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A SYSTEMATIC REVIEW TO DETERMINE RELIABILITY AND USEFULNESS OF THE FIELD-BASED TEST BATTERIES FOR THE ASSESSMENT OF PHYSICAL FITNESS IN ADOLESCENTS – THE ASSO PROJECT

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Abstract
The aim of the present review is to investigate the main field-based tests, used alone or included in sport or fitness batteries, for the assessment of health- and skill-related physical fitness components in adolescents. Different scientific databases were searched through using the selected key words related to physical fitness and its components for adolescence. The search focused on original articles and reviews/meta-analyses using valid, reproducible and feasible tests that fit within the school environment. A total of 100 scientific manuscripts were included in the qualitative synthesis. The present systematic review pointed out 5 fitness tests that well adapt to the evaluation of the components of physical fitness of adolescents within a school environment: the 20 m shuttle run test for cardio-respiratory endurance; the handgrip strength test for upper body maximal strength; the standing broad jump test for lower body maximal strength; the sit-up test to exhaustion for muscular endurance and the 4×10 m shuttle run test for speed, agility and coordination. These fitness tests have been finally selected and incorporated into the Adolescents and Surveillance System for the Obesity prevention – Fitness Test Battery (ASSO-FTB), and will be adopted within the ASSO Project for evaluation purposes. This instrument could be also provided to teachers and people working in schools in order to assess physical fitness of adolescents over time and prevent obesity and related diseases.

Key words:
Fitness tests, Adolescents, Health education, ASSO project, Physical fitness, School context

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INTRODUCTION

Given that many chronic diseases in adulthood begin during childhood, children and adolescents' lack of exercise is considered as one of the "primary predisposing factors of increased morbidity" [1]. Some scientists are currently defending the concept of "Exercise Deficit Disorder" and the need to diagnose and prevent such phenomenon during childhood [2–4]. In adulthood lifestyle changes are either unsuccessful or difficult to apply. In order to prevent such disorders and their health consequences, a regular screening of the practiced physical activity of the adolescent population should be considered a public health priority [5].

Physical activity is a primary factor associated with the improvement of physical fitness [6], since an increased level of physical activity in children and adolescents improves physical fitness, and a high level of fitness has a positive effect on health [7]. Physical fitness is defined as "the ability to perform daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits, and to meet unforeseen emergencies" [8,9]. Reduced physical fitness is also associated with several non-communicable diseases that affect people's health [10].

Furthermore, there is a common agreement that 2 components can be recognised in physical fitness – one mainly related to health and the other related to motor skills that pertain more to performance [11–14].

The generally recognized components related to health, beyond body composition, include 4 parameters: cardiorespiratory endurance (e.g., ability of the blood vessels, heart, and lungs to take in, transport and utilize oxygen); muscular strength (e.g., the maximum amount of force a muscle or a muscle group can exert); muscular endurance (e.g., the length of time a muscle or a muscle group can exert force prior to fatigue); and flexibility (refers to the range of motion in the joints) [15–18]. These components have been investigated over the past years by a variety of studies on adolescents; as a result of which there is now better understanding of the methods of their evaluation and awareness of how to improve such skills in this continuously evolving population [19–25].

Laboratory tests have been used for many years as the gold standard for the assessment of components of physical fitness, since they are usually accurate, reliable and safe. However, lower costs, feasibility and the large number of participants that can be screened using field-based tests, make these more suitable for large epidemiological studies on adolescents [23]. Different field-based tests have been shown to be valid and reliable, and have been used in adolescent populations throughout the world [26–29]. Some initiatives were quite successful in some regions, such as Assessing Levels of PHysical Activity (the ALPHA study), Healthy Lifestyle in Europe by Nutrition in Adolescence (the HELENA study) and others [16,28,30–33], but an accurate monitoring of the level of physical fitness in most countries is still facing significant difficulties.

It is in a similar context that the Adolescents and Surveillance System for the Obesity prevention (ASSO) Project is initiated with support from the Italian Ministry of Health. The Project is addressed to the population of adolescents attending secondary schools and aims at development of a web-based surveillance system that allows for a continuous and sustainable collection of data from schools regarding weight status and lifestyles in adolescence [34].

In more detail, the project is based on the use of a web-based system for collection of data, accessed via the World Wide Web within the schools [35], and by the development of a standardized methodology that provides accurate and reliable data [36].

For this purpose, an ASSO-toolkit is being developed, which beyond the questionnaires for the assessment of dietary intake and lifestyles [37], will include an instrument for collection of the physical fitness data. This review is aimed, therefore, at providing an overview of previously validated and reliable field-based tests, used alone

or included in batteries, for the assessment of health- and skill-related physical fitness components in adolescents within school environment.

MATERIAL AND METHODS

Eligibility criteria

A systematic review of papers using valid and reliable field-based fitness tests (FTs), alone or combined in a battery, within a school environment for the assessment of adolescents' physical fitness, was carried out. No restriction criteria were applied for the country, while limits were imposed by restricting the publications to the English language ones and the publication date mainly to the last decade. Systematic reviews, meta-analyses, original articles and research notes were included, according to the following inclusion criteria:

- adolescent subjects,
- healthy subjects,
- studies that assessed generic categories of sport or fitness,
- physical fitness assessed through physical tests.

Questionnaires were not used for such evaluation.

Information sources and keywords

The following databases were searched: Medline-NLM (Medical Literature Analysis and Retrieval System online – National Library of Medicine), Medline-EBSCO (Medline with full text), Web of Science (TS), Scopus, Cochrane, DOAJ (Directory of Open Access Journals) and PLOS ONE. Additional search was carried out on the websites of national and international organizations (e.g., university websites and relevant professional societies or organizations).

Standardized keywords were used alone or combined when necessary. These were words or phrases related to the health- and skill-related components of physical fitness and to the school environment: fitness, physical fitness, fitness test, test, field-based test, adolescent, health, health-related component, cardio-respiratory, cardiovascular, strength, upper body strength, lower body strength, speed, agility, flexibility, endurance, musculoskeletal, muscular, fitness battery, fitness batteries, school. The keywords were selected according to the mainly used terminology found in the screened manuscripts.

Data collection process

All the retrieved articles were transferred into the EndnoteX6 software. After exclusion of all duplicates, the screening of titles and abstracts was performed. Exclusion criteria were applied on the eligible articles retrieved, and full texts of those papers were analyzed to obtain the studies for the final qualitative synthesis.

The 2 different categories of reviews/meta-analyses and original articles were analyzed separately. The article screening was conducted by 2 independent investigators. After a standardization of the screening procedures, both investigators cross-checked the retrieved articles. In case of any incongruity, the investigators, after further analysis and discussions, decided to include or exclude the manuscripts.

RESULTS

A total of 353 records were initially identified through the literature search (Figure 1). Seventy-eight articles were removed as duplicates. The 1st screening of titles and abstracts highlighted a number of 275 eligible articles. After application of the inclusion criteria, a number of 161 manuscripts was obtained and their full texts were further analyzed. A final number of 100 papers (15 reviews/meta-analyses and 85 original articles) was obtained and analyzed for a qualitative synthesis of the main field-based fitness tests.

Finally, the search allowed to obtain an overview of the most used worldwide Fitness Test Batteries for adolescents.

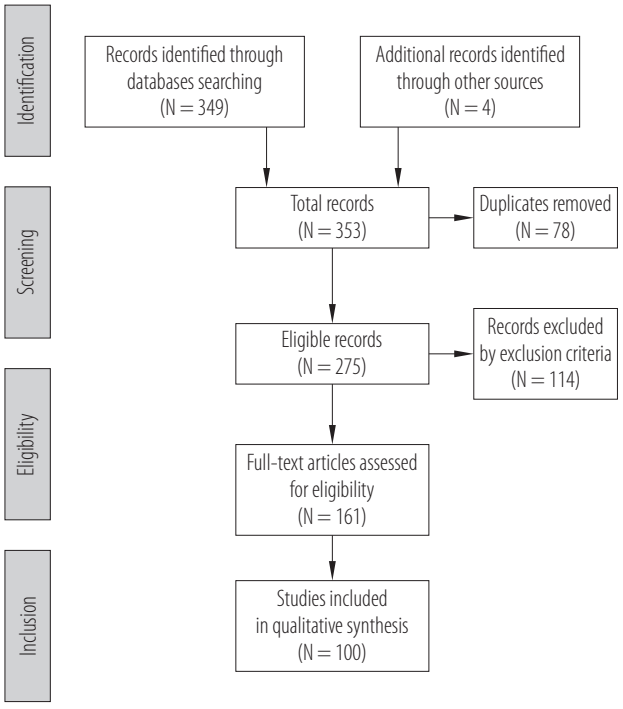

Fig. 1. Flow diagram of the study selection

Reviews and meta-analyses

Ten systematic reviews and 5 meta-analyses were retrieved (Table 1).

Most of them [20,38–46] analyzed human performance and the secular trends of physical fitness of adolescents from different countries, highlighting the importance of promoting fitness among adolescents and showing the main fitness tests used to assess physical fitness. The reviews from Castro-Piñero [47] and Artero [48] were particularly useful for our purposes, since they have studied the validity and reliability of the existing field-based fitness tests used in children and adolescents. The same findings have also been shown by an original article by España-Romero et al. [49].

In that case, the authors have stated that there is strong evidence for the validity and reliability of 20 m shuttle run test (SRT) as a good test to estimate cardio-respiratory fitness; the hand-grip strength test (HG) as a valid measure of musculoskeletal fitness, and together with the standing broad jump being a reliable test. According to the authors the 4×10 mSRT is a reliable test to measure motor fitness; skinfold thickness and body mass index (BMI) are good estimates of body composition, and waist circumference is a valid measure to estimate central body fat. Moreover, height, weight, BMI, skinfolds, circumferences and body fat percentage estimated from skinfold thickness are reliable tests to measure body composition. A large number of other field-based fitness tests presented limited evidence, mainly due to a limited number of studies.

Out of 79 studies found, 50 high quality studies were selected in order to state the evidence of the validity of the physical tests: 14 of those have validated tests such as 20 mSRT [6,50–56] or the 1-mile walk [50,57–61] for the assessment of the cardio-respiratory component of physical fitness; 1 study has stated that the bent arm hang, the push-up, normal or modified pull-ups are not valid tests for the assessment of muscular endurance in adolescents [62]; 2 studies have validated the back-saver sit and reach test and the trunk lift for the flexibility assessment [63,64], stating that they were moderately valid. The 1st test has been mainly related to hamstring flexibility but not to lower back flexibility; 2 studies have included validation of the HG, standing broad jump (SBJ) and vertical jump tests for the assessment of upper and lower strength [65,66]; and 31 studies have validated instruments for the assessment of body composition [67–97], such as BMI, waist circumference and skinfold thicknesses.

The review from Ruiz et al. [98] has summarized the work developed by the European ALPHA fitness test battery for children and adolescents, stating that this battery is valid, reliable, feasible and safe for the assessment of health-related physical fitness in children and adolescents, to be used for health monitoring purposes at a population level.

Cvejić et al. [99] have shown a summary of the fitness test batteries used worldwide: most of them are used in the USA and include the most common FITNESSGRAM

Table 1. Overview of the retrieved reviews and meta-analyses

Author	Year	Study design	Objectives	Main outcomes
Catley et al. [44]	2013	systematic review	to provide sex- and age-specific normative values for health-related fitness of 9–17-year-old Australians	this study provides the most up-to-date sex- and age-specific normative centile values for the health-related fitness of Australian children
Cvejić et al. [99]	2013	systematic review	to select the components that are necessary to test and propose a valid, reliable and objective battery of tests to assess the physical form of children and adolescents	the ideal battery of tests should assess the components of fitness that are associated with the health of children and adolescents; the ALPHA-FIT battery of tests showed the best metric properties in European children, and could be used in many longitudinal and transversal studies
Artero et al. [48]	2011	systematic review	to study the reliability of the existing field-based fitness tests for children and adolescents	the 20 mSRT is a reliable test to measure cardiorespiratory fitness; handgrip strength and standing broad jump are reliable tests to measure musculoskeletal fitness; 4×10 m shuttle run is a reliable test to measure motor fitness; and height, weight, BMI, skinfolds, circumferences and percentage body fat estimated from skinfold thickness, are reliable tests to measure body composition
Ruiz et al. [31]	2011	systematic review	to summarize the work developed by the ALPHA fitness test battery for children and adolescents	the ALPHA fitness tests battery is valid, reliable, feasible and safe for the assessment of health-related physical fitness in children and adolescents to be used for health monitoring purposes at a population level
Ganley et al. [100]	2011	systematic review	to review components, measurement methods, and consequences of physical fitness, and to summarize evidence-based activity recommendations for youth	physical therapists should apply research relevant to health-related fitness when treating youth; promoting fitness, health, and wellness in our communities is a responsibility all therapists should assume
Behringer et al. [20]	2011	meta-analysis	to investigate whether the resistance training can enhance motor performance in children and adolescents	young subjects and nonathletes showed higher gains in motor performance following resistance training than their counterparts; resistance training provides an effective way for enhancing motor performance in children and adolescents
Castro-Piñero et al. [47]	2010	systematic review	criterion-related validity of the existing field-based fitness tests used in children and adolescents	the 20 mSRT test is a valid test to estimate cardiorespiratory fitness; the hand-grip strength test is a valid measure of musculoskeletal fitness; skin fold thickness and body mass index are good estimates of body composition; and waist circumference is a valid measure to estimate central body fat

Table 1. Overview of the retrieved reviews and meta-analyses – cont.

Author	Year	Study design	Objectives	Main outcomes
Kyröläinen et al. [43]	2010	systematic review	to assess associations between physical fitness, obesity and health	studies examining physical fitness profiles of young men suggest a disturbing worldwide trend of decreased aerobic fitness and increased obesity
Shephard et al. [40]	2007	systematic review	to assess secular trends of health-related fitness in Canadian students	Canadian students seem to be fitter than the United States students, but less fit than their peers in some European countries
Malina et al. [41]	2007	systematic review	to examine the status and secular trends of health-related fitness in school-age children from the United States	the majority of American school children meet or exceed criterion-referenced standards; a decline in maximal aerobic power in girls, and a fairly stable levels between the 1930s and today in boys is shown however, the highest values for boys occur in the 1960s and 1970s and more recent values are somewhat lower
Macfarlane et al. [42]	2007	meta-analysis	to summarize existing literature reporting explicitly on secular changes in the fitness test performance of Asian children and adolescents	few changes are shown in the power and speed test performances of Asian children and adolescents in recent decades, though, there has been a consistent decline in the cardiovascular endurance fitness performance across all studied Asian nations over the past 10–15 years
Tomkinson et al. [45]	2007	meta-analysis	to quantify the global change in paediatric aerobic fitness test performance	there has been a precipitous decline in paediatric aerobic performance since 1970, a pattern which is not observed in paediatric anaerobic performance
Tomkinson et al. [46]	2007	systematic review	to describe the variability in fitness test performance among children and adolescents from different parts of Europe	there is evidence that performance was related to socio-cultural factors, such as the place of exercise and sport in the national psyche
Olds et al. [39]	2006	meta-analysis	performance of children and adolescents on the 20mSRT over the world	there was wide and significant variability in the performance of children; there is evidence that performance was negatively related to being overweight, as well as to a country's average temperature
Tomkinson et al. [38]	2003	meta-analysis	to test the hypothesis that aerobic fitness of children and adolescents is declining	a decline in the 20 mSRT performance of children and adolescents is evident; the rate of decline is not related to the change in the country's relative wealth

ALPHA-FIT – Assessing Levels of PHysical Activity – Fitness; 20 mSRT – 20 m shuttle run test; BMI – body mass index; ALPHA – Assessing Levels of PHysical Activity.

test battery, The President's Council on Physical Fitness and Sports (the PCPF), The President's Council on Physical Fitness and Sports (PCHF), Amateur Athletic Union Test Battery (AAUTB), YMCA Youth Fitness Test (YMCA), etc.; in Canada, Canadian Association for Health, Physical Education and Recreation Fitness Performance Test (CAHPERFPT), Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA); in China, National Fitness Test Program in the Popular Republic China (NFTP-PCR); in New Zealand, New Zealand Fitness Test (NZFT); in Australia, Australian Fitness Education Award (AFEA); and in Europe, the EUROFIT battery. The authors have reported that the ideal battery of tests should assess the components of fitness that are associated with the health of children and adolescents; bearing in mind that the ALPHA-FIT battery of tests showed the best metric properties in European children.

The paper from Ganley et al. [100] has reviewed definitions of health-related fitness and its components (body composition, flexibility, cardio-respiratory endurance, muscular strength and endurance), measurement methods, available normative values and consequences of poor health-related fitness.

The meta-analysis from Behringer et al. [20] has revealed a combined mean effect size for motor skills like jumping, running and throwing. The study has pointed out that young subjects and non-athletes showed higher gains in the motor performance following resistance training than their counterparts.

Furthermore, the article states that a positive dose response relationship for "intensity" could be found in subgroups using traditional training regimens, concluding that resistance training provides an effective way for enhancing motor performance in children and adolescents.

Original articles

Eighty-five original articles were retrieved and analyzed. The different health-related and skill-related fitness components were analyzed separately through the used field-based tests.

Health-related components

Cardio-respiratory fitness

An important capacity that should be assessed in adolescents is cardio-respiratory fitness. It is known, in fact, that over the last decades the overall fitness level [101] and in particular, cardio-respiratory fitness of the general population has decreased [102] leading to an increase in health conditions related to physical inactivity [103,104]. Cardio-respiratory fitness is known to have positive associations with high-density lipoproteins, systolic blood pressure, diastolic blood pressure [105,106], BMI, measures of body fat [107], and arterial stiffness [108]. A positive association has been also found between cardio-respiratory fitness and measures of insulin sensitivity [105,108] although this relationship is stronger in boys than in girls [108].

According to our search criteria, the systematic review highlighted 3 mainly adopted tests for the assessment of cardio-respiratory fitness: the 1 mile run/walk test, with 8 records found [60,109–117]; the 20 mSRT, also called The Progressive Aerobic Cardiovascular Endurance Run (PACER test), with 20 records found [6,26,98,109,116–132]; and the 6-min walk test with a number of 2 records found [133,134] (Table 2). Other highlighted tests were the 1/2 mile walk test, the 1/4 mile walk test [109] and the Rockport Walk fitness test [135].

The 1 mile/run walk is not adequate to fit into a school setting, which can rarely provide such a huge area that is needed to perform the test (even if a smaller surface may be available, the repeated changes of directions could impair the results of the test). The 6-min walk test is described as a self-pace test where each participant decides about the speed of execution, although a surface of at least 30 m is needed to reduce the repeated

Table 2. Overview of the fitness tests used to assess cardiorespiratory endurance

Fitness test	First author	Year	Study design	Included in a project/study
1 mile run/walk test	Saint-Maurice [116]	2014	cross-sectional	n.a.
	Olvera [110]	2013	longitudinal	n.a.
	Aryana [117]	2012	longitudinal	FITNESSGRAM
	Castro-Piñero [109]	2011	cross-sectional	n.a.
	Martins [112]	2010	longitudinal	n.a.
	Roberts [113]	2010	cross-sectional	n.a.
	Cleland [114]	2005	cross-sectional	n.a.
	Beets [115]	2004	cross-sectional	n.a.
20 m shuttle run test (PACER)	Secchi [124]	2014	cross-sectional	n.a.
	Pienaar [126]	2014	cross-sectional	n.a.
	Fabricant [127]	2014	cross-sectional	n.a.
	Saint-Maurice [116]	2014	cross-sectional	n.a.
	Haugen [128]	2014	cross-sectional	n.a.
	Minatto [118]	2013	cross-sectional	n.a.
	Vieira [139]	2013	cross-sectional	n.a.
	Soares Ferreira [132]	2013	cross-sectional	n.a.
	Voss [129]	2013	cross-sectional	n.a.
	Tanaka [119]	2012	cross-sectional	n.a.
	Aryana [117]	2012	longitudinal	FITNESSGRAM
	Machado-Rodrigues [120]	2012	cross-sectional	n.a.
	Dumith [130]	2012	cross-sectional	n.a.
	Ruiz [31]	2011	statement	ALPHA study
	Ortega [121]	2011	statement	HELENA study
	Moreira [123]	2011	cross-sectional	n.a.
	Moliner-Urdiales [122]	2010	observational	AVENA and HELENA studies
	Ruiz [6]	2009	cross-sectional	n.a.
	Voss [125]	2009	cross-sectional	n.a.
	Bovet [131]	2007	cross-sectional	n.a.
6-min walk test	Ulrich [133]	2013	cross-sectional	n.a.
	Geiger [134]	2011	longitudinal	n.a.
1/2 mile walk test	Castro-Piñero [109]	2011	cross-sectional	n.a.
1/4 mile walk test	Castro-Piñero [109]	2011	cross-sectional	n.a.
Rockport Walk FT	Sharma [135]	2013	cross-sectional	n.a.

n.a. – non applicable; PACER – The Progressive Aerobic Cardiovascular Endurance Run; HELENA – Healthy Lifestyle in Europe by Nutrition in Adolescence; AVENA – Alimentación y Valoración del Estado Nutricional de los Adolescentes (Food and Assessment of the Nutritional Status of Adolescents); FT – fitness test.
Other abbreviations as in Table 1.

changes of direction that would arise with a lower distance.

Such condition could inadvertently compromise the result of the test. The 20 mSRT has been initially validated by Léger and Gadoury [136], who have found a correlation coefficient of r = 0.84 between a standard laboratory maximal oxygen consumption (VO_{2max}) assessment and the 20 mSRT. This has been confirmed by Metsior et al. [26], who have demonstrated no mean differences between the VO_{2max} assessed through the 20 mSRT and a laboratory test, and have found a correlation coefficient of r = 0.98 within a test-retest for reproducibility. This test doesn't need much space and multiple participants can execute it concurrently.

In addition, the review of Castro-Piñero et al. [47] has shown the psychometric properties of the shuttle test and concluded that the test is a valid field measure for children and adolescents (Table 2).

Strength

Another important health-related fitness component is muscular strength [137]. By definition, strength is the maximum amount of force that someone could develop through a muscle or a muscular group against a strain [138].

According to this definition, isometric contractions or high intensity low volume contractions can be considered accurate and reliable methods to assess strength. According to our search criteria, the systematic review highlighted a mainly adopted test for the assessment of upper body maximal strength: the HG, with a number of 10 retrieved records [66,124,139–146] (Table 3). Other tests found through the bibliographic search were: the 30 s push-up test, the arm-hang test and the handheld myometer tests (this last test is equivalent to the hand grip strength predictiveness test), the push-up to failure test, the pull-up test and the overhead medicine ball throw [117,127,128,132,139,144,147–149] (Table 3). As demonstrated by Milliken et al. [64] through a multiple regression analysis between 1-repetition maximum (1 RM) of a chest press test, the BMI and the HG in youth, a predictiveness of 58.6% is evinced, therefore the HG may be useful for assessing muscular fitness in youths. In addition, a study from España-Romero et al. [66] has shown that performing the HG with the elbow extended is the most appropriate protocol to assess maximal HG strength in adolescents. In a school environment it is easy to administer, to be repeated, very practical and not time consuming at all.

Conversely, for lower body strength, the systematic review highlighted 3 main tests that have been adopted for such assessment: the SBJ with 12 records found [19,28,29,124,128,130,138,141,149–152], the Abalakov jump with 3 records found [28,29,153], and the vertical jump test with 3 records found [130,153,154] (Table 4). Counter movement jump, leg press and the Sargent test have also emerged from the search [139,153,155–157] (Table 4).

Analyzing the different aspects of the above tests we can see that in the 1st instance the vertical jump requires specific tools that are often quite expensive (e.g., the Ergojump); the other tests, on the other hand, analyze and assess the same motor skills with homemade materials. A more practical approach is provided by the use of the Abalakov jump and the SBJ.

Over the years, the scientific literature has validated each of these tests confirming both feasibility, reliability and accuracy, even though the Abalakov jump is more specific for sports in which maximal strength is expressed on a vertical plane [29,158].

In addition, strong levels of evidence have shown no significant differences with a test-retest performed with the SBJ (-0.3 ± 12.9 cm for boys and 0.3 ± 9 cm for girls), both for boys and girls aged on average 13.6 years old [48]. Such results have been also confirmed by Ortega et al. [28], adding that neither learning nor a fatigue effect was found and that such test is reliable for the assessment of lower body muscular strength both for male and female adolescents.

Table 3. Overview of the fitness tests used to assess upper body muscular strength

Fitness test	First author	Year	Study design	Included in a project/study
Hand grip strength test	Secchi [124]	2014	cross-sectional	n.a.
	Vieira [139]	2013	cross-sectional	n.a.
	Lad [141]	2013	cross-sectional	n.a.
	Cuenca-García [143]	2013	cross-sectional	HELENA study
	Moliner-Urdiales [14]	2011	cross-sectional	HELENA study
	España-Romero [66]	2010	cross-sectional	n.a.
	Hands [140]	2009	longitudinal	n.a.
	Cantell [144]	2008	cross-sectional	n.a.
	Benson [145]	2006	cross-sectional	n.a.
	Ravisankar [146]	2005	cross-sectional	n.a.
30 s push up test	Cantell [144]	2008	cross-sectional	n.a.
Arm-hang test	Aryana [117]	2012	longitudinal	FITNESSGRAM
	Ekblom [147]	2004	comparative	n.a.
Handheld myometer test	Engelbert [148]	2006	cross-sectional	n.a.
Push-up to failure	Haugen [128]	2014	cross-sectional	n.a.
	Fabricant [127]	2014	cross-sectional	n.a.
	Aryana [117]	2012	longitudinal	FITNESSGRAM
Push-up test	Woll [149]	2014	cross-sectional	n.a.
	Soares Ferreira [132]	2013	cross-sectional	n.a.
Pull-up test	Aryana [117]	2012	longitudinal	FITNESSGRAM
Overhead medicine ball throw – 3 kg	Vieira [139]	2013	cross-sectional	n.a.

Abbreviations as in Table 2.

Table 4. Overview of the fitness tests used to assess lower body muscular strength

Fitness test	First author	Year	Study design	Included in a project/study
Standing broad jump test	Woll [149]	2014	cross-sectional	n.a.
	Secchi [124]	2014	cross-sectional	n.a.
	Haugen [128]	2014	cross-sectional	n.a.
	Vieira [139]	2013	cross-sectional	n.a.
	Artero [29]	2012	cross-sectional	n.a.
	Monyeki [150]	2012	cross-sectional	PAHL study
	Dumith [130]	2012	cross-sectional	n.a.
	Martinez-Gomez [151]	2012	cross-sectional	AFINOS study
	Moliner-Urdiales [142]	2011	cross-sectional	HELENA study
	Ortega [19]	2008	cross-sectional	AVENA study
	Ortega [28]	2008	cross-sectional	HELENA study
	Albon [152]	2008	longitudinal	n.a.

Table 4. Overview of the fitness tests used to assess lower body muscular strength – cont.

Fitness test	First author	Year	Study design	Included in a project/study
Abalakov jump test	Artero [29]	2012	cross-sectional	n.a.
	Santos [153]	2012	cross-sectional	n.a.
	Ortega [28]	2008	cross-sectional	HELENA study
Vertical jump test	Buchan [154]	2012	longitudinal	n.a.
	Bovet [131]	2007	cross-sectional	n.a.
	Nuzzo [155]	2006	cross-sectional	n.a.
Counter movement jump	Vieira [139]	2013	cross-sectional	n.a.
	Santos [153]	2012	cross-sectional	n.a.
	Korff [155]	2009	cross-sectional	n.a.
Sargent jump	Westerstahl [156]	2003	longitudinal	n.a.
Leg press	Nuzzo [157]	2006	cross-sectional	n.a.

PAHL study – Physical Activity and Health Longitudinal Study; AFINOS – La Actividad Física como Agente Preventivo del Desarrollo de Sobrepeso, Obesidad, Alergias, Infecciones y Factores de Riesgo Cardiovascular en Adolescentes (Physical Activity as a Preventative Agent of the Development of Overweight, Obesity, Allergies, Infections, and Cardiovascular Risk Factors in Adolescents).
Other abbreviations as in Table 2.

Muscular endurance

Good muscular endurance has to be maintained since people are likely to have better posture, fewer back problems, and a better tolerance to muscle fatigue than people who lack muscular endurance [159]. With regard to the assessment of muscular endurance, the bent-arm hang test (also called flexed arm hang) assesses upper-limbs endurance strength, since it considers mainly the arm, shoulder and dorsal muscular endurance.

Results from Alimentación y Valoración del Estado Nutricional de los Adolescentes (AVENA – Food and Assessment of the Nutritional Status of Adolescents) study suggest that the results of the bent-arm hang test are positively associated with high-density lipoprotein (HDL) cholesterol and with total cholesterol to HDL cholesterol ratio, as well as with body fat, expressed as the sum of skinfolds, and/or percentage of body fat estimated by the Slaughter equation [160]. Reference values of a sample of Spanish adolescents participating in the AVENA study and a detailed methodology of the test can be found in the previously mentioned study [160]. A major concern, though, has arisen from the results of such test, since a considerable number of subjects scored 0: indeed, the test measures the total time in seconds by which the subject is able to sustain a contraction hanging on a horizontal bar, through his arms in a flexed position, and being able to maintain his chin above the bar; indeed such conditions make the test difficult to execute.

Moreover, the test is weight dependent, underlining the low accuracy of such test in an adolescent population [161] and suggesting to consider some other test for the assessment of muscular endurance. The systematic review highlighted other adopted tests for the assessment of muscle endurance like the sit-up tests, with different versions: the 60 s sit up test with 6 records found [130,162–166]; the 30 s sit up test with 5 records found [131,150,167–169]; the 7 stage sit up test and the sit up test to exhaustion [23,127,170,171] (Table 5). However, in 60 s or, even worst, 30 s, the actual abdominal endurance could not

Table 5. Overview of the fitness tests used to assess muscular endurance

Fitness test	First author	Year	Study design	Included in a project/study
Curl up test	Soares Ferreira [132]	2013	cross-sectional	n.a.
	Aryana [117]	2012	longitudinal	FITNESSGRAM
60 s sit up test	Lucertini [163]	2013	cross-sectional	n.a.
	Dumith [130]	2012	cross-sectional	n.a.
	Martinez-Gomez [164]	2011	cross-sectional	n.a.
	Huang [165]	2010	longitudinal	n.a.
	Mak [166]	2010	correlational	HKSOS study
	Gabbet [162]	2008	cross-sectional	n.a
30 s sit up test	Monyeki [150]	2012	cross-sectional	n.a.
	Armstrong [168]	2011	cross-sectional	n.a.
	Taeymans [167]	2009	longitudinal	n.a.
	Bovet [131]	2007	cross-sectional	n.a.
	Mikkelsson [169]	2006	longitudinal	n.a.
7-stage sit up test	Eather [169]	2013	cross-sectional	Fit-4-Fun
	Lubans [23]	2011	longitudinal	n.a.
Sit up to failure	Fabricant [127]	2014	cross-sectional	n.a.
	Coksevim [171]	2005	cross-sectional	n.a.

HKSOS – Hong Kong student obesity surveillance.

Table 6. Overview of the fitness tests used to assess flexibility

Fitness test	First author	Year	Study design	Included in a project/study
Sit and reach test	Haugen [128]	2014	cross-sectional	n.a.
	Marques [179]	2014	cross-sectional	n.a.
	Santos [180]	2014	cross-sectional	n.a.
	Muyor [181]	2014	cross-sectional	n.a.
	Vieira [139]	2013	cross-sectional	n.a.
	Minatto [118]	2013	cross-sectional	n.a.
	De Moraes [182]	2013	cross-sectional	n.a.
	Tucker [183]	2013	cross-sectional	n.a.
	Bustamante [184]	2012	cross-sectional	n.a.
	Aryana [117]	2012	longitudinal	FITNESSGRAM
	Dumith [130]	2012	cross-sectional	n.a.
	Sauka [185]	2011	cross-sectional	n.a.
	Hui [186]	1999	cross-sectional	n.a.
	Patterson [63]	1996	cross-sectional	n.a.
Lowest point reached by the fingertips while standing on a box with legs extended	Woll [149]	2014	cross-sectional	n.a.

Table 6. Overview of the fitness tests used to assess flexibility – cont.

Fitness test	First author	Year	Study design	Included in a project/study
V-sit and reach	Hui [187]	2000	cross-sectional	n.a.
Shoulder stretches	Joshi [188]	2012	cross-sectional	n.a.
	Aryana [117]	2012	longitudinal	FITNESSGRAM

be assessed properly and particularly endurance-gifted subjects could not be easily identified. Knudson and Johnston, already in 1998, concluded that the 60 s sit-up or curl-up test commonly used in fitness classes can be criticized as being measures of muscular power rather than endurance [132,172] and it appears that longer "exposure times" are needed in order to evaluate abdominal muscular endurance properly.

The 7 stage sit up is composed by 7 different ranges of motion and in order to complete it the subject has to perform 1 repetition for each level, without ever lifting the feet off the ground. The main disadvantage of this test is that of being difficult to be concluded in those subjects with heavy upper bodies. In order to find a test that could fit for everybody (under, normal or overweight) this test does not meet the standards of the Adolescents and Surveillance System for the Obesity prevention – Fitness Test Battery (ASSO-FTB). The sit up test to exhaustion (SUT), then, looks more suitable for a school environment, even though it has not been yet validated.

Flexibility

Flexibility is usually defined as the range of motions in a joint or related series of joints such as the spine [58,173,174]. It is determined by several factors: connective tissue microstructure, age, sex, joint structure, activity levels and many more. Women tend to be more flexible than men; young people tend to be more flexible than older people [174].

Flexibility is considered one of the pillars of fitness characteristics when it comes to artistic sports to express and achieve unusual postures and/or elegant positions. Some authors support the idea that there is growing evidence about the associated benefits of flexibility, including range of motions and functions, improved athletic performance, reduced injury risk, prevention or reduction of post exercise soreness, improved coordination [98], increase of mental and physical relaxation, help in the development of body awareness, reduced risk of joint and muscle strains and speeded up recovery from training [174]. Other authors support the idea that increasing range of motions (flexibility) beyond function through stretching is not beneficial and can actually cause injury and decrease performance [175]. Additionally, 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 [176], while several authors stated that "strong evidence exists that stretching has no beneficial effect on injury prevention" [177,178].

The only clear information that is coming out from the studies previously mentioned is that there is an ideal flexibility range (U-shaped curve) able to predict a good health status. The relation between the grade of flexibility and the health status is not linear, like for body composition (J-shaped curve).

The review highlighted the sit and reach test with a number of 14 records found [63,118,128,139,179–186] – the lowest point reached by the fingertips while standing on a box with legs extended with 1 record found [149], the V-sit and reach with 1 record found [187] and the shoulder stretches with 2 records found [117,188] (Table 6).

The sit-and-reach test (SART) is one of the most common field tests in physical fitness batteries to evaluate flexibility of the subjects [186,187,189]. It is included in the EUROFIT battery [190,191] and in its modified version back-saver sit-and-reach test it is a part of the FITNESSGRAM battery [192]. The back-saver sit-and-reach test differs from the sit-and-reach test in that the subject performs the test with 1 leg bent at the knee; therefore, it may be safer on the back by restricting flexion. The reliability and validity of the back-saver sit-and-reach tests have been reported [63]. Another version is the v-sit and reach, used in the President's Challenge Fitness Awards [100,193], a modification of the sit and reach test that does not require a box, but a straight line extending approximately 60 cm marked on the floor as baseline.

The SART has been usually performed in the background of physical education classes at school, suggesting its feasibility and applicability in this context. Therefore, the possibility of performing the back-saver sit-and-reach test instead of SART would not be a problem [194]. However, flexibility is a component incorporated in other tests evaluating the skill-related components, as explained in the next paragraph.

Skill-related components

The skill-related components such as speed, agility, power, balance, coordination or reaction time [12] are highly related to each other, and 1 component can include others. "Speed" refers to the rate at which motions are performed [9]. "Agility" is often considered as motions performed in a coordinated way – this means that a coordinative component is also involved. In fact, speed cannot be applied for an endless time; moreover, on our daily basis in order to perform common tasks we always combine it with some coordinated actions and flexibility. Children and adolescents achieve better results in the speed and agility components when compared to adults. Apart from those who lack mobility because of a health condition, adolescents often combine speed and agility within their usual activities (common sport activities such as football, basketball, tennis, swimming, etc.) [195,196]. These 2 qualities are in line with the hormonal changes and the increase of the overall strength and skills repertoire that occur at this period of the lifespan. "Power" is actually the application of an optimum amount of force (not maximal) and an optimal speed in order to perform an exercise [173].

The present search highlighted 2 main adopted tests for the assessment of speed, agility and coordination: the 4×10 mSRT with 9 records found [28,31,49,122,124,142,197–199] and the 10×5 m sprint test with 4 records found [160,185,200,201] (Table 4). The search also highlighted various sprint tests covering several distances (5 m, 9.14 m, 10 m, 20 m, 25 m, 30 m, 36.58 m, 37 m, 40 m, and 50 m), the side to side jump [128,151] and specific agility tests such as the Illinois agility test [202–205] (Table 7). Several studies assessed agility using the plate tapping test (EUROFIT), which has also been performed to assess coordination in the same battery.

A validation protocol including related tables containing reference values, for any of the sprint tests mentioned above hasn't been documented well in the literature, except for the 4×10 mSRT, the 10×5 m sprint and the Illinois agility test. The latter, though, needs specific equipment, so the 4×10 mSRT and the 10×5 m sprint have protocols that better suit the standards of the ASSO-FTB. A study on 69 boys and 54 girls with an average age of 13.6 years, as shown for the 4×10 mSRT a non-significant ($p > 0.05$) mean difference of 0.1±0.7 s for boys and 0.1±0.8 s for girls in a test-retest, as well as no evidence of heteroscedasticity [28]. The 4×10 mSRT is a modification of the 10×5 test adopted in the EUROFIT [191] and it allows for measurement not only of speed but also agility and coordination, in line with our initial hypothesis.

Table 7. Overview of the fitness tests used to assess skills related to performance

Fitness test	First author	Year	Study design	Included in a project/study
4×10 shuttle run test	Secchi [124]	2014	cross-sectional	n.a.
	Ruiz [31]	2011	statement	ALPHA study
	Moliner-Urdiales [142]	2011	cross-sectional	HELENA study
	Vicente-Rodriguez [197]	2011	comparative	n.a.
	Ortega [198]	2011	cross-sectional	n.a.
	España-Romero [49]	2010	cross-sectional	ALPHA study
	Moliner-Urdiales [122]	2010	longitudinal	AVENA and HELENA studies
	Jimenez-Pavon [199]	2010	cross-sectional	AVENA study
	Ortega [28]	2008	cross-sectional	HELENA study
10×5 shuttle run test	Karppanen [200]	2012	correlational	n.a.
	Sauka [185]	2011	cross-sectional	Latvian Physical Health in Youth Study
	Keane [201]	2010	cross-sectional	n.a.
	Ortega [160]	2005	correlational	AVENA study
Illinois agility test	Pino-Ortega [202]	2010	correlational	n.a.
	Vescovi [203]	2007	cross-sectional	n.a.
10, 20 and 40 m sprint	Gabbett [162]	2008	cross-sectional	n.a.
25 m sprint	Tanaka [119]	2012	correlational	n.a.
	Taeymans [167]	2009	longitudinal	
37 m sprint test	Noyes [204]	2013	cross-sectional	n.a.
9.14 and 36.58 m sprint	Vescovi [203]	2007	cross-sectional	n.a.
5 and 10 m sprint	Gabbett [205]	2006	cross-sectional	n.a.
50 m sprint	Mikkelsson [176]	2006	correlational	n.a.
Side-to-side jump	Haugen [128]	2014	cross-sectional	n.a.
	Woll [149]	2014	cross-sectional	n.a.
30 m sprint	Vieira [139]	2013	cross-sectional	n.a.

Abbreviations as in Tables 1 and 2.

Fitness Test Batteries

The existing Fitness Test Batteries with their field-based tests used worldwide in children and adolescents, and found through the search are summarized in Table 8.

The commonly used FTB in adolescents in the USA is the FITNESSGRAM test battery, developed by the Cooper Institute and adopted by the President's Council on Fitness, Sports & Nutrition within the "Presidential Youth Fitness Program," a comprehensive school-based program that promotes health and regular physical activity for America's youth. The program is also supported by the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD). A total of 52 articles have been found that used this FTB (we do not report them in this review), while 1 article has evaluated the validity and reliability of this battery [199]. This is a 6-test battery, including Bent arm hang, Curl-up, 90 degree push-Up, modified Pull Up, Back Saver Sit and Reach, Shoulder Stretch, Trunk Lift (Table 8).

Table 8. Overview of the most commonly used worldwide Fitness Test Batteries on adolescents

Country	Fitness test battery	Test battery [n]	Field based tests included in the battery	Studies [n]
USA	FITNESSGRAM test battery	6	bent arm hang, curl-up, 90° push-up, modified pull up, back saver sit and reach, shoulder stretch, trunk lift	53
USA	International Physical Fitness Test (IPFT)	5	bent arm hang, 50-m sprint, 10-m shuttle run, back throw, 1 000 m run	grey literature
USA	Fitness tests of the National Health and Nutrition Examination Survey (NHANES) National Youth Fitness Survey (NNYFS)	4	handgrip, modified pull up, hand-held dynamometer for lower body muscle strength, plank exercise, treadmill fitness measure consisting of walking, test of gross motor development	grey literature
Canada	Canadian Association for Health, Physical Education and Recreation Fitness Performance Test II (CAHPER FPT II)	6	bent arm hang, 50 yard run, 300 yard run, shuttle run, speed sit ups, standing long jump	grey literature
Canada	Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) and Canadian Society for Exercise Physiology (CSEP)	10	weight lift for up to 10 times, hand dynamometer, push-ups, curl-ups, back extension test, sit and reach, vertical jump, single stage treadmill walking test, YMCA cycle ergometer sub-maximal test, 1-mile walking test	1 and grey literature
Australia	Fit-4-Fun test battery	6	20 m shuttle run, sit and reach, standing jump, 7-stage sit-up, basketball throw, push-up	4
Brazil	None	8	sit and reach, standing long jump, 1-min curl-up, modified pull-up, medicine-ball throw, 9-min run, 20 m run and 4 m shuttle run	2
Brazil	None	5	sit and reach, curl-up, trunk-lift, push-up, progressive endurance run	1
Europe	EUROFIT test battery	9	20 m endurance shuttle-run, bent arm hang, sit-ups in 30 s, sit-and-reach, handgrip, standing broad jump, 10×5 m shuttle run, plate tapping, flamingo balance	29
Europe	ALPHA test battery	4	20 m shuttle-run, handgrip, standing broad jump, 4×10 m shuttle run	13
Europe	HELENA fitness test battery	4	20 m shuttle-run, handgrip, standing broad jump, 4×10 m shuttle run	38
Europe: Spain	AVENA fitness test battery	5	20 m shuttle-run, handgrip, standing broad jump, 4×10 m shuttle run, bent arm hang	12
Europe: The Netherlands	MOPER test battery	8	arm pull, standing high jump, bent arm hang, 10 leg lifts, sprinting, plate tapping, sit-and-reach, endurance run (max distance in 12 min)	5

EUROFIT – fitness test battery provided by the Committee for the Development of Sport of the Concil of Europe, Eurofit Project; MOPER – Motor Performance Fitness. Other abbreviation as in Tables 1 and 2.

Another battery adopted in the USA is the International Physical Fitness Tests (IPFT). It is a battery of tests developed within the cooperation between The United States Sports Academy [200] and the Supreme Council for Youth and Sports [201]. The operative manual is based on norms collected in Arab youth aged 9 to 19, and has been adopted by more than 21 nations throughout the years. The battery measures the basic components of physical activity – speed, strength, suppleness and stamina. In addition to measurements of height and weight, the battery includes: 50-meter sprint test, Flexed Arm Hang, 10-meter shuttle run, Back throw, 1000 m run (Table 8).

Recently, the Center for Disease Control and Prevention (CDC) through the National Youth Fitness Survey (NNYFS) promoted the HG, dynamometer for lower body muscle strength, modified pull up, treadmill fitness measure consisting of walking [202].

The Canada Fitness Award Program was a national fitness test and evaluation program operated by the Government of Canada department Health and Welfare Canada from 1970 to 1992. Millions of primary and secondary school children participated in the program [203]. The used fitness tests consisted of 6 short duration events for 7- to 18-year-old individuals: the 50 yard run, the 300 yard run, flexed arm hangs, the shuttle run, speed sit ups, and the standing long jump (Table 8). It was based on the fitness performance tests developed by the Canadian Association for Health, Physical Education and Recreation (CAHPER, now Physical and Health Education Canada). The revision introduced an endurance run to measure aerobic capacity.

Another fitness test battery used in Canada is the one from the Canadian Physical Activity, Fitness, and Lifestyle Appraisal (CPAFLA) [204] – a standardized battery of tests commonly used to assess asymptomatic individuals, including: weight lift for up to 10 times, hand dynamometer, push-ups, curl-ups, back extension test, sit and reach, vertical jump, single stage treadmill walking test, YMCA cycle ergometer submaximal test, 1-mile walking test [205]. In Australia the recent Fit-4-Fun program is widely used in schoolchildren to assess physical fitness [165,206,207]. It's a 6 test health-related fitness battery, including the 20 mSRT, sit and reach test, SBJ, 7-stage sit-up test, basketball throw test, push-up test, beyond the body composition assessment measures of height and weight (BMI), even though it is used in children around 10 years of age. The study from Lubans [23] has assessed the reliability of 5 tests used in Australian adolescents (leg dynamometer, 90° push-up, 7-stage sit-up, and wall squat tests, beyond the bioelectrical impedance analysis).

In China the China's National Sports and Physical Education Committee adopted a fitness test battery that focused on skill-related fitness instead of health-related fitness [CNSPEC 1990a, CNSPEC 1990b, CNSPEC 2001]. Other batteries used outside Europe were: the 8-tests battery in Brazil (SART, SBJ, 1-min curl-up, modified pull-up, medicine-ball throw, 9-min run, 20 m run and 4 m shuttle run) [130,208]; and the 5-tests battery also in Brazil (SART, curl-up, trunk-lift, push-up, progressive endurance run) [209].

The 2 most used batteries in Europe are the EUROFIT test battery and the ALPHA test battery. Twenty-nine articles have been retrieved that adopted the 9-test battery developed by EUROFIT; this includes the 20 mSRT, bent arm hang, sit-ups in 30 s, sit-and-reach, HG, SBJ, 10×5 m SRT, plate tapping, flamingo balance (Table 8).

The ALPHA test battery was used in 13 studies, and includes the 4 tests: 20 mSRT, HG, SBJ, 4×10 mSRT (Table 8). Thirty-eight articles published on behalf of the HELENA study have been retrieved using field-based FTs, but they used the same tests as those in the ALPHA study (20 mSRT, HG, SBJ, 4×10 mSRT, BMI, waist circumference, skinfold measure of % body fat) (Table 8).

Different fitness test batteries have been used at a national level in European countries. In the AVENA study, which was conducted in Spain and used in 13 studies, physical fitness was assessed in adolescents by using field tests such as HG, bent arm hang, SBJ, 4×10 m SRT and 20m SRT.

In the Netherlands, the Motor Performance Fitness (MOPER) Test Battery has been used within the Amsterdam Growth and Health Longitudinal Study (AGAHLS) in different studies [210–212]. It is an 8-test battery including the arm pull, standing high jump, flexed arm hang, 10 leg lifts, sprinting, plate tapping, SART, endurance run (max distance in 12 min) (Table 8). Its validation and reliability have been shown in the article of Uijtdewilligen et al. [210]. Other fitness test batteries were retrieved that have been used at a national level, such as in Norway – the 12-test battery [213], Czech Republic [214], Switzerland [215] and other less recent in Sweden [216], Portugal [217] and England [218].

In this paper the 3 most commonly used worldwide batteries were compared in order to establish which one or part of it could be adopted in the ASSO Project, and included in the ASSO-FTB. The comparison is shown in Table 9, where the tests used were considered by health- and skill-related fitness components.

Moreover, the tables show the hypothetical field-based FTs to be included in the ASSO-FTB selected basing on the need of covering all the health-and skill-related components of physical fitness and being suitable to the ASSO purposes.

Table 9. Comparison between the FITNESSGRAM battery, ALPHA test battery, EUROFIT test battery and the proposed ASSO – Fitness Test Battery

Component	FITNESSGRAM battery	ALPHA test battery (high priority version)	EUROFIT test battery	ASSO – Fitness Test Battery
Health-related				
body composition	BMI	BMI	BMI	BMI
		waist circumference		waist circumference
	skinfold measure of % body fat (5 skinfolds: biceps, triceps, subscapular, suprailiac, calf)		skinfold measure of % body fat (5 skinfolds: biceps, triceps, subscapular, suprailiac, calf)	
	portable bioelectric impedance analyzer			
cardiorespiratory endurance		20 m shuttle-run	20 m shuttle-run	20 m shuttle-run
muscular endurance	bent arm hang		bent arm hang	sit-up to exhaustion
	curl-up		sit-ups in 30 s	
	90 degree push-up			
	modified pull-up			
flexibility	back saver sit-and-reach		sit-and-reach	
	shoulder stretch			
	trunk lift			

Table 9. Comparison between the FITNESSGRAM battery, ALPHA test battery, EUROFIT test battery and the proposed ASSO – Fitness Test Battery – cont.

Component	FITNESSGRAM battery	ALPHA test battery (high priority version)	EUROFIT test battery	ASSO – Fitness Test Battery
Health-related – cont.				
muscular strength	curl-up	handgrip	handgrip	handgrip
	90° push-up	standing broad jump	standing broad jump	standing broad jump
	modified pull-up			
Skill-related				
speed		4×10 m shuttle run	10×5 m shuttle run	4×10 m shuttle run
			plate tapping	
agility		4×10 m shuttle run		4×10 m shuttle run
balance			flamingo balance test	
coordination		4×10 m shuttle run		4×10 m shuttle run
power		standing broad jump	standing broad jump	standing broad jump
reaction time				4×10 m shuttle run

ASSO-FTB – Adolescents and Surveillance System for the Obesity prevention – Fitness Test Battery.
Other abbreviations as in Tables 1, 2 and 8.

DISCUSSION

This review provides an overview of the main adopted, valid and reproducible field-based FTs and the most commonly used FTB worldwide for the purpose of assessment of physical fitness. It made it possible to select tools to be included in the ASSO-FTB, that could easily fit into a school context and that are accurate, reliable and cheap. The analysis of the most commonly used FTB revealed that the EUROFIT test battery is the most complete for what concerns the use of health-related and skills-related fitness tests; however, due to the time constraints of the school environment, it is not applicable in such a context. The high priority ALPHA health related fitness test battery, which, compared to its 1st version, omits the assessment of the skinfold thickness, could fit this purpose. Measurement of skinfold thickness is the most skill demanding, so in these cases BMI and waist circumference could be enough to assess body composition. The ALPHA battery, however, does not assess muscular endurance. The FITNESSGRAM battery uses different tests for the assessment of physical fitness, and the evaluation of muscular endurance is combined with the evaluation of muscular strength. However, it is not applicable within the schools, due to the high number of tests to be performed, which do not fit the school time constraints.

Five fitness tests covering the assessment of the health- and skill-related components were then identified to be included in the ASSO-FTB: 20 mSRT, SUT, HG, SBJ, 4×10 mSRT, beyond the body composition assessment tests of height and weight (BMI) and waist circumference.

As shown in Table 9, this tests battery selected for the ASSO purposes has some tests in common with other batteries; however, it includes a different test for the assessment of muscular endurance – the sit up test to exhaustion. The reason laying down this choice is that other adopted tests such as the bent-arm hang or the 60-s/30-s sit ups have major disadvantages. The first one is difficult to execute, and in such a population, it does not provide reliable results; while the second one is performed in

such a short time that it cannot assess muscle endurance properly. The sit up test to exhaustion fits to the purpose of the ASSO-FTB better, and according to the reviewed literature, can provide an accurate esteem of muscular endurance, being able for its nature to detect particularly endurance gifted subjects.

All the other included tests, apart from the latter, were previously validated and their reproducibility assessed.

With regard to the assessment of cardio-respiratory endurance, since one of the aims of the ASSO-FTB is to provide field-based tests that can be used within a school context, the 1 mile/run walk must be inevitably excluded, due to the inability of the school to provide such a huge area needed to perform the test. The 6-min walk test needs a surface of at least 30 m, thus, it is not considered adequate to be performed within the school environment as well. Therefore, the most suitable test is the 20 mSRT, as it doesn't need much space, multiple participants can execute it concurrently and there are validation tables that ensure a clear classification of each participant with a specific level of cardio-respiratory fitness. Moreover, it is widely validated and demonstrated to be reliable.

For the assessment of strength, 2 separate tests were chosen for upper and lower body assessment, the HG and the SBJ, respectively. Although the HG instrument has a relatively high cost, it is effective, very practical, not time consuming at all and easy to use. Additionally, its immediate approach makes it an indispensable component for fitness evaluation within a school context.

For the lower body assessment, the vertical jump is quite expensive (due to the required equipment) and the Abalakov jump is more specific for sports in which maximal strength is expressed on a vertical plane, thus they don't meet the standards of the ASSO-FTB. Since the SBJ is a simple, cheap and safe test, it can be considered a suitable test for the assessment of lower body maximal strength in the ASSO-FTB.

As regards flexibility, our experience suggests that using the SART and/or its variants can arise criticisms. This is in agreement with other scientists: such test is not testing 1 particular muscular group but rather the interaction of many joints and muscle groups (pelvis, hamstrings, spine, abdomen-shoulder); the results could vary if assessed by different assessors; the participant could perform a good score by bending the knees and therefore, monitoring them would be a key factor while performing the test.

In our view, according to the recent findings [48,98] and the ASSO purposes, we retain unnecessary to include a specific flexibility field based test in the ASSO-FTB.

Assessment of this component can be actually incorporated in other tests evaluating the skill-related components. These are other important aspects of physical fitness in adolescents, indirectly related to health status, and also highly related to each other, so that 1 component can include another one. The 4×10 mSRT is able to assess speed, agility and coordination. It can be performed without the need of specific equipment and, even though, only 1 participant at a time can be evaluated, it is not time consuming. The other highlighted test for speed and agility was the 10×5 m sprint test but the repeated changes of direction and restarts which the participants are subjected to could affect the final results in causing alterations to the vestibular system with consequent dizziness [219]. The last test also needs specific equipment. The 4×10 mSRT was, then, considered the most adequate for the ASSO-FTB, in line with the standards proposed by the ALPHA Health Related Fitness Test Battery for Children and Adolescents [98].

Actually, we are simply not able to describe the blending of physical fitness categories that often spell the qualities of specific fitness. For example, a fitness characteristic composed of strength and speed refers to the application of high levels of force but rapidly. Speed-strength

is a similar idea but the emphasis is on the speed component. The combinations of fitness characteristics show how complex a fitness model might become; and we're not going to delve deeper into the types of fitness. In other words, while the above model helps to narrow our universe of things that merit consideration, we must acknowledge that actually the combination of these fitness components has to be fully considered.

Adolescents and Surveillance System for the Obesity prevention – Fitness Test Battery is aiming at providing a complete tool enabling to assess "all" the physical fitness components related to health and additionally, in order to evaluate specific endurance of the abdominal region, the ASSO-FTB has included another test (the sit up test to exhaustion).

CONCLUSIONS

The ASSO Project has been created with the intention of providing teachers and people working in schools within a fitness context with an instrument able to monitor physical fitness over time in order to prevent obesity and future related diseases. The ultimate aim of this paper is to offer an accessible, low cost battery of fitness tests that could be applied worldwide within a school environment. Five fitness tests that well adapt to the assessment of physical fitness components and can predict teenagers' health status in adolescents have been selected: the 20 mSRT for cardio-respiratory endurance; the HG test for upper body maximal strength; the SBJ test for lower body maximal strength; the 4×10 mSRT for speed, agility and coordination and the SUT to exhaustion for abdominal muscle endurance. These will be incorporated into the ASSO-FTB.

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