J Public Health
DOI 10.1007/s10389-006-0059-z

REVIEW ARTICLE

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

Jonatan R. Ruiz · Francisco B. Ortega · Angel Gutierrez · Dirk Meusel · Michael Sjöström · Manuel J. Castillo

Received: 15 June 2006 / Accepted: 22 June 2006

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

J. R. Ruiz · F. B. Ortega · A. Gutierrez · M. J. Castillo
Department of Physiology, School of Medicine,
University of Granada,
Granada, Spain

D. Meusel
Research Association Public Health Institute of Clinical Pharmacology, Medical Faculty,
Technische Universität,
Dresden, Germany

J. R. Ruiz · F. B. Ortega · M. Sjöström
Unit for Preventive Nutrition,
Department of Biosciences and Nutrition at NOVUM,
Karolinska Institutet,
Huddinge, Sweden

M. J. Castillo (✉)
Department of Physiology, School of Medicine,
University of Granada,
Granada, Spain
e-mail: mcgarzon@ugr.es

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-

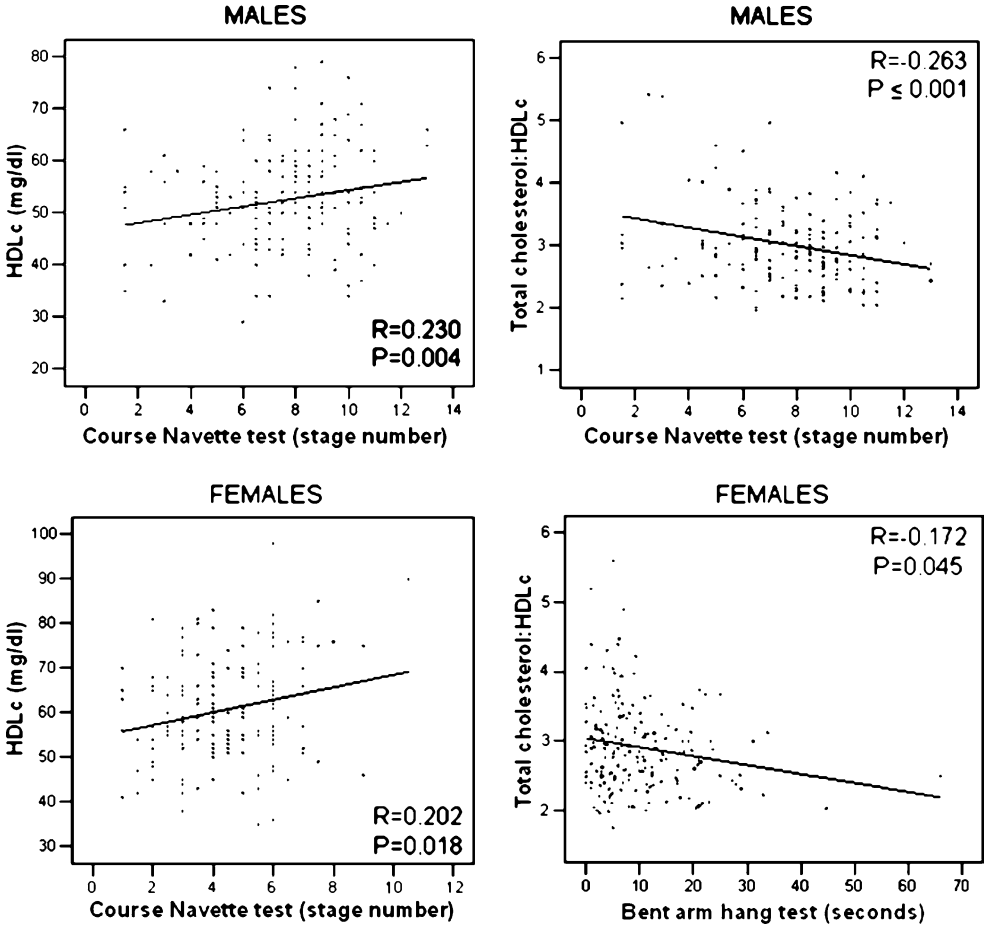

Fig. 1 Physical fitness variables associated with cardiovascular risk factors among normal-weight Spanish adolescents. Normal-weight category was categorised following the International Obesity Task Force (IOTF)-proposed gender- and age-adjusted body mass index (BMI) cutoff points

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

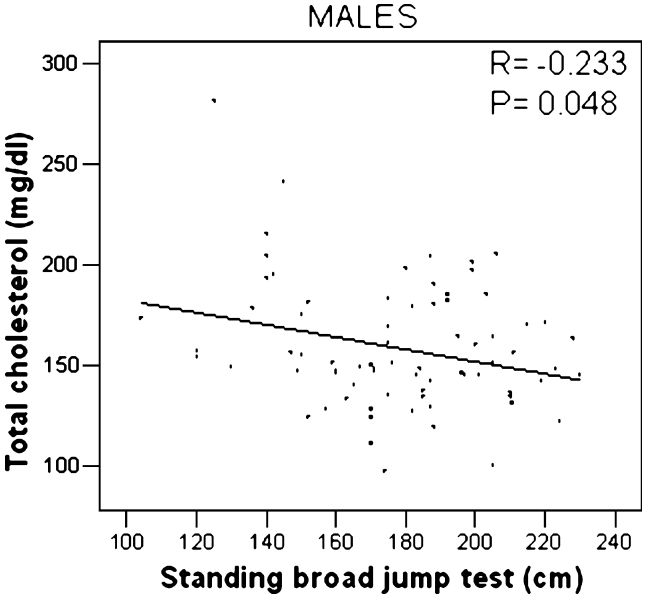

Fig. 2 Associations between standing broad jump and total cholesterol in overweight/obese Spanish adolescents. Overweight/obese category was categorised following the International Obesity Task Force (IOTF)-proposed gender- and age-adjusted body mass index (BMI) cutoff points

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.

Acknowledgements The AVENA study was funded by the Spanish Ministry of Health, FEDER-FSE funds FIS no. 00/0015, CSD grants 05/UPB32/0, 109/UPB31/03 and 13/UPB20/04, the Spanish Ministry of Education (AP2003-2128; AP-2004-2745), and scholarships from Panrico S.A., Madaus S.A. and Procter and Gamble S.A. The Swedish part of the EYHS was supported by grants from the Stockholm County Council (MS), and the Estonian part of EYHS was supported by a grant from the Estonian Science Foundation No. 3277 and 5209 and by the Estonian Centre of Behavioural and Health Sciences. The HELENA study takes place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD-CT-2005-007034). The content of this article reflects only the authors' views, and the European Community is not liable for any use that may be made of the information contained therein. The authors of the present paper are responsible partners of the physical activity and fitness assessment in the HELENA Study.

Conflict of interest statement No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. None of the authors had any conflict of interest.

References

Arokoski JP, Valta T, Airaksinen O, Kankaanpaa M (2001) Back and abdominal muscle function during stabilization exercises. Arch Phys Med Rehabil 82:1089–1098

Australian Sports Commission (1999) 20m shuttle run test: a progressive shuttle run test for measuring aerobic fitness. Belconnen (ACT): Australian Coaching Council

Baquet G, Twisk JW, Kemper HC, Van Praagh E, Berthoin S (2006) Longitudinal follow-up of fitness during childhood: interaction with physical activity. Am J Hum Biol 18:51–58

Bosco C, Luhtanen P, Komi PV (1983) A simple method for measurement of mechanical power in jumping. Eur J Appl Physiol 50:273–282

Bouchard C (1986) Genetics of aerobic power and capacity. In Sports and Human Genetics. Human Kinetics, Champaign, IL

Brewer J, Ramsbottom R, Williams C (1988) Multistage fitness test: a progressive shuttle-run test for the prediction of maximum oxygen uptake. National Coaching Foundation, Leeds

Castillo Garzon MJ, Ortega Porcel FB, Ruiz Ruiz J (2005) [Improvement of physical fitness as anti-aging intervention]. Med Clin 124:146–155

Committee of Experts on Sports Research EUROFIT (1993) Handbook for the EUROFIT Tests of Physical Fitness. Council of Europe, Strasburg, GE

Cooper Institute for Aerobics Research (1999) FITNESSGRAM test administration manual. Human Kinetics, Champaign

Deforche B, Lefevre J, De Bourdeaudhuij I, Hills AP, Duquet W, Bouckaert J (2003) Physical fitness and physical activity in obese and nonobese Flemish youth. Obes Res 11:434–441

Goldberg MS, Scott SC, Mayo NE (2000) A review of the association between cigarette smoking and the development of nonspecific back pain and related outcomes. Spine 25:995–1014

Gonzalez-Gross M, Ruiz JR, Moreno LA, De Rufino-Rivas P, Garaulet M, Mesana MI, Gutierrez A; AVENA Group (2003) Body composition and physical performance of Spanish adolescents: the AVENA pilot study. Acta Diabetol 40:S299–S301

Hansen HS, Froberg K, Nielsen JR, Hyldebrandt N (1989) A new approach to assessing maximal aerobic power in children: the Odense School Child Study. Eur J Appl Physiol Occup Physiol 58:618–624

Hildebrandt VH, Bongers PM, Dul J, van Dijk FJ, Kemper HC (2000) The relationship between leisure time, physical activities and musculoskeletal symptoms and disability in worker populations. Int Arch Occup Environ Health 73:507–518

Izaak SI, Panasiuk TV (2005) [The age- and sex specificity of physical development of schoolchildren]. Gig Sanit 5:61–64

Jonker JT, De Laet C, Franco OH, Peeters A, Mackenbach J, Nusselder WJ (2006) Physical activity and life expectancy with and without diabetes: life table analysis of the Framingham Heart Study. Diabetes Care 29:38–43

Kemper HC, Twisk JW, van Mechelen W, Post GB, Roos JC, Lips P (2000) A fifteen-year longitudinal study in young adults on the relation of physical activity and fitness with the development of the bone mass: The Amsterdam growth and health longitudinal study. Bone 27:847–853

Keyserling WM (2000) Workplace risk factors and occupational musculoskeletal disorders: Part 1. A review of biomechanical and psychophysical research on risk factors associated with low-back pain. Am Ind Hyg Assoc J 61:39–50

Kibler WB, Goldberg C, Chandler TJ (1991) Functional biomechanical deficits in running athletes with plantar fasciitis. Am J Sports Med 266:185–196

Klasson-Heggebo L, Andersen LB, Wennlof AH, Sardinha LB, Harro M, Froberg K, Anderssen SA (2006) Graded associations between cardiorespiratory fitness, fatness, and blood pressure in children and adolescents. Br J Sports Med 40:25–29

Koutedakis Y, Bouziotas C (2003) National physical education curriculum: motor and cardiovascular health related fitness in Greek adolescents. Br J Sports Med 37:311–314

Leach RE, James S, Wasilewski S (1981) Achilles tendinitis. Am J Sports Med 9:93–98

Leboeuf-Yde C (2000) Body weight and low back pain: a systematic literature review of 56 journal articles reporting on 65 epidemiologic studies. Spine 25:226–237

Léger LA, Lambert A, Goulet A, Rowan C, Dinelle Y (1984) Capacity aerobic des Quebecois de 6 a 17 ans - test Navette de 20 metres avec paliers de 1 minute. Can J Appl Sport Sci 9:64–69

Liu NYS, Plowman SA, Looney MA (1992) The reliability and validity of the 20-meter shuttle test in American students 12 to 15 years old. Res Q Exerc Sport 63:360–365

McHugh M, Connolly D, Eston R, Kremenic IJ, Nicholas SJ, Gleim GW (1999) The role of passive stiffness in symptoms of exercise-induced muscle damage. Am J Sports Med 27:594–599

Mesa JL, Ruiz JR, Ortega FB, Warnberg J, Gonzalez-Lamuno D, Moreno LA, Gutierrez A, Castillo MJ (2006a) Aerobic physical fitness in relation to blood lipids and fasting glycaemia in adolescents: Influence of weight status. Nutr Metab Cardiovasc Dis 16:285–293

Mesa JL, Ortega FB, Ruiz JR, Castillo MJ, Hurtig Wennlöf A, Gutiérrez A (2006b) The importance of cardiorespiratory fitness for healthy metabolic traits in children and adolescents. The AVENA Study. J Public Health 14:178–180

Metter EJ, Talbot LA, Schrager M, Conwit R (2002) Skeletal muscle strength as a predictor of all-cause mortality in healthy men. J Gerontol A Biol Sci Med Sci 57:B359–B365

Mikkelsson L, Kaprio J, Kautiainen H, Kujala U, Mikkelsson M, Nupponen H (2006) School fitness tests as predictors of adult health-related fitness. Am J Hum Biol 18:342–349

Mokdad AH, Marks JS, Stroup DF, Gerberding JL (2004) Actual causes of death in the United States, 2000. JAMA 291:1238–1245

Monyeki MA, Koppes LL, Kemper HC, Monyeki KD, Toriola AL, Pienaar AE, Twisk JW (2005) Body composition and physical fitness of undernourished South African rural primary school children. Eur J Clin Nutr 59:877–883

Myers J, Prakash M, Froelicher V, Do D, Partington S, Atwood JE (2002) Exercise capacity and mortality among men referred for exercise testing. N Engl J Med 346:793–801

Nourbakhsh MR, Arab AM (2002) Relationship between mechanical factors and incidence of low back pain. J Orthop Sports Phys Ther 32:447–460

Ortega FB, Ruiz JR, Castillo MJ, Moreno LA, Gonzalez-Gross M, Warnberg J, Gutierrez A; Grupo AVENA (2005) [Low level of physical fitness in Spanish adolescents. Relevance for future cardiovascular health (AVENA study)]. Rev Esp Cardiol 58:898–909

Ortega FB, Ruiz JR, Gutiérrez A, Moreno LA, Tresaco B, Martínez JA, González-Lamuño D, Wärnberg J, Castillo MJ, and the AVENA Study group (2004) Is physical fitness a good predictor of cardiovascular disease risk factors in normal-weight and overweight or obese adolescents? The AVENA Study. [abstract] Int J Obes Relat Metab Disord 28:S120

Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Martin-Matillas M, Warnberg J, Bueno M, Tercedor P, Gutierrez A, Castillo MJ (2006) Cardiorespiratory fitness and sedentary activity are associated with adiposity in adolescents. Obesity (in press)

Pope R, Herbert R, Kirwan J, Grahan BJ (2000) A randomized trial of pre-exercise stretching for prevention of lower limb injury. Med Sci Sports Exer 32:271–277

Richards LG, Olson B, Palmiter-Thomas P (1996) How forearm position affects grip strength. Am J Occup Ther 50:133–138

Riddoch CJ (1990) The Northern Ireland health and fitness survey - 1989: the fitness, physical activity, attitudes and lifestyles of Northern Ireland post-primary schoolchildren. The Queen's University of Belfast, Belfast

Ruiz JR, Rizzo N, Wennlof A, Ortega FB, Harro M, Sjostrom M (2006a) Relations of total physical activity and intensity to fitness and fatness in children; The European Youth Heart Study. Am J Clin Nutr 84:299–303

Ruiz JR, Ortega FB, Meusel D, Harro M, Oja P, Sjöström M (2006b) Cardiorespiratory fitness is associated with features of metabolic risk factors in children. Should cardiorespiratory fitness be assessed in a European health monitoring system? The European Youth Heart Study. J Public Health 14:94–102

Ruiz JR, España-Romero V, Ortega FB, Sjöström M, Castillo MJ, Gutiérrez A on behalf of the HELENA Study (in press) Hand-size influences optimal grip span in male and female adolescents. J Hand Surgery (Am)

Ruiz-Ruiz J, Mesa JLM, Gutiérrez A, Castillo MJ (2002) Hand size influences optimal grip span in women but not in men. J Hand Surg 27A:897–901

Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, Hergenroeder AC, Must A, Nixon PA, Pivarnik JM, Rowland T, Trost S, Trudeau F (2005) Evidence based physical activity for school-age youth. J Pediatr 146:732–737

Trainor TJ, Trainor MA (2004) Etiology of low back pain in athletes. Curr Sports Med Rep 3:41–46

Vicente-Rodriguez G, Jimenez-Ramirez J, Ara I, Serrano-Sanchez JA, Dorado C, Calbet JA (2003) Enhanced bone mass and physical fitness in prepubescent footballers. Bone 33:853–859

Vicente-Rodriguez G, Ara I, Perez-Gomez J, Serrano-Sanchez JA, Dorado C, Calbet JA (2004a) High femoral bone mineral density accretion in prepubertal soccer players. Med Sci Sports Exerc 36:1789–1795

Vicente-Rodriguez G, Dorado C, Perez-Gomez J, Gonzalez-Henriquez JJ, Calbet JA (2004b) Enhanced bone mass and physical fitness in young female handball players. Bone 35:1208–1215

Wärnberg J (2006) Inflammatory status in adolescents; the impact of health determinants such as overweight and fitness. Thesis for doctoral degree, Karolinska University Press, Stockholm

Watanabe T, Owashi K, Kanauchi Y, Mura N, Takahara M, Ogino T (2005) The short-term reliability of grip strength measurement and the effects of posture and grip span. J Hand Surg 30:603–609

Witvrouw E, Lysens R, Bellemans J, Cambier D, Vanderstraeten G (2000) Intrinsic risk factors for the development of anterior knee pain in an athletic population: a two year prospective study. Am J Sports Med 28:480–489

Witvrouw E, Bellemans J, Lysens R, Danneels L, Cambier D (2001) Intrinsic risk factors for the development of patellar tendinitis in the athletic population. Am J Sports Med 29:190–195