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PHYSICAL FITNESS ASSESSMENT IN CHILDREN AND ADOLESCENTS: A SYSTEMATIC REVIEW

Stefan Kolimechkov[i]
Physiology and Biochemistry Department,
National Sports Academy 'Vassil Levski',
Sofia, Bulgaria

Abstract:
Physical fitness is a key indicator of health in children and adolescents and can predict the health status in the later phases of an individual's life. Physical fitness has a multidimensional structure and can be assessed through its different components: body composition, cardiorespiratory fitness, musculoskeletal fitness, motor fitness, and flexibility. There are more than fifteen health-related physical fitness test batteries which are used worldwide. The aim of this study was to analyse the most widely implemented field-based test batteries for assessing physical fitness and their ability to represent the relationship between the physical fitness components and the health of children and adolescents. The analyses of the literature showed that the test batteries 'Eurofit', 'FitnessGram' and 'Alpha-fit' are the most widely applied. The components and the tests which are included in these batteries were presented in detail, as well as the applicability of the implementation of these tests within the framework of a school programme. The newly proposed test battery 'PREFIT' appears to be the only one for assessing pre-school children between the ages of three and five.
Conclusion: the physical fitness assessment of children and adolescents presents us with vital information which can be utilised to maintain and improve children's health. Therefore, it is of particular importance for schools to implement health-related physical fitness test batteries which are in accordance with the age of the participants and best reflect the relationship between physical fitness and their health.

Keywords: physical fitness, children, adolescents, health, test batteries

[i] Address of the academic affiliation: 1700, Studentski grad, Sofia, Bulgaria.
Author's mailing address: 45 Westminster Road, N9 8RA, London, United Kingdom.
E-mail: kolimechkov@gmail.com

1. Introduction

Results from cross-sectional and longitudinal studies in Europe show that physical fitness is a key health marker in childhood and adolescence (Ruiz et al., 2006) and can be utilised to predict health status in the later phases of an individual's life (Ruiz et al., 2009). Therefore, all of these findings reinforce the need to include physical fitness testing in health monitoring systems (Ortega et al., 2008). Moreover, the World Health Organisation (WHO) advocates that regular testing of physical fitness and physical activity should be considered a public health priority (WHO, 2010).

Although physical fitness and physical activity are two different concepts, they are sometimes used interchangeably in the literature, which is not always appropriate, and, therefore, their meaning should be distinguished (Castillo-Garzon et al., 2006; Ortega et al., 2008; Plowman and Meredith, 2013).

Physical activity is a behaviour (something that you do) and includes any body movement produced by the contractions of skeletal muscles, which increase energy expenditure above a base level (Ortega et al., 2008; Plowman and Meredith, 2013; American College of Sports Medicine, 2014). Systematic investigation and research on the relationship between physical activity and health began after 1960 and from that time forward scientific literature has firmly established the link between these two areas (American College of Sports Medicine, 2014). Physical activity has a vital impact on the overall health and well-being of everyone, including all school-age children, and it also contributes to the building and maintenance of healthy bones and muscles (Elliot et al., 2013). The World Health Organisation and the American Alliance for Health, Physical Education, Recreation and Dance recommend that children and adolescents should spend at least one hour per day in moderate to vigorously intense physical activity (WHO, 2010; Ganley et al., 2011; Elliot et al., 2013).

The Council of Europe presents physical fitness as the ability to carry out daily tasks with vigour and alertness without undue fatigue, and with enough energy remaining to enjoy leisure-time pursuits and to negotiate unusual situations and unforeseen emergencies (Council of Europe, 1983). The American College of Sports Medicine highlights that physical fitness is the measurable outcome of a person's physical activity and exercise habits, and that is the reason why many health care providers are increasingly placing value upon the measurement of health-related physical fitness (American College of Sports Medicine, 2014).

The physical fitness of children and adolescents has been a primary concern of teachers, educators, physicians and parents since the mid-1950s. From that time onwards numerous test batteries have been developed and applied in local and national surveys (Seefeldt and Vogel, 1989).

There are more than fifteen test batteries for assessing health-related physical fitness in children and adolescents which are utilised in different parts of the globe (Castro-Pinero. J. et al., 2009; Cvejic et al., 2013; Ruiz et al., 2010)

The aim of our study was to analyse the most widely implemented test batteries and their ability to reflect the relationship between physical fitness components and the health of children and adolescents.

2. Physical fitness assessment

Physical fitness can be measured accurately through laboratory methods; however, due to the necessity for qualified technicians and sophisticated instruments, as well as the high costs and time constraints, it is still not feasible for laboratory tests to be conducted on the whole population in any particular location. On the contrary, field-based fitness tests are easy to administer, involve minimal equipment, have a low cost and can be utilised on a larger number of participants over a period of time (Romero et al., 2010). These test batteries are widely used for measuring and assessing physical fitness in children and adolescents.

The components of health-related fitness have been defined in scientific literature in different ways over the years (Cvejic et al., 2013; Plowman and Meredith, 2013). Despite different definitions, there is a consensus that health-related physical fitness has a multidimensional structure comprising several components (Plowman and Meredith, 2013). For instance, some European studies take into consideration the following components: body composition, cardiorespiratory fitness, musculoskeletal fitness and motor fitness (speed, agility and coordination) (ALPHA, 2009; Ruiz et al., 2010; Secchi et al., 2014; Ruiz et al., 2009; Artero et al., 2011). The American College of Sports Medicine suggests five components: body composition, cardiorespiratory fitness, muscular strength, muscular endurance and flexibility (American College of Sports Medicine, 2014). Other authors consider only body composition, cardiorespiratory fitness, muscular strength and flexibility (Castillo-Garzon et al., 2006) or body composition, cardiorespiratory fitness, musculoskeletal fitness and flexibility as components of health-related fitness (IOM (Institute of Medicine), 2012).

On the whole, it can be summarised that there are three main health-related fitness components: body composition, cardiorespiratory fitness and a component that includes the following physical qualities: strength, speed, agility and flexibility, all of which will be characterised separately.

2.1 Body composition

Body composition refers to the relative amount of different types of body tissues (bone, fat and muscle) and the most common health-related measure is that of body fat percentage (%BF) (American College of Sports Medicine, 2014), and this component is essential for optimal health and athletic performance in many sports. Excess fat exposes these individuals to increased risks of obesity, cardiovascular disease, diabetes, etc (Cvejic et al., 2013).

In order to successfully assess body composition, anthropometric measures such as height, weight, skin-folds, as well as some body circumferences are taken into account. Growth in children and body dimensions at all ages reflect the overall health and welfare of individuals and groups of people, and, therefore, anthropometry can be used to predict performance, health and survival prospects (WHO, 1995). Anthropometric indices, such as the Body Mass Index (BMI), waist-to-height ratio, upper arm muscle area (UAMA) and others, are also calculated.

The Body Mass Index, with the simplicity of its calculation, is the most common and widely used anthropometric measure, both for children and adults (Pekar, 2011; Keys et al., 2014; Flegal et al., 2006). However, BMI does not distinguish between the relative proportion of fat and muscle mass, and may not provide accurate information about body composition, especially when it is used in athletes who engage in strenuous physical activity, participate in strength sports and have a larger muscle mass. (Bogin and Varela-Silva, 2012). Similar results were observed in our previous studies, in which BMI did not accurately assess the weight of young gymnasts with large muscle mass (Kolimechkov et al., 2013; Kolimechkov et al., 2016). It is recommended that BMI should be used in combination with other anthropometric indices to avoid such inadequacies (Wilson et al., 2011).

Body fat percentage (%BF) can be calculated by measuring skin-folds (NHNES, 2007), and there have been different equations for performing this task. Slaughter's equations are a very common method, which can be found throughout scientific literature (Boye et al., 2002; Heyward and Stolarczyk, 1996), and these are based on only two skin-folds. These prediction equations, which represent the sum of the skin-folds triceps and scapula (referred to hereafter as the ∑SKF), are especially adapted for children and adolescents, and are widely used in Europe and the USA (Slaughter et al., 1988).

Boys (all ages): $\%BF = 1.21 (\sum SKF) - 0.008 (\sum SKF)^2 – I^*$

Girls (all ages): $\%BF = 1.33 (\sum SKF) - 0.013 (\sum SKF)^2 – 2.5$

*I = intercept substitutions based on maturation and ethnicity for boys: -1.7 prepubescent, -3.4 pubescent, -5.5 postpubescent white boys; and -3.2 prepubescent, -5.2 pubescent, -6.8 postpubescent black boys.

Providing that the ∑SKF is greater than 35mm, the following equations are used:

Boys (all ages): %BF = 0.783 (∑SKF) + 1.6
Girls (all ages): %BF = 0.546 (∑SKF) + 9.7

A widely employed method for assessing muscle mass in children and adults is the calculation of upper arm muscle area (UAMA). In order to compute UAMA, anthropometric measures of arm circumference and triceps skin-fold are required (Boye et al., 2002).

$$\text{UAMA} = [\text{upper arm circumference (cm)} - (\pi \times \text{triceps skin-fold (mm)})]^2/4\pi$$

2.2 Cardiorespiratory fitness

Cardiorespiratory fitness refers to the ability of the circulatory and respiratory systems to supply enough oxygen for the working muscles during sustained physical activity (American College of Sports Medicine, 2014). It is one of the most important components of health-related physical fitness and is a direct indicator of the physiological status of children and adolescents (Cvejic et al., 2013). Maximal oxygen intake (VO_{2max}) is the criterion for measuring cardiorespiratory endurance, and provides information about the highest rate of oxygen consumed by the skeletal muscles during physical exercises. It is reported in litres of oxygen per minute (absolute) or relative to body weight in millilitres of oxygen per kilogram body weight per minute (mL/kg/min) (Ganley et al., 2011).

Most field-based test batteries include one of the following tests: 20 m shuttle run test with progressive load until exhaustion (beep test), 1.5 mile run/walk test, 1600 m run test and submaximal cycle ergometer test (PWC170), in order to measure cardiorespiratory fitness. The outcome of the tests are expressed in the literature in different ways: measured maximum oxygen consumption (VO_{2max}), estimated VO_{2max}, duration of the test and number of completed laps in the 20 m shuttle run test (Ruiz et al., 2009); however, in order to compare results from different studies, the data should be presented as measured or estimated VO_{2max}..

2.3 Other physical qualities (strength, flexibility, balance, coordination, agility and speed)

These physical qualities are sometimes grouped in different ways and might be found in the literature as separate components. They mostly reflect the development of the musculoskeletal and nervous systems.

Muscular strength refers to the ability to perform activities that require a high level of muscular force. It can be found as a separate component of health-related fitness, because there is very strong evidence to suggest that muscular strength is associated with the following: improved posture and a lower risk of musculoskeletal injuries; better bone mass, which decreases the risk of osteoporosis; improved glucose uptake, which provides better blood glucose control; and an increased metabolic rate when at rest, which provides for better body weight control (American College of Sports Medicine, 2014).

Flexibility refers to the ability to move a joint through its complete range of motion, and this can be found as a separate component of health-related physical fitness. Inadequate flexibility levels in different joints may decrease the performance of activities involved in daily life. Moreover, poor flexibility in the back and hip joints may contribute to the development of lower back pain, which is one of the most costly medical conditions for many adults (American College of Sports Medicine, 2014; Plowman and Meredith, 2013).

Muscle strength and flexibility can sometimes be found together in one musculoskeletal component. The most widely performed tests for measuring strength are the standing long jump test, handgrip strength test, flexed arm hang, curl-up or sit-up tests, and for assessing flexibility these consist of shoulder stretch and sit-and-reach tests.

The physical qualities of balance, coordination, agility and speed are often combined together in one motor fitness component, and can be found in the literature as skill-related or performance-related fitness (Plowman and Meredith, 2013; Ortega et al., 2015). Widely implemented tests for assessing motor fitness in children and adolescents are the 50m run test, flamingo balance test and 4x10m shuttle run test (Ruiz et al., 2009).

2.4 Physical fitness test batteries

Modern test batteries are created on the basis of the tests for assessing health-related physical fitness components, all of which, i.e. the tests and the components, were described above in our systematic review. There are more than fifteen field-based physical fitness test batteries for children and adolescents (Table 1) which are implemented in different parts of the world (Castro-Pinero. J. et al., 2009; Cvejic et al., 2013; Ruiz et al., 2010).

Table 1: Field-based physical fitness test batteries for children and adolescents [modified by Castro-Pinero (Castro-Pinero. J. et al., 2009) with additions - *].

Age (years)	Acronym	Organisation / Test Battery	Region / Year*
3-5	PREFIT*	The PREFIT Battery for assessing FITness in PREschool children (Ortega et al., 2015)	Europe 2015
5-17	FITNESSGRAM	The Cooper Institute	USA 1982
5-17	NYPFP	National Youth Physical Program. The United States Marines Youth Foundation	USA 1967
5-18	HRFT	Health-Related Fitness Test, American Association for Health, Physical Education, and Recreation (AAHPER)	USA 1980
5-18	Physical Best	American Association for Health, Physical Education, and Recreation (AAHPER)	USA 1988
6-12	NZFT	New Zealand Fitness Test. Rusell/Department of Education	New Zealand
6-17	AAUTB	Amateur Athletic Union Test Battery. Chrysler Foundation / Amateur Athletic Union	USA 1988
6-17	PCPF	President's Challenge: Physical Fitness. The President's Council on Physical Fitness and Sports/American Association for Health, Physical Education, and Recreation (AAHPER)	USA 1986
6-17	PFAAT*	Physical Fitness and Athletic Ability Test (Japan) (Shingo and Takeo, 2002)	Japan 1964
6-17	YMCA YFT	YMCA Youth Fitness Test	USA 1989
6-18	ALPHA-FIT*	The ALPHA (Assessing Levels of Physical Activity and Fitness) Project (ALPHA, 2009)	Europe 2009
6-18	EUROFIT	Council of Europe Committee for the Development of Sport	Europe 1983
7-69	CAHPER-FPT II	Fitness Performance Test II. Canadian Association for Health, Physical Education and Recreation (CAHPER)	Canada 1980
9-18	AFEA	Australian Fitness Education Award. The Australian Council for Health, Education and Recreation, ACHER	Australia
9-19	IPFT	International Physical Fitness Test (United States Sports Academic / General Organization of Youth and Sport of Bahrain)	Middle East 1977 г.
9-19+	NFTP-PRC	National Fitness Test Program in the Popular Republic China (China's National Sport and Physical Education Committee)	China
12-24	NAPFA*	Singapore National Physical Fitness Award/Assessment (Schmidt, 1995)	Singapore 1982
13-17	ASSO-FTB*	Adolescents and Surveillance System for the Obesity prevention – Fitness Test Battery (Bianco et al., 2015)	Europe 2015
15-69	CPAFLA	The Canadian Physical Activity, Fitness & Lifestyle Approach (Canadian Society for Exercise Physiology)	Canada

Most of these test batteries have been conducted at regional or national levels. Our systematic review of the literature studied shows that the most widely used test batteries worldwide, and consequently those enjoying the greatest level of interest, are 'Eurofit', 'FitnessGram' and 'Alpha-fit' (Table 2).

Table 2: Comparison between the components and the field-based tests of the health-related physical fitness batteries for children and adolescents: 'Eurofit', 'FitnessGram' and 'Alpha-fit'.

Components	'Eurofit'	'FitnessGram'	'Alpha-fit'
Body composition	- Height and weight, % Body fat (5 skinfolds: biceps, triceps, scapular, suprailiac, calf)	- Height, weight, BMI, % Body fat (2 skinfolds: triceps and calf) - Portable Bioelectric Impedance Analysers	- Height and weight, BMI, waist circumference, % Body fat (2 skinfolds: triceps and scapular)
Cardiorespiratory fitness	- 20m shuttle run test (Beep test) - Bicycle ergometer test (PWC 170)	- PACER: Progressive aerobic cardiovascular endurance run (Beep test) - 1 mile run/walk - 1 mile walk test	- 20m shuttle run test (Beep test)
Muscular strength and endurance	- Handgrip strength - Standing broad jump - Bent arm hang - Sit-ups	- Curl-ups - Bent arm hang - Push-ups - Modified pull-ups - Trunk lift	- Handgrip strength - Standing long jump
Motor fitness	- Shuttle run (10x5m) - Plate tapping		- 4x10m shuttle run test
Flexibility	- Sit and reach test	- Back saver sit and reach test - Shoulder stretch	
Balance	- Flamingo balance test		

The test battery 'Eurofit' was developed in 1983, was subsequently accepted by the majority of European countries, and has often been implemented in countries outside Europe as well (Cvejic et al., 2013). This battery includes simple and inexpensive tests which can be performed by physical education teachers, either as part of or in addition to any physical education programmes in schools (Table 2). The tests can also be used in sports clubs or in sports medical centres. One of the main objectives of 'Eurofit' is to motivate children and adolescents to take regular exercise and to engage in sports, not only when they are at school but also in later adult life (Council of Europe, 1983).

The idea of 'FitnessGram' started in 1977 when Dr Charles Sterling recognised the interest of parents and school administrators in a physical fitness 'report card' similar to that used in other educational areas. The actual implementation of 'FitnessGram' developed over time in phases, with its conception being in 1982. Nowadays the test battery is an educational assessment and reporting software system, which has been used by thousands of teachers with millions of youngsters in schools worldwide in order to help teachers both to track health-related fitness and physical activity data over time, and to produce personalised reports for the pupils (Plowman and Meredith, 2013; Plowman et al., 2006). Moreover, 'FitnessGram' is one of the most widely implemented fitness test batteries throughout the world, used in all of the fifty states of the USA and fourteen other countries. Furthermore, it was estimated that in just 2012 twenty-two million pupils from 67,000 schools were assessed (Plowman and Meredith, 2013).

ALPHA (Assessing the Levels of Physical Activity and Fitness) was the first collaborative project in Europe, designed to provide a set of evidence-based instruments for assessing physical fitness and physical activity in a comparable way within the European Union. 'Alpha-fit' test battery for children and adolescents is part of ALPHA and aims to assess health-related fitness status. The fitness battery, which can be utilised simultaneously on a large number of people, is both time efficient and low in cost and equipment requirements. 'Alpha-fit' provides a set of valid, reliable, feasible and safe field-based fitness tests to be used for health monitoring purposes in children and adolescents (ALPHA, 2009). There are three slightly different versions of the fitness battery which can be implemented, depending upon the time available for their administration, and the extended version is presented in Table 2.

'Alpha-fit' includes field-based tests for children and adolescents, 6-18 years of age (ALPHA, 2009), as well as tests for adults, 18-69 years of age (Suni and P., 2009); however, information about tests and results for pre-school children is still insufficient. Due to this limited information, a new fitness test battery called 'PREFIT' was proposed, based on a systematic review in pre-school children, together with existing evidence in older children and adolescents. 'PREFIT' includes the following tests: measuring height, weight and waist circumference, beep test, handgrip strength test, standing long jump, 4x10m shuttle run test and flamingo balance test, and it was developed to assess health-related physical fitness in children between the ages of three and five (Ortega et al., 2015). The new test battery is feasible, reliable and well received by children at this age. 'PREFIT' can be presented as part of a fairy tale, which makes it as much fun and as enjoyable as any other active games. The anthropometric measures, cardiorespiratory fitness, upper-body muscular strength and speed agility have been shown to be reliable in pre-schoolers, whereas balance enjoys a poorer level of reliability, and lower-body muscular strength requires further research (Cadenas-Sanchez et al., 2016).

Some fitness batteries include a considerable number of tests, which makes it difficult for teachers to implement them in schools, where the time for testing is limited. The new fitness test battery for adolescents (13-17 years of age) 'ASSO-FTB' (Adolescents and Surveillance System for Obesity prevention – Fitness Test Battery) includes the following tests: BMI, waist circumference, 20m shuttle run test, sit-ups to the point of exhaustion, handgrip strength, standing broad jump and 4x10m shuttle run test (Bianco et al., 2015). The fitness test battery was successfully implemented in Italy and the results of this study present for the first time the percentile cut-off values of adolescents in that country (Bianco et al., 2016).

Traditional tests which concentrate on latent dimensions of motor space, such as speed, strength, coordination, etc., have been replaced by tests which assess the health-related physical fitness of children (Cvejic et al., 2013). This can be witnessed in the structures and priorities of the most widely used test batteries ('Eurofit' and 'FitnessGram'), as well as in the content of the newest fitness batteries ('Alpha-fit' and 'ASSO-FTB'). When choosing a fitness battery with the ideal set of tests, one has to take into consideration the time and facilities which the administrator of such tests possesses, and to identify the level of the relationship which the tests themselves have with the different components of health-related physical fitness. Furthermore, it is of particular importance to determine which of these components present the greatest amount of and most important information about the relationships between physical fitness and health.

In a systematic review, which includes forty-two longitudinal studies (Ruiz et al., 2009) on the relationship between the physical fitness of children and adolescents and their health, the following strong pieces of evidence were found: a higher level of physical fitness, i.e. cardiorespiratory fitness, muscular strength and body composition, both in childhood and adolescence, is associated with a healthier cardiovascular profile and with a lower risk of developing cardiovascular deceases; a healthier body composition in childhood and adolescence is also associated with a lower risk of death in adulthood; muscular strength improvements from childhood to adolescence are inversely proportional to changes in overall adiposity. The National Academy of Medicine, NAM (formerly known as the Institute of Medicine) recommends to those who develop or implement fitness test batteries in schools that they include the following tests: measuring height and weight to calculate BMI when assessing body composition, 20m shuttle run test for assessing cardiorespiratory fitness, and standing long jump and handgrip strength to assess muscular strength, because of the strong relationship between the three components of body composition, cardiorespiratory fitness and musculoskeletal fitness, and the health of youngsters (IOM (Institute of Medicine), 2012). These three health-related components are also the core of the test batteries 'Alpha-fit' and one of the recent ones "ASSO-FTB". The former possesses three clear advantages over the latter: the first of these is that it has been the subject of many studies which have been conducted widely throughout the world; the second is that it encompasses a broader range (from 6-18 years) in terms of the age of the participants; and thirdly, and very importantly, is that it enjoys the reputation of possessing three slightly different versions, as opposed to one, which can be implemented, depending upon the time available for their administration. Based on solid scientific evidence from numerous longitudinal and cross-sectional studies, many authors define 'Alpha-fit' as valid, reliable, feasible and a safe field-based fitness test battery for assessing children and adolescents in a comparable way within the European Union (Ruiz et al., 2010; Santos and Mota, 2011; ALPHA, 2009). Whereas some authors make reference to 'Alpha-fit' as an ideal battery of tests for assessing physical fitness in children and adolescents (Cvejic et al., 2013), the educational software system 'FitnessGram' remains the most widely implemented fitness test battery in the world (Plowman and Meredith, 2013), despite the fact that it consists of more tests and might be difficult for administrators to implement in many schools (Bianco et al., 2015).

4. Conclusion

Physical fitness is an important health factor in children and adolescents, and, therefore, its tracking and assessment have to be considered a high priority in all schools. The assessment of health-related physical fitness in children and adolescents provides us with substantial information, which can be used to maintain and improve their health.

The most widely implemented health-related physical fitness test batteries are 'Eurofit', 'FitnessGram' and 'Alpha-fit'. 'Eurofit' has been used all over Europe for more than thirty years, whilst 'FitnessGram' is applied extensively in the USA and throughout the rest of the world. Based on recent systematic reviews of the relationship between physical fitness components and our health, the 'Alpha-fit' fitness test battery has been widely recommended for assessing physical fitness in children and adolescents, especially throughout the European Union. According to our study, 'PREFIT' appeared to be the only appropriate test battery which assesses health-related physical fitness of pre-school children between three and five years of age.

It is of particular importance to take into consideration the design of the study and the geographical location of the participants, as well as the time and the resources available, when selecting a physical fitness test battery. The test battery should be in accordance with the age of the participants and best reflect the relationship between the levels of physical fitness and health of the children concerned.

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