata, deve coinvolgere molti movimenti diversi e permettere una normale respirazione durante i movimenti di spostamento. Un esercizio di resistenza intenso può causare invece un drastico e repentino aumento della pressione sistolica e diastolica.

Il «Modello di progressione dell'allenamento di resistenza per gli adulti sani», stabilito nel 2002 dall'American College of Sports Medicine, consiglia, per iniziare, una serie di 8-12 ripetizioni di 8-10 esercizi, incluso un esercizio per tutti i principali gruppi muscolari (10-15 ripetizioni per le persone più anziane e deboli).

Gli esercizi fisici per migliorare la flessibilità

Gli esercizi che migliorano la flessibilità vengono di solito eseguiti durante la fase di riscaldamento o di defatigamento e sono utili per i soggetti che sono poco flessibili e soffrono di problemi muscolari o articolari (per esempio dolori lombari).

Questo tipo di esercizi non migliorano la resistenza o la forma, ma diversi studi hanno dimostrato che sono in grado di migliorare il rendimento muscolare e la flessibilità dei tendini, permettendo inoltre di aumentare l'ampiezza dei movimenti e la funzionalità articolare. È quindi consigliabile includere questo tipo di esercizi nel proprio programma di allenamento mirato a migliorare la forma fisica.

Bisognerebbe anche mettere a punto un programma generale di stretching che includa esercizi di allungamento dei principali gruppi muscolo-tendinei (catena anteriore e posteriore degli arti inferiori, cingolo scapolare ecc.) utilizzando tecniche statiche (contrazione/rilassamento, tenuta/rilassamento, attive/guidate) e di agevolazione propriocettiva neuromuscolare. Negli esercizi di stretching statici bisognerebbe tenere la posizione per 10-20 secondi, mentre le tecniche di agevolazione propriocettiva neuromuscolare comprendono delle contrazioni di 6 secondi seguite da stiramento guidato per 10-20 secondi.

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In pillole

- Gli studi epidemiologici hanno riscontrato negli ultimi quindici anni una forte associazione tra la forma fisica e l'indice di morbilità-mortalità della popolazione. Migliorare la propria forma fisica può ridurre del 44% il rischio di morte
- Il consumo massimo di ossigeno è il fattore predittivo più importante di mortalità dovuta a qualunque causa e in particolare a causa cardiovascolare
- Gli studi pubblicati hanno evidenziato una corrispondenza inversa tra la forma cardiorespiratoria e i fattori di rischio cardiovascolari anche nei bambini e negli adolescenti
- Migliorare la forma fisica permette di aumentare l'aspettativa di vita e prevenire le malattie senili

Annex IV: Primer premio de investigación concedido por el Instituto Andaluz del Deporte al mejor trabajo de investigación sobre deporte y ejercicio físico en el 2006 [1st Award granted by the Andalusia Institute of Sports, as the best investigation on sports and exercise in 2006]

LA FUERZA JOVEN DE ANDALUCÍA EN ESPAÑA Y EUROPA *

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RESUMEN:

Introducción: La adolescencia es una etapa decisiva en el desarrollo humano por los múltiples cambios fisiológicos y psicológicos que en ella ocurren, los cuales, a su vez, condicionan tanto las necesidades nutricionales como los hábitos de alimentación, actividad física y comportamiento. Además, está demostrado que estos hábitos tienen repercusión en el estado de salud en la vida adulta. El interés de este tema así como su apropiado desarrollo ha merecido una financiación por parte del Fondo de Investigación Sanitaria del Instituto de Salud Carlos III así como, más recientemente, del VI Programa Marco de la U.E. **Objetivos**: Aportar las herramientas necesarias que permitan evaluar el estado de salud de niños y adolescentes a partir del nivel condición física, demostrando científicamente la dimensión que alcanza el nivel de condición física como indicador biológico del estado de salud integral del sujeto. **Metodología:** Para alcanzar el objetivo, se han estudiado 2859 adolescentes (1357 varones y 1502 mujeres), de entre 13 y 18,5 años en cinco ciudades españolas, entre las que había una andaluza. En los cuales se evaluó: 1. nivel actividad física; 2. nivel de condición física; 3. antropometría y composición corporal; 4. el perfil fenotípico lipídico y metabólico; 5. perfil genotípico de factores de riesgo cardiovascular; 6. perfil inmunológico. En este estudio el grupo andaluz ha sido responsable de los apartado 1, 2 y 4. Los resultados que se desprenden de este proyecto han sido científicamente complementados con datos procedentes de un estudio europeo de similares características (European Youth Heart Study), en el cual se evaluaron a más de mil niños y adolescentes. Todo ello gracias a la fructífera colaboración establecida entre nuestro grupo de investigación y otros grupos de investigación europeos, entre los que destaca el Karolinska Institutet (Suecia) y la Universidad de Bonn (Alemania). Esta colaboración se plasma además en estancias de formación e intercambio científico de investigadores. **Resultados:** De la presente investigación se desprenden, entre otros hallazgos, los valores normativos de condición física expresados en tablas y curvas de percentiles específicas por grupo de edad y género. Se ha obtenido una fórmula matemática que permite calcular el agarre óptimo en función del tamaño de la mano, que permitirá evaluar la fuerza de prensión manual con mayor precisión en niños y adolescentes. Se ha observado también, que la capacidad aeróbica se relaciona inversamente tanto con el porcentaje de masa grasa total como con el abdominal en niños y adolescentes. Igualmente, la capacidad aeróbica estuvo inversamente asociada con el riesgo metabólico-lipídico en ambos sexos. En relación a las variantes genéticas, los niveles saludables de capacidad aeróbica para los portadores del alelo S2 del gen *APOC3* o del alelo ε4 de *APOE* (en total 33% de la población analizada) son mayores que los valores de capacidad aeróbica para los portadores de los genes *APOC3* S1/S1 o *APOE* ε3/ε3, y esto para presentar el mismo índice de riesgo metabólico-cardiovascular. De igual modo, la capacidad aeróbica se asoció inversamente a un factor de riesgo novel como la homocisteina en adolescentes, y esto tras ajustar por diferentes variables de confusión, incluidos los factores genéticos (*MTHFR 677C>T*). La capacidad aeróbica, y fuerza muscular (fuerza de prensión manual y salto horizontal pies juntos) se asociaron inversa e independientemente con factores de riesgo cardiovascular recientemente reconocidos, tales la proteína C-reactiva. **Conclusión:** Tras contrastar los niveles de condición física obtenidos en adolescentes españoles con los datos procedentes de otros países europeos, se observa la necesidad de mejorar el nivel de condición física de los adolescentes españoles. La mejora de la capacidad aeróbica posee un efecto preventivo sobre el riesgo cardiovascular en niños y adolescentes, según muestran los resultados obtenidos con parámetros metabólico-lipídicos, niveles de homocisteína, proteínas inflamatorias e indicadores de obesidad total y central. Por último, se ha observado que la capacidad aeróbica mínima capaz de reducir el riesgo metabólico-cardiovascular parece ser genético-dependiente.

INTRODUCCIÓN

En España, al igual que en el resto de los países occidentales, las enfermedades cardiovasculares constituyen la principal causa de muerte. Estimaciones recientes sugieren que la falta de ejercicio y la obesidad (ambas íntimamente ligadas) son dos claros factores de riesgo no sólo para la enfermedad cardiovascular sino para muchas otras enfermedades, atribuyéndosele responsabilidad directa en más de 400.000 muertes por año en Estados Unidos (Mokdad y col., 2004), siendo previsible que la situación sea similar en el resto de los países occidentales.

Un factor íntimamente relacionado con el nivel de actividad física y ejercicio que se realiza es el estado de condición física (o forma física) que se posee. El nivel de condición física refleja el estado general del sistema cardiovascular y respiratorio, y se define como la capacidad que una persona tiene para realizar ejercicio. Recientes estudios han puesto claramente de manifiesto que el nivel de condición física es un factor predictor de mortalidad no sólo por enfermedad cardiovascular sino por cualquier causa y ello tanto en hombres como mujeres, tanto si estaban sanas o presentaban antecedentes de enfermedad cardiovascular (Referencias propias). Al igual que ocurre con otros factores de riesgo, el nivel de condición física que se tiene en la vida adulta, está condicionado en gran medida por el que ya se posee en la infancia o adolescencia (Eisenmann y col., 2005).

El objetivo del presente estudio es aportar las herramientas necesarias que permitan evaluar el estado de salud de niños y adolescentes a partir del nivel condición física, demostrando científicamente la dimensión que alcanza el nivel de condición física como indicador biológico del estado de salud integral del sujeto.

MATERIAL Y MÉTODOS

Sujetos y diseño experimental

El presente estudio de investigación forma parte del Estudio AVENA (Alimentación y Valoración del Estado Nutricional en Adolescentes). Se trata de un estudio multicéntrico realizado en adolescentes de entre 13 y 18,5 años de edad en cinco ciudades españolas. Con objeto de abarcar la heterogeneidad de la población, el estudio se realizó tanto en centros públicos como privados de Enseñanza Secundaria o Formación Profesional del territorio Español.

El muestreo fue polietápico, aleatorizado y estratificado: por procedencia, condiciones socio-económicas (en base a la localización del centro educativo; información aportada por las diferentes Consejerías de Educación autonómicas), sexo y edad. Se establecieron los siguientes criterios de exclusión: diagnóstico clínico de diabetes, embarazo, abuso de alcohol o drogas y en general patologías que no estén relacionadas directamente con la nutrición. La exclusión efectiva del estudio se aplicó a posteriori, sin conocimiento por parte de los alumnos, para evitar situaciones no deseadas.

Para la determinación del tamaño total de muestra se tomó el parámetro de mayor varianza en la población, utilizando los datos que había publicados en la bibliografía cuando se planeó el estudio (Moreno y col., 1997), este fue el índice de masa corporal (IMC). El muestreo estuvo determinado por esta dispersión. El nivel de confianza es del 95% con un error ± 0,25. Se calculó un n=2100 para el estudio completo. El n total se distribuyó igualmente por ciudades y proporcionalmente por sexo y grupos de edad (13, 14, 15, 16, 17-18,5). La muestra se sobredimensionó para prevenir pérdidas de información. Se ajustó finalmente con un factor de ponderación para equilibrar la muestra según la distribución de la población española y garantizar la representación real de cada uno de los grupos definidos por los dos factores

mencionados (Fuente: INE). Una vez eliminados los sujetos que no cumplían los criterios de inclusión del estudio, el n final fue de 2859 (1357 varones y 1502 mujeres).
El estudio se llevó a cabo siguiendo escrupulosamente las normas deontológicas reconocidas por la Declaración de Helsinki (revisión de Ediburgo 2000) Convenio de Oviedo y siguiendo las recomendaciones de Buena Práctica Clínica de la CEE (documento 111/3976/88 de julio de 1990) y la normativa legal vigente española que regula la investigación clínica en humanos (Real Decreto 561/1993 sobre ensayos clínicos).
Para complementar los resultados científicos derivados del presente estudio, se presentarán algunos resultados procedentes de un estudio Europeo de similares características, The European Youth Heart Study (EYHS). Los jóvenes investigadores firmantes del presente trabajo han tenido la oportunidad de participar de manera destacada en dicho estudio, como resultado de varias estancias de investigación realizadas en el Karolinska Institutet (Suecia), uno de los centros de investigación más prestigiosos del mundo.

Principales variables estudiadas

Las siguientes variables fueron evaluadas en cada una de las cinco ciudades involucradas en estudio AVENA.

Valoración de la condición física
Se realizaron seis pruebas integradas dentro de la batería EUROFIT (EUROFIT, 1992), validada y estandarizada por el Consejo de Europa, en el orden que se indica:
1. *Flexión de tronco adelante en posición sentado:* Con el sujeto sentado en el suelo y valiéndose de un soporte estandarizado (Glosser, 1998) se determinó la máxima distancia alcanzada con la punta de los dedos mediante flexión anterior de tronco. Test indicativo de la amplitud de movimiento o flexibilidad. 2. *Dinamometría manual: M*ediante el empleo de un dinamómetro digital Takei TKK 5101 (rango 5-100 kg), se valoró la fuerza de prensión manual máxima en ambas manos. 3. *Salto de longitud con pies juntos y sin impulso: Se r*egistró la máxima distancia horizontal alcanzada. Esta prueba evalúa la fuerza-explosiva de las extremidades inferiores. 4. *Suspensión con flexión de brazos: M*ediante test estandarizado de máximo tiempo de suspensión en barra fija. Esta prueba estima la fuerza-resistencia del tren superior. 5. *Carrera de ida y vuelta: 4 x 10 metros:* Con esta prueba se evaluó de manera integrada la velocidad de desplazamiento y LA coordinación. Para ello el sujeto hacía 4 carreras de ida y vuelta a la máxima velocidad posible entre dos líneas separadas 10 m. En cada extremo depositaba y recogía un objeto (esponja) situado en el suelo y junto a la línea. 6. *Test de Course-Navette:* Esta prueba evalúa la capacidad aeróbica máxima a partir de un test de campo indirecto-incremental-máximo de ida y vuelta de 20 m (Léger y col., 1984), utilizando las ecuaciones propuestas por Léger y colaboradores (Léger y col., 1988) para estimar del consumo máximo de oxígeno (VO2max). La fiabilidad y validez de este test para predecir el VO2max en niños y adolescentes, ha sido suficientemente demostrada (Léger y col., 1988; Liu y col., 1992; Van Mechlen y col., 1986).

Nivel de actividad física
La valoración del comportamiento hacia la actividad física y el deporte, condicionado por las actitudes, motivaciones y valores que se tienen sobre la misma, se realizó a partir de un cuestionario elaborado específicamente para el estudio AVENA, el cual ha sido sometido a un proceso de validación y fiabilidad en las diferentes edades del estudio. Este cuestionario ha sido construido atendiendo a una síntesis realizada a partir de herramientas ya utilizadas en la bibliografía, aportaciones del propio grupo de investigación y estudios experimentales realizados por los propios investigadores del proyecto. Con ello se valora: 1. Actitudes,

intereses y valores hacia la actividad física y el deporte, mediante los items correspondientes de la encuesta de García Ferrando (1998); 2. Motivaciones y causas de abandono hacia la práctica de actividad físico-deportiva, mediante la misma técnica y los items del cuestionario de Mendoza y col. (1994); 3. Actitudes hacia el proceso y el producto relacionadas con la salud, a partir del cuestionario de actitudes de actividad física orientada a la salud de Pérez Samaniego (1999); 4. Percepción de la utilidad de la práctica de actividad física y el deporte hacia la salud, valorada a partir del diferencial semántico de Sánchez Bañuelos (1996).

Evaluación antropométrica

Las mediciones antropométricas se llevaron a cabo por investigadores experimentados. Se valoraron los siguientes parámetros siguiendo el protocolo más común para la población infantil en Europa (1992): 1. *Masa corporal* (báscula modelo Seca 714 con precisión de 100 g y un rango 0.1-130 kg); 2. *Talla* (tallímetro incorporado a la báscula modelo Seca 714, rango 60 – 200 cm); 3. *Seis pliegues cutáneos* (tricipital, bicipital, subescapular, suprailíaco, muslo y gemelo) mediante un plicómetro de compás modelo Holtain con presión constante de 10 g/mm^2 de superficie de contacto (rango 0 – 40 mm); 4. *Cinco perímetros corporales* (brazo relajado, brazo contraído, cintura, cadera y muslo) mediante una cinta métrica de material inextensible (rango 0-150 cm); 5. *Tres diámetros óseos* (muñeca, codo y fémur) mediante pié de rey modelo Holtain (rango 0-14 cm); 6. *Índices antropométricos de composición corporal:* 6.1. Índice de masa corporal (IMC): Es la relación entre el peso en kg y la talla en metros al cuadrado. Es un índice adecuado para la identificación de niños y adolescentes obesos (Moreno y col., 1999); 6.2. Porcentaje de grasa corporal: mediante la fórmula de Slaughter y col. (1988); 6.3. Índices de distribución de la grasa corporal: se valoró el perímetro de la cintura y algunas relaciones entre perímetros y pliegues cutáneos (Moreno et al., 1998); 7. *Maduración Sexual*: Se valoraron los distintos estadios de desarrollo sexual siguiendo la metodología descrita por Tanner y Whitehouse. (1976). Se distinguen 5 estadios para cada una de las características: desarrollo genital y vello pubiano en varones y desarrollo mamario y vello pubiano en mujeres; 8. También se evaluó la edad de la menarquia mediante un cuestionario donde se registraba la edad de la primera menstruación.

Análisis sanguíneo

Se realizó una extracción sanguínea a una submuestra elegida aleatoriamente (según edad, género, localización geográfica y nivel económico) de 470 adolescentes. Las extracciones sanguíneas se realizaron en ayunas, entre las 8:00 y las 9:00 e.m. por punción en la vena cubital. Los adolescentes fueron avisados de no ingerir alcohol ni realizar ejercicio físico extenuante las 48 h previas a la extracción sanguínea. Las muestras sanguíneas fueron inmediatamente centrifugadas y el suero fue enviado refrigerado al laboratorio central del estudio multicéntrico (este laboratorio es el correspondiente al grupo andaluz que firma el trabajo), donde se almacenaron a -80ºC hasta su posterior análisis.

Se analizaron los niveles de glucosa, triglicéridos (TG), colesterol total (TC) y colesterol de lipoproteínas de alta densidad (HDLc) mediante el analizador Hitachi 911 (Roche Diagnostics, Indianapolis, Ind, USA). El colesterol de lipoproteínas de baja densidad (LDLc) se calculó mediante la fórmula de Friedewald (Friedewald y col., 1972) ajustado para los niveles de triglicéridos plasmáticos (Nakanishi y col., 2000). Los niveles de apolipoproteina (apo) A-1, apo B-100 y lipoproteina(a) [Lp(a)] se midieron mediante ensayo de immunonefelometría usnado el sistema Array 306 (Beckman GMI, Inc., Albertville, Minnesota, USA). También se calcularon los siguiente índices aterogénicos: TC/HDLc, TC-HDLc, (TC-HDLc)/HDLc, TG/HDLc, LDLc/HDLc, apo B-100/apo A-1, y apo B-100/LDLc. La calidad de los ensayos bioquímicos fue controlada por el Servicio Andaluz de Salud.

Los niveles de homocisteina (tHcy) se analizaron mediante fluorescencia en el kit IMx® (Abbott Laboratories, IL, USA). Los niveles de folato y vitamina B_{12} se midieron por el método flourometrico con el kit Abbot IMx® autoanalyser (Abbot Laboratory, Chicago, USA).
El perfil inmunológico se analizó en el Laboratorio del Instituto del Frío (CSIC, Madrid). Se midieron los niveles de proteína C reactive, los factores de complemento C3, C4 y la ceruloplasmina mediante immunoturbidimetria (AU2700 biochemistry analyzer; Olympus, Rungis, France). También se analizó la tranthyretina (conocida como pre-albúmina) mediante la misma técnica (Roche/Hitachi 912).

Análisis genético
El DNA genómico se extrajo de 500 µL de sangre anticoagulada mediante la técnica descrita por Higuchi (Higuchi, 1989). La caracterización del genotipo de la methylenetetrahydrofolate reductase (*MTHFR*) para el polimorfismo *C677T* se realizó según el protocolo desarrollado por Frosst y col. (1995) por medio de la reacción en cadena de la polimerasa (PCR) y posterior digestión de los productos amplificados con el enzima de restricción *Hinf* I. A continuación se realizó una electroforesis de los fragmentos digeridos en un gel de agarosa al 3% en TBE 1x a 100 voltios durante 45 minutos y se visualizaron en un trasilumnidor de luz ultravioleta tras tinción con bromuro de etidio.
También se midieron los polimorfismos de los genes *APOE* y *APOC3* mediante PCR y posterior digestión específica (Hha I y SstI, respectivamente), seguida de electroforesis. *Se* determinaron las frecuencias alélicas para cada una de las isoformas *S1, S2* de *APOC3* y *ε2, ε3 y ε4* de *APOE.*

RESULTADOS

Nota: De los resultados obtenidos en el estudio AVENA, en este trabajo se presentan sólo aquellos relativos al nivel de condición física y actividad física practicada. Todos los datos presentados a continuación han sido previamente publicados o están aceptados para publicación en revistas científicas con índice de impacto, así como en destacados eventos científicos de carácter internacional (Ver anexo I y II). Se incluyen al final del texto algunas figuras representativas de los resultados que se muestran a continuación

1. Valoración de la condición física: evaluación e interpretación

Se han presentado los valores normativos de condición física de la población adolescente española, expresados en tablas y curvas de percentiles específicas por grupo de edad y género, que permitirán valorar el nivel de condición física de cualquier adolescente en función de su edad y género (Ver anexo III). El rango del percentil 5 respecto a la capacidad aeróbica máxima (test de Course Navette) es de 2,0-3,3 paliers y 1,4-1,9 paliers, para varones y mujeres respectivamente (Referencias propias). Aproximadamente 1 de cada 5 adolescentes presentan riesgo cardiovascular futuro, en base al umbral cardiorespiratorio mínimo para garantizar la salud cardiovascular futura propuesto por el Cooper Institute (1999). Este subgrupo de adolescentes mostró también una peor forma física que el resto de adolescentes en todas las pruebas físicas realizadas (Referencias propias). En comparación con otros países europeos, los adolescentes españoles poseen una menor fuerza muscular y peor capacidad aeróbica, a excepción de los adolescentes estadounidenses, quienes mostraron la peor capacidad aeróbica de entre los estudios revisados (Referencias propias)

2. Importancia de la condición física para salud integral en niños y adolescentes.

2.1. Condición física y factores de riesgo cardiovascular

2.1.1. Capacidad aeróbica y factores de riesgo cardiovascular

Se analizaron las asociaciones existentes entre la capacidad aeróbica y parámetros lipídicos individuales y con un índice continuo de riesgo metabólico-cardiovascular calculado a partir del HDLc y LDLc, triglicéridos y glucosa. Tras ajustar por variables de confusión (edad, maduración sexual, y estatus socioeconómico), el riesgo metabólico-cardiovascular estuvo inversamente asociado con la capacidad aeróbica en varones (P=0,018) y en mujeres (P=0,045, del 2º cuartil al 4º cuartil de capacidad aeróbica). Para un nivel dado de capacidad aeróbica, los adolescentes con sobrepeso-obesidad presentaron un riesgo significativamente mayor que sus compañeros con normopeso (P=0,001). Del mismo modo, para un estado de peso dado, los adolescentes con mayor capacidad aeróbica mostraron un menor riesgo metabólico-cardiovascular (P<0,05). Tras establecer la capacidad aeróbica mínima para presentar un perfil lipídico favorable mediante análisis de curvas ROC, alrededor del 50% de los chicos no alcanzaron dicho umbral cardiosaludable (Referencias propias).

Se examinaron las relaciones entre capacidad aeróbica asociados a un bajo riesgo metabólico-cardiovascular en adolescentes, considerando variantes de los genes *APOC3* y *APOE*. Para ello, se calculó un índice de riesgo metabólico-cardiovascular (definido por los niveles plasmáticos de glucemia, TG, HDLc, LDLc e IMC. Se caracterizaron para los polimorfismos comunes de los genes *APOC3* (alelos *S1 y S2*) y *APOE* (alelos *ε2, ε3 y ε4*). La capacidad aeróbica se relacionó con el índice de riesgo metabólico-cardiovascular tanto en varones (P<0,001) como en mujeres (P=0,012), tras ajustar por edad y maduración sexual. Al tener en cuenta variantes genéticas, y tras ajustar por género, edad y maduración sexual, se obtuvieron diferentes relaciones para cada variante genética, excepto para los portadores del alelo *ε2*, en los que no existió asociación entre capacidad aeróbica y riesgo metabólico-cardiovascular. Los niveles saludables de capacidad aeróbica para los portadores del alelo *S2* del gen *APOC3* o del alelo *ε4* de *APOE* (en total 33% de la población analizada) son mayores que los valores de capacidad aeróbica para los portadores de los genes *APOC3 S1/S1* o *APOE ε3/ε3*, y esto para presentar el mismo índice de riesgo metabólico-cardiovascular. Por tanto, este estudio sugiere que la capacidad aeróbica necesaria en adolescentes para presentar un bajo riesgo metabólico-cardiovascular debe de ser individualizada en función de aspectos genéticos. Igualmente, los datos sugieren que, en función de factores genéticos, uno de cada tres adolescentes españoles podría requerir mayores niveles de capacidad aeróbica que el resto de la población, con objeto de compensar su predisposición hacia un mayor riesgo metabólico-cardiovascular (Referencias propias).

Resultados procedentes del estudio AVENA mostraron también una asociación inversa entre la capacidad aeróbica y factores de riesgo cardiovascular recientemente reconocidos, tales como proteínas inflamatorias (e.g. proteina C reactiva, fibrinógeno, ceruloplasmina y factores de complemento C3 y C4) y homocisteína, en adolescentes. En mujeres, la asociación entre homocisteína y capacidad aeróbica fue significativa incluso cuando factores potencialmente influyentes fueron controlados en el análisis (edad, desarrollo madurativo, peso al nacimiento, fumador/no fumador, estatus socioeconómico, sumatorio de 6 pliegues cutáneos y "methylenetetrahydrofolate reductase 677C>T genotype") (Referencias propias).

2.1.2. Fuerza muscular y factores de riesgo cardiovascular

Diversos estudios han demostrado inequívocamente que la fuerza muscular está inversamente relacionada con la mortalidad por causa cardiovascular y por todas las causas en adultos

(Metter et al., 2002). Sin embargo, poco ha sido estudiado en relación a la fuerza y parámetros de salud en niños y adolescentes. Datos procedentes del estudio AVENA, mostraron que independientemente de la capacidad aeróbica que se tenga, la fuerza muscular, definida como un índice integrado de fuerza explosiva tren inferior, fuerza resistencia tren superior y fuerza de prensión máxima, se asocia con el perfil lipídico-metabólico (triglicéridos, LDLc, HDLc y glucosa), especialmente en sujetos de sexo femenino. Recientemente hemos observado que la fuerza muscular esta asociada no sólo con factores de riesgo cardiovascular convencionales, sino también parámetros de riesgo cardiovascular recientemente establecidos, tales como proteínas inflamatorias. En este sentido, cabe destacar que la fuerza muscular se asoció con la proteína C reactiva, tanto en adolescentes con normopeso, como con aquellos con sobrepeso (Referencias propias).

2.2. Condición física, actividad física y composición corporal

2.2.1. Condición física, actividad física y grasa corporal total

Se examinaron las asociaciones entre capacidad aerobia, actividad física medida objetivamente (mediante acelerometría) y grasa corporal, definida por el sumatorio de 5 pliegues cutáneos. Los resultados muestran que la capacidad aeróbica y la actividad física intensa, pero no la moderada, están inversamente relacionadas con la grasa corporal total en niños. Los resultados obtenidos sugieren que el ejercicio físico requiere un mínimo de intensidad para obtener beneficios en la composición corporal de niños y adolescentes (Referencias propias).

2.2.2. Condición física, actividad física y distribución de la grasa corporal

Se examinó si la capacidad aeróbica, nivel de actividad física y el nivel sedentarismo está relacionado con índices antropométricos de adiposidad total (IMC) y abdominal (perímetro de cintura), como previamente había sido observado en adultos. No se encontró ninguna relación entre la actividad física practicada en el tiempo libre y el IMC o perímetro de cintura. Por el contrario y tras ajustar por diferentes variables de confusión (edad, estado de maduración sexual y nivel socioeconómico) la capacidad aeróbica se estuvo inversamente relacionada con el IMC y perímetro de cintura en ambos sexos, independientemente del nivel de actividad física practicado ($P \leq 0{,}001$). Aunque en menor medida, las actividades sedentarias se relacionaron también directamente e independientemente del nivel de actividad física practicado, con el perímetro de cintura ($P \leq 0{,}05$) y IMC ($P \leq 0{,}05$) en ambos sexos. La capacidad aeróbica explicó el 13% y 16% de la varianza del perímetro de cintura, en varones y mujeres, respectivamente. Tras dividir la muestra en sujetos con normopeso y con sobrepeso-obesidad, el perímetro de cintura ajustado por el IMC (para estudiar las asociaciones específicas con la grasa abdominal) estuvo inversamente correlacionado con el VO2 en adolescentes con sobrepeso-obesidad ($P \leq 0{,}05$), observándose una tendencia a la significación en las adolescentes con sobrepeso-obesidad ($P \leq 0{,}1$) (Referencias propias). Con el objeto de profundizar en las asociaciones entre actividad física y grasa abdominal, nuestro grupo examinó dichas asociaciones en niños y adolescentes suecos, valorando la actividad física mediante acelerometría, el método por excelencia en estudios epidemiológicos actualmente. El resultado fue que ninguna de las variables de actividad física estudiadas (actividad moderada, intensa, moderada + intensa y tiempo total de actividad) estuvieron relacionadas con la grasa abdominal. Al igual que con los adolescentes españoles, la capacidad aeróbica también se asoció inversamente con la grasa abdominal en esta población de estudio. Los resultados obtenidos, sugieren que los beneficios de la actividad física sobre la grasa abdominal se producirán siempre y cuando la actividad física practicada sea suficiente para mejorar el nivel de condición física (Referencias propias).

3. De Andalucía a España, de España a Europa. ANEXO IV

Sobre la base de la experiencia del proyecto AVENA y de los resultados que de él se han obtenido, el grupo andaluz liderado por fisiólogos de dilatada experiencia y empujado por la intensa actividad de sus jóvenes investigadores, se ha involucrado recientemente en la extensión del AVENA a Europa, el Proyecto HELENA: **Healthy Life Style in Europe by Nutrition in Adolescence.** En el proyecto HELENA participan 25 grupos pertenecientes a 10 países europeos, con el objeto de estudiar el estado de salud de los adolescentes europeos, y crear estrategias de intervención sobre la salud de los adolescentes europeos. El proyecto ha sido financiado por la Comisión Europea con 4.999.996 €. En este proyecto, nuestro grupo de investigación es responsable de la evaluación de la condición física (ver work package 7) junto con el Department of Biosciences and Nutrition del Karolinska Institutet, Suecia.
Aunque dicho proyecto se encuentra aun en fase de recogida de datos, el grupo andaluz ya posee dos artículos publicados y otros dos en trámite de publicación en revistas internacionales, liderando en producción científica el proyecto HELENA.

CONCLUSIONES

1. Los resultados obtenidos en el presente estudio permiten evaluar e interpretar correctamente el nivel de forma física de cualquier adolescente en base a su edad y género. La utilización de estos valores de referencia en centros deportivos y educativos para la evaluación de la condición física como indicador de salud, así como para la detección de talentos deportivos resulta de gran interés clínico y social. Los resultados obtenidos indican la necesidad de mejorar el nivel de condición física de los adolescentes españoles, así como la necesidad de plantear estrategias de intervención para mejorar el perfil lipídico.

2. Los resultados encontrados sugieren que tanto la capacidad aeróbica y fuerza muscular, como el mantenimiento de un peso adecuado son necesarios para la prevención del riesgo metabólico-cardiovascular en adolescentes. Se ha propuesto los niveles mínimos de capacidad aeróbica asociados a un perfil lipídico saludable. Esto supone una nueva herramienta que podría ser utilizada en los centros educativos y deportivos como estándares de capacidad aeróbica deseables.

3. La capacidad aeróbica y la actividad física intensa, pero no la de intensidad moderada (objetivamente medida por acelerometría), se asocia inversamente con la grasa corporal total. Una capacidad aeróbica moderada-alta está asociada a una menor grasa abdominal, sin embargo no existe relación entre el nivel de actividad física practicada (valorada a través de cuestionario u objetivamente medida por acelerometría) y la grasa abdominal.

4. La capacidad aeróbica necesaria en adolescentes para presentar un bajo riesgo metabólico-cardiovascular debe de ser individualizada en función de aspectos genéticos. Igualmente, los datos sugieren que, en función de factores genéticos, uno de cada tres adolescentes españoles podría requerir mayores niveles de capacidad aeróbica que el resto de la población, con objeto de compensar su predisposición genética hacia un mayor riesgo metabólico-cardiovascular.

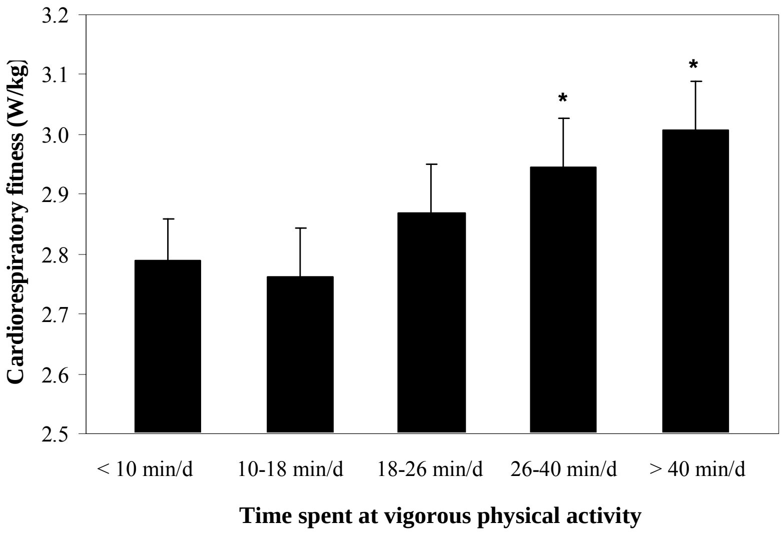


Figure 1. Mean cardiorespiratory fitness stratified by time spent at vigorous physical activity in Swedish and Estonian children. Errors bars represent 95 % CIs. * A significant difference was observed between those who accumulated > 40 min of vigorous physical activity per day and those who accumulated < 18 min/d at this intensity level. ^ A significant difference was also observed between children who accumulated 26-40 min/d of vigorous physical activity compared to those who accumulated 10-18 min/d at this level of intensity (Referencias propias).

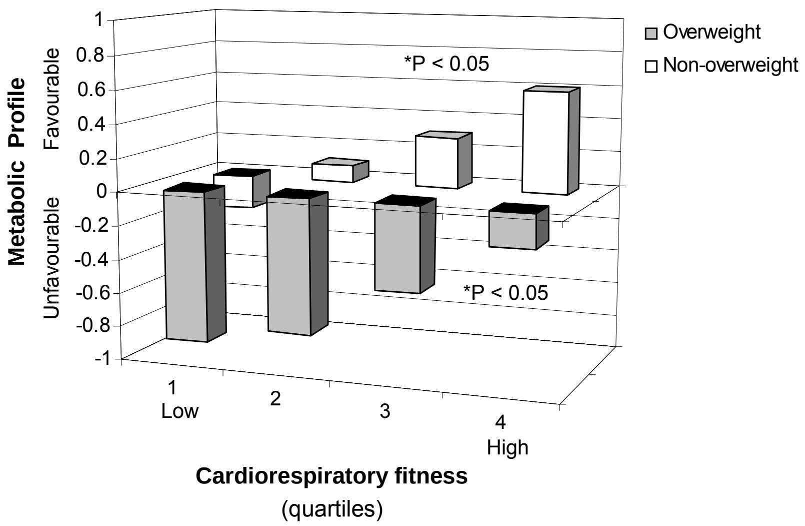


Figure 2. Association between metabolic profile (computed with age- gender specific standardized values of triglycerides, low density lipoprotein cholesterol, high density lipoprotein cholesterol and fasting glycaemia) and cardiorespiratory fitness quartiles in non-overweight and overweight Spanish adolescents. The higher is the metabolic profile the healthier. Weight categories were constructed following the International Obesity Task Force-proposed gender- and age-adjusted body mass index cutoff points. Data shown as mean and standard error of the mean. *P for trend in both overweight and non-overweight categories.

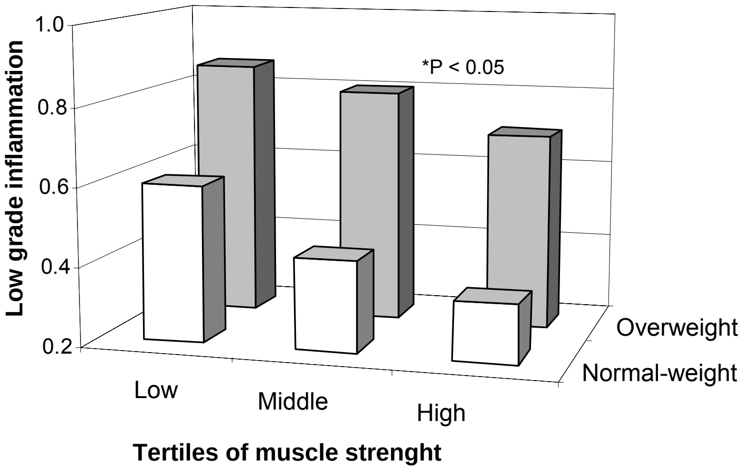


Figure 3. Associations between tertiles of muscle strength and low grade inflammation (estimated as a compound index of C-reactive protein and C3). These results are presented according to weight categories in Spanish adolescents. Weight categories were constructed following the International Obesity Task Force-proposed gender- and age-adjusted body mass index cut-off points. *P value from the regression analyses for the overweight category.

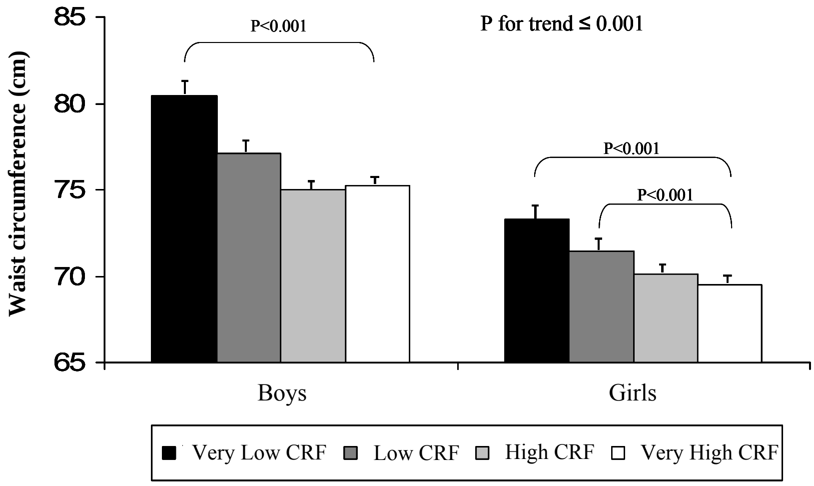


Figure 4. Waist circumference (means ± standard error of the mean) according to cardiorespiratory fitness (CRF) quartiles in Spanish adolescents.

ANEXO IV-1

REPERCUSIÓN CIENTÍFICA DEL ESTUDIO A NIVEL DE PUBLICACIONES (FORMATO ANÓNIMO)

Nota: A continuación se presentan en formato anónimo las publicaciones en que se basan los resultados aquí presentados. Se incluyen sólo los artículos más destacados de los 6 últimos años donde el principal objeto de estudio fue la condición física y/o actividad física y donde los autores que postulan al Premio figuran como principales autores de los mismos. Los documentos originales de todo lo que se cita a continuación pueden ser presentados si se solicita.

1) Artículos científicos

1. Physical exercise reverses diet-induced increases in LDL-cholesterol and apo B levels in healthy ovo-lactovegetarian subjects. **Nutrition Research** 20: 1707 – 1714 (2000).
2. La nutrición en la práctica deportiva: Adaptación de la pirámide nutricional a las características de la dieta del deportista. **Arch Latinoam Nutri** 51: 321-331 (2001).
3. Three days fast in sportsmen decrease physical work capacity but not strength or perception-reaction time. **Int J Sports Nutr** 11: 420-9 (2001).
4. Hand size influences optimal grip span in women but not in men. **J Hand Surg (Am)** 27A: 897-901 (2002).
5. Creatine supplementation and muscle metabolism in physical exercise. **Sport Med** 32: 903-944 (2002).
6. Use of sauna to induce a rapid weight loss in young healthy athletes competing in weight class events. **Int J Sport Med** 2003 Oct;24(7):518-22.
7. Exposure to hypoxia decreases growth hormone response to physical exercise in untrained subjects. **J Sports Med Phy Fitness** 2003;43(4):554-8.
8. Physical fitness evaluation-interpretation software. **Int J Comp Sci Sport** 2: 160-162 (2003).
9. Software for anthropometric assessment providing indexes of interest for health and sport. **Int J Comp Sci Sport** 2: 142-144 (2003).
10. Alimentación y valoración del estado nutricional de los adolescentes españoles (Estudio AVENA). Evaluación de riesgos y propuesta de intervención. I. Descripción metodológica del proyecto. **Nutr Hosp** 18: 15-28 (2003).
11. Body composition and physical performance of Spanish adolescents. The AVENA pilot study. **Acta Diabetol** 40: S299-S301 (2003).
12. Hiponatremia en esfuerzos de ultraresistencia: efectos sobre la salud y el rendimiento. **Arch Latinoam Nutr** 52:155-164 (2004).
13. Deportes con alto grado de estrés físico afectan negativamente el perfil lipídico plasmático. **Rev Esp Cardiol** 57: 499-506 (2004)
14. Un programa de intervención nutricional y actividad física de seis meses previene el incremento de masa grasa en adolescentes. **Rev Esp Pediatr** 60:283-290 (2004).
15. La mejora de la forma física como terapia anti-envejecimiento. **Med Clin** 2005;124:146-55.
16. Increased susceptibility to plasma lipid peroxidation in untrained subjects after an extreme mountain bike challenge. **Int J Sports Med** 2005;26:1-3.
17. Forma física como factor de riesgo cardiovascular: Valores normativos de condición física de los adolescentes españoles. **Rev Esp Cardiol** 2005;58(8):898-909. * ^

   * **Editorial asociado** en el mismo número: Actividad física. Un eficiente y olvidado elemento de la prevención cardiovascular, desde la infancia hasta la vejez. Roberto Elosua, 2005;58 (8):887-90.

^ 2º Accesit del **Premio al mejor trabajo publicado en Revista Española de Cardiología en el 2005**. Concedido por la Sociedad Española de Cardiología. 18 de Octubre de 2006.

18. The importance of cardiorespiratory fitness for healthy metabolic traits in children and adolescents. The AVENA Study. **J Public Health** 2006; 14: 178-180.
19. Aerobic physical fitness in relation to blood lipids and fasting glycaemia in adolescents. Influence of weight status. **Nutr Metab Cardiovas** 2006;16: 285-293.
20. Hand-size influences optimal grip span in young healthy subjects. **J Hand Surgery** (Am) 2006; 31:1367-1372.
21. Anti-aging therapy through fitness enhancement. **Clin Interv Aging** 2006; 1213-220.
22. Extreme mountain bike challenges may induce sub-clinical myocardial damage. **J Sport Med Phys Fitness** 2006;46(3):489-493.
23. Health-related fitness assessment in childhood and adolescence; A European approach based on the AVENA, EYHS and HELENA studies**. J Public Health** 2006; 84(2):298-302.

2) Artículos en trámite de publicación

1. Cardiorespiratory fitness and sedentary activities are associated with favorable abdominal adiposity in adolescents. **Obesity**.
2. Anthropometric determinants of a clustering of lipid-related atherogenesis risk factors in overweight and non-overweight adolescents. Influence of cardiorespiratory fitness. **Ann Nutr Metab**.
3. Cardiovascular fitness is negatively associated with homocysteine levels in female adolescents. **Arch Pediatr Adol Med**.
4. Homocysteine levels in Swedish children and adolescents; associations with physical activity, fitness and fatness with regard to MTHFR 677C>T genotype. **Brit J Nutrition**.
5. Physical fitness according to sex and age in adolescence: utility for fitness assessment in the school, the sport centres and health institutions (The AVENA study). **J Sport Med Phy Fitness**
6. Physical Fitness is an Important Additional Contributor to Health for the Adults of Tomorrow. **World Rev Nutr Diet** .
7. APOE and APOC3 genotype-dependent associations between cardiorespiratory fitness and lipid-related metabolic traits in adolescents. The AVENA study. **Nutr Metab Cardiovasc Dis.**
8. Physically active adolescents are more likely to have a cardiovascular fitness level adequate for cardiovascular health. **Scand J Med Sci Sports**.
9. Moderate to high levels of cardiovascular fitness, but not physical activity, are associated with lower abdominal adiposity in children and adolescents. The European Youth Heart Study. **J Pediatr**.
10. Lipid-metabolic risk profile is more related to physical fitness (cardiorespiratory fitness and muscle strength) than to physical activity. The AVENA study. **Rev Esp Cardiol.**
11. High Cardiorespiratory Fitness is Associated with Low Metabolic Risk Score in Children; The European Youth Heart Study **Pediatrics Res**.
12. Development and validation of an artificial neural network-based equation to estimate VO2max from 20 m shuttle run test in adolescents aged. **J Appl Physiol**.
13. Relative associations of physical activity, fitness and fatness to low-grade inflammation in prepubertal children; The European Youth Heart Study. **Int J Obes**.
14. Association of insulin resistance markers with fatness and fitness in prepubertal children. The European Youth Heart Study. **Diabetologia**.
15. Inflammatory proteins are associated with muscle strength in adolescents; The AVENA study. **Circulation**.
16. Relationship of physical activity, fitness and fatness with features of metabolic syndrome in Swedish children and adolescents; The European Youth Heart Study. **J Pediatrics**.

ANEXO IV-2

DIFUSIÓN CIENTÍFICA DEL ESTUDIO MEDIANTE EVENTOS CIENTÍFICOS DE CARÁCTER INTERNACIONAL (FORMATO ANÓNIMO)

Nota: Debido al gran volumen de ponencias y comunicaciones a eventos científicos (más de 100), se han seleccionado solamente aquellos de carácter internacional desarrollados durante el 2006. Se presentan en formato anónimo (sin nombres de autores). Los documentos originales de todo lo que se cita a continuación pueden ser presentados si se solicita.

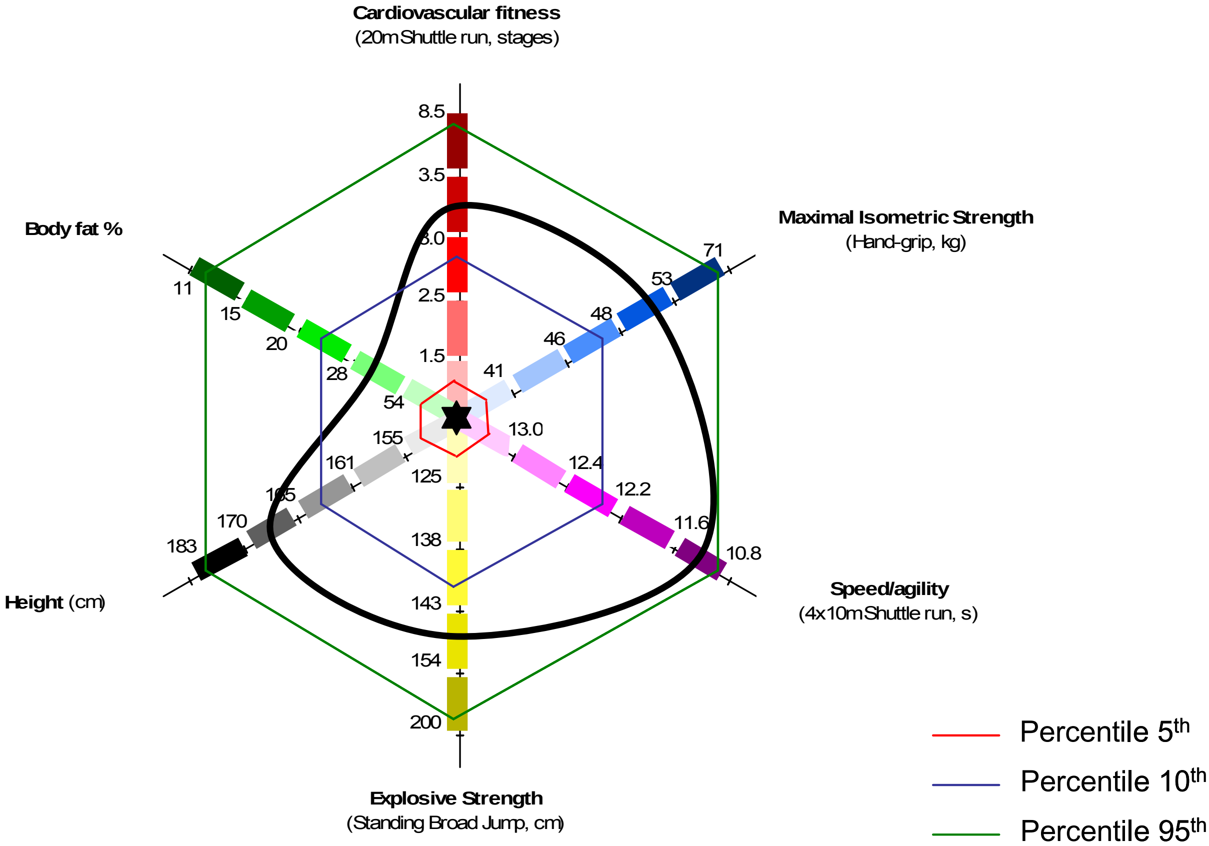
1. Sedentary activities, but not physical activity, are associated with abdominal adiposity in adolescents. The AVENA study. **2nd Scandinavian Pediatric Obesity Conference**. Malmö (Sweden) 2006.
2. Cardiorespiratory fitness is associated with a favorable lipid profile independent of abdominal fat in male adolescents. **53rd Annual Meeting of the American College of Sports Medicine**. Denver, Colorado, May 2006. Med Sci Sports Exerc, 2006;38(5 Suppl):S7-8.
3. Association of Fitness and Fatness to Low-Grade Systemic Inflammation in Adolescents. The AVENA Study. **53rd Annual Meeting of the American College of Sports Medicine**. Denver, Colorado, May 2006.Med Sci Sports Exerc, 2006;38(5 Suppl):S8.
4. Metabolic Health Criterion for Cardiorespiratory Fitness in Children; The European Youth Heart Study. **53rd Annual Meeting of the American College of Sports Medicine**. Denver, Colorado, May 2006. Med Sci Sports Exerc, 2006;38(5 Suppl):S433-4.
5. Should Cardiorespiratory Fitness of Children be Assessed in Public Health Monitoring Systems? **International Congress on Physical Activity and Public Health**. Atlanta, 2006.
6. Waist circumference and cardiorespiratory fitness in Spanish adolescents. The AVENA study. **Children, Physical Activity & Health The 4th European Youth Heart Study Symposium** & Objective Measurement of Physical Activity Satellite meeting of 'The 6th International Conference on Diet Assessment Methods'. University of Southern Denmark Odense, Denmark 24th - 26th April 2006.
7. Rationale for including cardiorespiratory fitness assessment in public health monitoring systems in children. **Children, Physical Activity & Health The 4th European Youth Heart Study Symposium** & Objective Measurement of Physical Activity Satellite meeting of 'The 6th International Conference on Diet Assessment Methods'. University of Southern Denmark Odense, Denmark 24th - 26th April 2006.
8. Body composition as predictor of muscle strength. The AVENA study. **11th European College of Sport Science Congress** 05-08 July, Lausanne 2006/Switzerland.
9. Cardiovascular fitness in Swedish and Spanish adolescents: influence of sexual maturation status. **2nd annual meeting of HEPA Europe**. 14-16 June, Tampere (Finland), 2006.
10. Influence of amount and intensity level of physical activity on cardiovascular fitness and fatness in children. **2nd annual meeting of HEPA Europe**. 14-16 June, Tampere (Finland), 2006.
11. Cardiovascular fitness, objectively measured physical activity and waist circumference in Swedish children and adolescents. **I World Congress of Public Health Nutrition. VII National Congress of the Spanish Society of Community Nutrition**. Barcelona, Spain 28-30 September 2006. Public Health Nutr 2006; 9:193.
12. Homocysteine levels in Swedish children and adolescents; associations with physical activity, fitness and fatness. **I World Congress of Public Health Nutrition. VII National Congress of the Spanish Society of Community Nutrition**. Barcelona, Spain 28-30 September 2006. Public Health Nutr 2006; 9:193-4.
13. Association of breakfast habits with higher risk for overweight, abdominal obesity, and fitness. The AVENA study. **I World Congress of Public Health Nutrition. VII National Congress of the Spanish Society of Community Nutrition**. Barcelona, Spain 28-30 September 2006. Public Health Nutr 2006; 9:212.
14. Cardiovascular fitness and homocysteine levels in Spanish adolescents. **The Hematology and Hemotherapy Spanish Association - XXIII Annual Meeting of The Thrombosis and Haemostasis Spanish Society**. 26-28 October 2006.

ANEXO IV-3

REPERCUSIÓN SOCIAL DEL ESTUDIO

Nota: Tenemos constancia expresa de que los valores normativos de la condición física publicados por nuestro grupo están siendo usados en institutos de educación secundaria y centros deportivos para evaluar e interpretar el nivel de condición física de forma individualizada. De igual modo, nuestro grupo desempeña una actividad asistencial basada en nuestra experiencia y actividad científica. Se muestra aquí a modo de ejemplo una de las herramientas que utilizamos para la interpretación inmediata de la condición física de una persona. La línea negra representa el perfil de condición física de un sujeto evaluado. De forma simple y rápida se obtiene una valoración global de su condición física, destacando puntos fuertes y débiles. La valoración de la condición física realizada de esta forma permite prescribir programas individualizados de ejercicio físico orientados a la mejora de la condición física, permite controlar los efectos del entrenamiento con sucesivas valoraciones, e incluso orientar deportivamente a la persona hacia las modalidades más adecuadas según su condición física (detección de talentos).

PERFIL DE CONDICIÓN FÍSICA



ANEXO IV-4

PRESENTACIÓN ESTUDIO HELENA

The key to health promotion and disease prevention in the 21st century is to establish an environment that supports positive health behaviour and healthy lifestyle. In spite of scientific advance, non-communicable diseases are still the most common causes of morbidity and mortality in Europe. Most of these diseases have their origin during childhood and adolescence, but the relationship between the development of non-communicable diseases and the adolescence process is poorly understood. The interactions between the environment, the genetic predisposition and growth in children and adolescents have not been studied yet. Adolescence is a crucial period in life and implies multiple physiological and psychological changes that affect nutritional needs and habits. Many healthy (or unhealthy) life-long habits begin in adolescence. The HELENA proposal includes cross-sectional, crossover and pilot community intervention multi-centre studies, as an integrated approach to the above-mentioned problem. The following aspects will provide the full information about the nutritional status of the European adolescents: (1) dietary intake, nutrition knowledge and eating attitudes; (2) food choices and preferences (3) body composition; (4) plasma lipids and metabolic profile; (5) vitamin status; (6) immune function related to nutritional status; (7) physical activity and fitness; and (8) genotype (to analyse gene-nutrient and gene-environment interactions). The requirements for health promoting foods will also be identified, and three sensory acceptable products for adolescents will be developed. Both scientific and technological objectives should result in reliable and comparable data of a representative sample of European adolescents. This will contribute to understand why health-related messages are not being as effective as expected in the adolescent population; and to propose a realistic intervention strategy in order to try to achieve the goals of understanding and effectively enhancing nutritional and lifestyle habits of adolescents in Europe.

HELENA Project objectives

1. To develop and harmonise innovative methods for the assessment of lifestyle habits of adolescents across Europe with special focus on diet, nutrition and physical activity
2. To assess dietary and physical activity patterns as well as nutritional status among European adolescents
3. To investigate knowledge and attitudes towards nutrition among adolescents and to establish the main determinants of their food choice and preference
4. To describe regional, cultural, social, genetic and gender differences and similarities across Europe
5. To identify adolescents at risk of eating disorders, dislipemia, obesity and/or type 2 diabetes
6. To develop a number of healthy foods and identify marketing strategies for consumers, in order to improve the diet of adolescents
7. To develop a Lifestyle Education Programme and test its efficacy for improving adolescent's health

HELENA Workplan

The work has been broken down according to types of activities: Research, technological development and innovation related activities; demonstration activities; project management activities; and quality control activities. The main part of the work plan is devoted to research, technological development and innovation related activities. This part of HELENA has been designed in order to fit with the requirements of the call, Priority thematic area 5: Food Quality and Safety, Epidemiology of food-related diseases and allergies, (T2.4) Nutritional and lifestyle habits of adolescents throughout Europe, including development of health-promoting foods with sensory properties attractive to adolescents – STREP. HELENA includes four main studies: cross-sectional studies (HELENA-CSS) (WPs 5, 6, 7, 8, 9, and 10), behavioural studies and development of new foods (HELENA-BEFO) (Wps 11 and 12), lifestyle education intervention (HELENA-LSEI) (WP 13), and crossover multi-centre studies (HELENA-COMS) (WP 14). Aiming to optimise the resources and the duration of the project, all these studies will run in parallel during 36 months.

CURRICULUM VITAE RESUMIDO

[SHORT CV]

I. DATOS PERSONALES [PERSONAL DATA]

- Name: **FRANCISCO B. ORTEGA PORCEL**
- Address:
  Department of Physiology
  School of Medicine
  Avd/ Madrid s/n,
  18012, Granada,
  Spain
- Identity card: 75.228.381 G
- Date of birth: 27-05-1979
- E-mail: ortegaf@ugr.es

1. FORMACIÓN ACADÉMICA [QUALIFICATIONS]

- Degree in **Physical Activity and Sports Sciences, University of Granada, Spain** (1998-2002).
- **Ph.D. student**, University of Granada, Spain. (2002-2008)
  Date for public defense: 18-04-2008
- **Ph.D. student**, Karolinska Institutet, Sweden. (2005-2008)
  Date for public defense: 11-03-2008

2. SITUACIÓN PROFESIONAL ACTUAL [PRESENT APPOINTMENTS]

- Research Fellow. Training Grant (National Level) from the Spanish Ministry of Education. Spanish Training Program for University Faculty (from 01-04-2005 to date). The EFFECTS-262 research group, School of Medicine, University of Granada, Spain.

3. ACTIVIDAD PROFESIONAL PREVIA [PREVIOUS APPOINTMENTS]

- Visiting Teacher. Grant-in-Aid from the Spanish Ministry of International Relationships (from 01-09-2002 to 31-10-2002). Stay at the University of Ciego de Ávila, Cuba.
- Research Fellow. Training Grant (National Level) from the Spanish Ministry of Education (from 01-10-2001 to 31-07-2002). The EFFECTS-262 research group, School of Medicine, University of Granada, Spain.
- Research Fellow. Training Grant from the National Sport Council (from 2003 to 2005). The EFFECTS-262 research group, School of Medicine, University of Granada, Spain.
- Visiting Research Fellow. Grant-in-Aid from the Spanish Ministry of Education (from 01-02-2006 to 03-07-2006). Stay at the Unit for Preventive Nutrition, Karolinska Institutet, Sweden.
- Visiting Research Fellow. Grant-in-Aid from the Spanish Ministry of Education (from 15-08-2007 to 19-01-2008). Stay at the Unit for Preventive Nutrition, Karolinska Institutet, Sweden.

4. LÍNEAS DE INVESTIGACIÓN Y CAPACIDAD TÉCNICA [RESEARCH INTEREST AND EXPERTISES]

1. Physical fitness assessment: Experience in field fitness testing and physiology of exercise laboratory testing, including treadmill and biking tests with gas analysing and muscular fitness assessment by isokinetic techniques.
2. Anthropometry and body composition assessment. Experience in field anthropometric techniques and bioelectric impedance, as well as more accurate and sophisticated techniques, such as Dual Energy X-ray Absorciometry (DXA).
3. Physical activity assessment by self-reported techniques (eg. questionnaires) and objective techniques (eg. heart rate monitoring and accelerometry).
4. Scientific experience in terms of publications mainly focussed on the study of the inter-relationships among physical activity, physical fitness and body composition in young populations.

5. OTROS INTERESES Y HABILIDADES ADQUIRIDAS [OTHER PERSONAL INTERESTS AND EXPERTISES]

- *LANGUAGES*

English: FCE (FIRST CERTIFICATE IN ENGLISH), certificated by the University of Cambridge ESOL Examinations in 2007.

- *COMPUTERS*

Knowledge to middle-high level of the following informatics software: Word, Excel, Access, PowerPoint, FrontPage, Dreamwever, software of Flash (CoffeeCup), PhotoShop, SPSS and Sigma Plot.

- *SPORTS*

Habitual practice of rock climbing and mountaineering. Eventual participation in long distance running and biking events, as well as team sports, such as soccer and volleyball, and individual sports, such as swimming and tennis.

II. INVESTIGACIÓN [RESEARCH]

1. PRINCIPALES PROYECTOS DE INVESTIGACIÓN: IMPLICACIÓN [MAJOR RESEARCH PROJECTS: INVOLVEMENT]

4. **The AVENA study** (2000-). The AVENA study (Alimentación y Valoración del Estado Nutricional de los Adolescentes / Feeding and assessment of nutritional status of Spanish adolescents) was conducted in nearly 3000 Spanish adolescents aged 13–18.5 years. Many factors related with the adolescents' physiological and psychological health status were assessed. *Involvement*: Data collection, data analysis and writing of scientific papers, with special implication on physical activity, fitness and anthropometry/body composition. Web site available (in Spanish): www.estudioavena.com
5. **The EYHS** (1998-). The EYHS (European Youth Heart Study) is an international cross-sectional study aiming to establish the nature, strength, and interactions between personal, environmental, and lifestyle influences on cardiovascular disease risk factors in European children and adolescents. A minimum of 1000 boys and girls ages 9 and 15 y were recruited from each of the following five European countries: Denmark, Estonia, Norway, Portugal and Sweden.
   Involvement: data analysis and writing of scientific papers, from the Swedish part of the EYHS.
6. **The HELENA study** (2005-). The HELENA study (Healthy Lifestyle in Europe by Nutrition in Adolescence) is an EU-funded project conducted in 3000 adolescents from 10 different European cities. The HELENA study aims to provide a broad picture of the nutritional and lifestyle status of the European adolescents, including objectively measured PA and a range of health-related physical fitness tests.
   Involvement: Under the supervision of Manuel J Castillo, coordination of physical fitness assessment, as well as data analysis and writing of scientific papers. Web site available (in English): www.helenastudy.com
7. **The ALPHA study** (2007-). The ALPHA study (Instruments for Assessing Levels of PHysical Activity and related health determinants) is EU-funded project, in the framework of the Public Health Programme. The ALPHA study aims, among others, to determine and test of a European test battery for the assessment of health-related fitness as a reliable key health indicator.
   Involvement: Participation in the review of the available information on physical fitness assessment in young people and drawing evidence-based recommendations for a proper fitness testing at an European level. Web site available (in English): www.thealphaproject.eu

2. ARTÍCULOS CIENTÍFICOS RECIENTES [RECENT SCIENTIFIC PAPERS]

Note: **Francisco B Ortega has published more than 60 scientific papers. Only the most relevant papers recently published (2007-) or in press are shown here**:

1. Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Martin-Matillas M, Mesa JL, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo MJ, and the AVENA study group. Cardiorespiratory fitness and sedentary activity is associated with favorable adiposity in adolescents. **Obesity (Silver Spring)**. 2007 Jun;15(6):1589-99.
2. Castillo-Garzon MJ, Ruiz JR, Ortega FB, Gutiérrez-Sainz A. A Mediterranean diet is not enough for health: Physical fitness is an important additional contributor to health for the adults of tomorrow. **World Rev Nutr Diet**. 2007;97:114-38.
3. Ruiz JR, Rizzo N, Ortega FB, Loit HM, Veidebaum T, Sjöström M. Association of insulin resistance markers with fatness and fitness in prepubertal children. The European Youth Heart Study. **Diabetologia** 2007 Jul;50(7):1401-8.
4. Ruiz JR, Ortega FB, Rizzo NS, Villa I, Hurtig-Wennlöf A, Oja L, Sjöström M. High cardiovascular fitness is associated with low metabolic risk score in children: the European Youth Heart Study. **Pediatr Res**. 2007 Mar;61(3):350-5.
5. Rizzo NS, Ruiz JR, Hurtig-Wennlöf A, Ortega FB, Sjöström M. Relationship of physical activity, fitness, and fatness with clustered metabolic risk in children and adolescents: the European youth heart study. **J Pediatr**. 2007 Apr;150(4):388-94.
6. Moreno LM, Mesana M, González-Gross M, Gil C, Ortega FB, Fleta J, Warnberg J, León J, Marcos A, Bueno M. Body fat patterning reference standards in Spanish adolescents. The AVENA Study. **Int J Obes** 2007 Dec;31(12):1798-805.
7. Ruiz JR, Hurtig-Wennlöf A, Ortega FB, Patterson E, Nilsson TK, Castillo MJ, Sjöström M. Homocysteine levels in children and adolescents are associated with the methylenetetrahydrofolate reductase 677C>T genotype, but not with physical activity, fitness or fatness: the European Youth Heart Study. **Br J Nutr**. 2007 Feb;97(2):255-62.
8. Ruiz JR, Sola R, González-Gross M, Ortega FB, Vicente-Rodríguez G, Garcia-Fuentes M, Gutiérrez A, Sjöström M, Pietrzik K, Castillo MJ. Cardiovascular fitness is negatively associated with homocysteine levels in female adolescents. **Arch Pediatr Adolesc Med**. 2007 Feb;161(2):166-71.
9. Garcia-Artero E, Ortega FB, Ruiz JR, Mesa JL, Delgado M, González-Gross M, Garcia-Fuentes M, Vicente-Rodríguez G, Gutiérrez A, Castillo MJ. [Lipid and metabolic profiles in adolescents are affected more by physical fitness than physical activity (AVENA study)]. **Rev Esp Cardiol**. 2007 Jun;60(6):581-8. *

   *** Associated Editorial**: Carreras-González G, Ordonez-Llanos J. [Adolescence, physical activity, and metabolic cardiovascular risk factors]. **Rev Esp Cardiol**. 2007;60(6):565-8.
10. Ruiz JR, Ortega FB, Warnberg J, Sjöström M. Relative associations of physical activity, fitness and fatness to low-grade inflammation in prepubertal children; The European Youth Heart Study. **Int J Obes (Lond)**. 2007 Oct;31(10):1545-51.
11. Ortega FB, Ruiz JR, Mesa JL, Gutiérrez A, Sjöström M. Cardiovascular fitness in adolescents: the influence of sexual maturation status. The AVENA and EYHS studies. **Am J Hum Biol**. 2007.
12. Ruiz JR, Ortega FB, Meusel D, Sjöström M. Traditional and Novel Cardiovascular Risk Factors in School-aged Children: Call for the Further Development of Public Health Strategies with Emphasis on Fitness. **J Public Health** 2007;15:171-177.
13. Moreno LA, González-Gross M, Kersting M, Molnár D, de Henauw S, Beghin L, Sjöström M, Manios Y, Gilbert C, Ortega FB, Dallongeville J, Arcella D, Wärnberg J, Hallberg M, Fredriksson H, Maes L, Widhalm K, Marcos A - on behalf of the HELENA Study Group. Healthy lifestyle in Europe by nutrition in adolescence. The HELENA Study. **Public Health Nutr**. 2008 Mar;11(3):288-299.
14. Ortega FB, Ruiz JR, Sjöström M, Castillo MJ. Physical fitness in childhood and adolescence: a powerful marker of health. **Int J Obes (Lond)**, 2008 Jan;32(1):1-11..*

   *** Invited Review**
15. Ruiz JR, Ortega FB, Warnberg J, Moreno LA, Carrrero JJ, González-Gross M, Marcos A, Gutiérrez A, Sjöström M. Inflammatory proteins are associated with muscle strength in adolescents; The AVENA Study. **Arch Pediatr Adolesc Med** 2007;161:166-71.
16. Ortega FB, Ruiz JR, Sjöström M. Physical activity, overweight and central adiposity in Swedish children and adolescents: the European Youth Heart Study. **Int J Behav Nutr Phys Act** 2007;4:61.
17. Artero EG, España-Romero V, Ortega FB, Jiménez-Pavón D, Carreño F, Ruiz JU, Gutiérrez A, Castillo MJ. Use of whole-body vibration as a mode of warming up before counter movement jump. **J Sports Sci Med** 2007;6:574-575.

18. Ruiz JR, Ortega FB, Loit HM, Veidebaum T, Sjöström M. Fatness is associated with blood pressure in school-aged girls with low cardiorespiratory fitness; The European Youth Heart Study. **J Hypertension**, 2007;25:2027-34.
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3. CONGRESOS CIENTÍFICOS MÁS RELEVANTES [MORE RELEVANT SCIENTIFIC EVENTS]

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4. PREMIOS RECIBIDOS [AWARDS]

1. The work titled "Low level of physical fitness in Spanish adolescents. Relevance for future cardiovascular health (AVENA study)" was awarded by the **Spanish Society of Cardiology** as "**One of the three best papers published in Rev Esp Cardiol in 2005**.
   Authors: Ortega FB, Ruiz JR, Castillo MJ, et al. Date: October 18th 2006.
2. The work titled: "Fuerza jóven de Andalucía en España" got the first prize from the **Andalusian Institute of Sport** as "**The best scientific work in 2006**".
   Authors: Ortega FB, Ruiz JR, Gutiérrez A, et al. Date: February 9th, 2007.

I confirm that, to the best of my knowledge, the information given on this document is true, complete and accurate, and that no information has been withheld.

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Cuento de una vida… agradecida

Nací en un pueblo de menos de 2000 habitantes en el norte de Almería, Chirivel, en el cual las llaves se dejaban puestas en las puertas de las casas, por si algún vecino necesitaba entrar a coger cualquier cosa. En tales condiciones de seguridad y confianza, mis primeros años de vida se desarrollaron en la más pura y sana libertad. Ello implicaba correr y jugar durante todo el día, independientemente de que el suelo estuviera seco, mojado o nevado. También recuerdo algún paseo en bici junto con mis padres y mi hermano, al lado del río. Para nada era consciente de que todo aquello era sin duda un estilo de vida activo y saludable. Quiero agradecer a mis padres **Joaquín y Paquita**, por haberme mostrado esta forma de vivir y haberme ofrecido posteriormente en Albox (otro pueblo almeriense al que nos mudamos cuando tenía 5 años) tantas posibilidades de hacer ejercicio: tenis, voleibol, balonmano, fútbol, etc. También por el cariño y el apoyo desinteresado e incondicional a todo lo que he decidido hacer en la vida, inclusive en aquellas actividades que no eran/son de su total agrado. No es posible ser mejores padres.

He de admitir que durante mi etapa en la escuela no estaba especialmente interesado en los estudios. Por el contrario cada vez me interesaba más todo lo relacionado con el ejercicio físico y el deporte. Recuerdo que un día, cuando aun tendría unos 12 años aproximadamente, mi hermano **Joaquín** trajo a casa un libro que había encontrado en la biblioteca del su instituto, decía algo de "INEF". Empecé a leer el libro con la mayor atención y admiración posible, pues dicho libro estaba abriendo una nueva ventana en mi mente que marcaría drásticamente mi vida. Existía una carrera universitaria que se centraba en el estudio del deporte, tanto en su dimensión de alto rendimiento, como docente, como de gestión. A partir de ese momento tenía una meta clara y única para mi futuro próximo, acceder a esa carrera, y poder convertir en mi profesión, lo que era también mi pasión. Ahora sí, estudiar tenía sentido para mí. Joaquín, este y otros muchos gestos te han convertido en alguien tremendamente especial e insustituible en mi vida, siendo al mismo tiempo uno de mis mejores amigos. Igualmente, mis queridos abuelillos, **Joaquín y Bartolomé**, y abuelillas **Resures y Flor**, me han animado y ayudado a dar cada paso en esta "maratón" de la vida. Nunca olvidaré el cariño y ternura que recibí y que aún recibo de vosotros/as.

Considero que mi vida ha sido un camino que he podido cómoda y placenteramente seguir, por haber contado con un ejército a mi alrededor que me daba la seguridad y confianza necesaria para afrontar cualquier batalla. Sabiendo que si en alguna de ellas, yo caía total o parcialmente derrotado, ellos me ayudarían a levantarme y saldría adelante con mayor firmeza incluso que al principio. Entre los miembros de este ejercito se encuentran: **mis tíos y primos** (Encarni, Paco, Cármen, Juan, Bartolomé,…); **mis amigos del pueblo** (Miguel, Jesús, Cheli, Maria Dolores, Peque, Lázaro, Pedro Marcos, Pedro de Lorca, Angelillo, Ana de cuevas,…); **mis amigos de Graná** (Miguelón, Juanmi, Dani, Jose Atrio, Óscar, Franki, Angelillo, los Peñas, Palma, Mariajo, Cristi,…); **mis amigos de "trabajo"** (Joni, Enrique, Pipi, David,…); **my "Swedish" friends** (Signe, Stefano, Nicolas, Germán,…); **mis colegas de montaña/escalada** (Presi, Pilar, Kiko, Maria José, Javi, Josemi, Angus, Carlos, Regina, Antonio, Ana, Paco,…); etc.

En 1998 di, lo que aun hoy día considero, uno de los pasos más importantes de mi vida profesional y personal, acceder a la carrera de mis sueños, Ciencias de la Actividad Física y el Deporte en Granada (INEF). Por tratarse de unos estudios eminentemente vocacionales y ser en consecuencia las expectativas bastante elevadas, muchos de mis compañeros se decepcionaron profundamente con la carrera. No fue mi caso, me centré en asignaturas y profesores que merecían por sí solos estudiar la carrera, y me limité a sacar las asignaturas que no me interesaban de la mejor forma posible. Dos asignaturas marcaron un antes y un después en mi formación, Fisiología del Ejercicio y Bases Neuronales del Movimiento, ambas impartidas por el profesor **Ángel Gutiérrez**. Él me enseñó mucho e interesante acerca de la Fisiología del Ejercicio, pero sobretodo, despertó en mí el interés y la pasión por la investigación. Haciéndome ver que aunque lejano, era posible, siempre y cuando se diera una combinación mágica: motivación, aptitud y constancia en el trabajo. Ángel, junto con el apoyo cálido y desinteresado de **Pablo Tercedor**, **Miguel Martín** y **Manuel Delgado**, me "presentó" al estudio AVENA y me invitó a participar en él. Proyecto que hoy da lugar a esta tesis doctoral. Por todo ello y mucho más, puedo decir sin duda alguna, que esta tesis no estaría aquí, y probablemente tampoco nuestro grupo de investigación, de no haber sido por Ángel. Él me invitó también a asistir a las reuniones que su grupo de investigación mantenía semanalmente en el INEF. Allí conocí a **Manuel Castillo**, catedrático de Fisiología de la Facultad de Medicina y director junto con Ángel del grupo de investigación EFFECTS-262. Con Manuel he aprendido casi todo lo que sé. Su experiencia y consejos prácticos han sido claves para dirigir en todo momento mi actividad académica e investigadora. Entre otras muchas cualidades, Manuel debe ser destacado por su profundo conocimiento aplicado y útil de la Fisiología Humana (e.g. teorías fisiológicas de la infidelidad, el amor, etc.), su eficiencia y operatividad en el trabajo diario, y su intuición para prever los cambios y anticiparse a ellos. Con Ángel y Manuel, he trabajado desde antes de terminar la carrera hasta hoy día, y espero poder hacerlo por muchos años más. Gracias a ellos y a mi motivación en el trabajo, he recibido diferentes becas de investigación (destacando la FPU del Ministerio de Educación y Ciencia) que han supuesto el soporte económico que me ha permitido hacer lo que deseaba. Gracias al proyecto AVENA y al grupo de investigación, conocí también a **Jonatan Ruiz**, otro alumno del INEF de mi quinta, repescado por Ángel y acogido afectuosamente por Manuel. Jonatan ha sido mucho más que un compañero de trabajo. Hemos trabajado codo con codo en todo lo que ambos hemos hecho desde el día en que nos conocimos. Es un investigador excepcional y mejor amigo aun. Gracias por todo

En todo este proceso ha habido otras dos personas claves, **Luis A Moreno** y **Marcela González-Gross**. Ellos me han guiado y aconsejado a lo largo de toda mi formación, al tiempo que me han ofrecido su confianza y amistad incondicional. Ambos tienen mucha "culpa" del éxito que ha tenido el estudio AVENA, y todos agradecemos enormemente su implicación en este estudio. Luis y Marcela han sido también el computador central que ha diseñado, creado y controla hoy día el estudio HELENA, un estudio financiado por la Comisión Europea y que ha sido también incluido en esta tesis. Manifiesto aquí mi más sincero aprecio y admiración por vuestra actividad profesional y vuestras personas. Mi más sincero agradecimiento también para **Laura Barrios**, por prestarme su valiosa ayuda en el análisis estadístico siempre que la he solicitado. Aprovecho esta oportunidad para agradecer el esfuerzo y dedicación mostrado por el resto de investigadores AVENA (**Ascensión Marcos, Miguel García Fuentes**,...).

El estudio HELENA me ha permitido conocer a investigadores de diversas partes de Europa, y entre ellos quiero destacar a Michael Sjöström. **Michael Sjöström** is the Head of the Unit for Preventive Nutrition, Karolinska Institutet (Sweden). He is a well known expert on objective methods of assessing physical activity, such as accelerometry. I have had the opportunity to stay at his Unit and work with him for some months, and I have found there the warmest and most friendly reception. His large experience and his way of being have made my stay at his Unit successful and pleasant. Thanks Michael for everything. I want also to acknowledge **Anita, Maria, Emma, Patrick, Nico, Lydia** and **Olle**, for your scientific and/or personal support.

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