



Review

# Field-Based Tests for the Assessment of Physical Fitness in Children and Adolescents Practicing Sport: A Systematic Review within the ESA Program

Garden Tabacchi <sup>1,2,\*</sup>, Guillermo F. Lopez Sanchez <sup>3</sup>, Fatma Nese Sahin <sup>4</sup>, Meltem Kizilyalli <sup>4</sup>, Rosario Genchi <sup>2</sup>, Michele Basile <sup>2</sup>, Musa Kirkar <sup>2</sup>, Carlos Silva <sup>5</sup>, Nuno Loureiro <sup>5</sup>, Eduardo Teixeira <sup>5</sup>, Yolanda Demetriou <sup>6</sup>, David Joseph Sturm <sup>6</sup>, Simona Pajaujene <sup>7</sup>, Ilona J. Zuoziene <sup>7</sup>, Manuel Gómez-López <sup>3</sup>, Ante Rada <sup>8</sup>, Jelena Pausic <sup>8</sup>, Nemanja Lakicevic <sup>1</sup>, Luca Petrigna <sup>1</sup>, Kaltrina Feka <sup>1</sup>, Ana Ribeiro <sup>9</sup>, Marianna Alesi <sup>1</sup> and Antonino Bianco <sup>1,2</sup>

<sup>1</sup> Department of Psychology, Educational Science and Human Movement, University of Palermo, Viale delle Scienze, Ed. 15, 90128 Palermo, Italy; lakinem89@gmail.com (N.L.); lucapetrigna@gmail.com (L.P.); kaltrina.feka92@gmail.com (K.F.); marianna.alesi@unipa.it (M.A.); antonino.bianco@unipa.it (A.B.)

<sup>2</sup> Palermo University Sport Center (CUS Palermo), Via Altofonte, 80, 90129 Palermo, Italy; rosgenchi@gmail.com (R.G.); miter702@libero.it (M.B.); kirkar@ceipes.org (M.K.)

<sup>3</sup> Department of Physical Activity and Sport, Faculty of Sports Sciences, University of Murcia, Calle Argentina, 19, 30720 Murcia, Spain; gfls@um.es (G.F.L.S.); mgomezlop@um.es (M.G.-L.)

<sup>4</sup> Department of Sport and Health, Faculty of Sport Sciences, Ankara University, Golbasi Yerleskesi Spor Bilimleri Fakultesi, 06830 Ankara, Turkey; nesehome@hotmail.com (F.N.S.); mekizilyalli@gmail.com (M.K.)

<sup>5</sup> Escola Superior de Desporto de Rio Maior (CIEQV - IPSantarem), Av. Dr. Mario Soares, 20413 RIO Maior, Portugal; csilva@esdrm.ipsantarem.pt (C.S.); nunoloureiro@esdrm.ipsantarem.pt (N.L.); eduardoteixeira@esdrm.ipsantarem.pt (E.T.)

<sup>6</sup> Department of Sport and Health Sciences, Technical University of Munich, Uptown Munich Campus D, Georg-Brauchle-Ring 60/62, 80992 Munich, Germany; yolanda.demetriou@tum.de (Y.D.); david.sturm@tum.de (D.S.)

<sup>7</sup> Department of Coaching Science, Lithuanian Sports University, Sporto 6, LT-44221 Kaunas, Lithuania; simona.pajaujene@lsu.lt (S.P.); ilona.zuoziene@lsu.lt (I.J.Z.)

<sup>8</sup> Faculty of Kinesiology, University of Split, Teslina 6, 21000 Split, Croatia; arada@kifst.hr (A.R.); jelenap@kifst.hr (J.P.)

<sup>9</sup> Escola Profissional de Aveiro, Rua Dr. Francisco Ferreira Neves. Apartado 567, Barrocas, 3800-510 Aveiro, Portugal; ana.ribeiro@epa.edu.pt

\* Correspondence: tabacchi.garden@libero.it; Tel.: +39-091-23896910; Fax +39-091-23860894

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**Abstract:** High levels of physical fitness (PF) can positively affect both health and cognitive function, thus monitoring its levels in youth can help increase health and quality of life in adult populations later on. This systematic review aims to identify PF field-based tests used in young European populations practicing sport to find tools that are adequate for the considered target involving a new battery within the Enriched Sport Activities (ESA) project. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was followed. In the 83 identified articles, the main tests used were: vertical/horizontal jumps (for muscular strength/power); push-ups, running at maximum effort, sit-ups (for muscular strength/endurance); multistage non-intermittent and intermittent tests (for aerobic endurance); sit and reach (for flexibility); sprinting and agility *T*-tests (for speed and agility, respectively); 10 × 5 m shuttle run (SR) (for both speed and agility). Few studies assessed coordination, reaction time, power, and balance. Although the selected tests are widely used and validated, they do not determine all PF aspects and do not reflect sport-specific features.

A final decision was made for the inclusion of the following tests: standing broad jump, seated medicine ball throw, 20 m SR test, 30 m sprint, Illinois test, and a new test, i.e., the crunning test, to assess different skill-related components at once. The use of this combination of tests allows for the assessment of all PF components and can help planning effective training programs and cultivate sporting talent.

**Keywords:** physical fitness; field-based test; children; sport; assessment

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## 1. Introduction

In the simplest terms, physical fitness (PF) refers to the ability of the body systems to work in synchrony to efficiently allow our bodies to be healthy and perform activities of daily living with ease [1]. Essentially, PF can be further branched into two different categories. In terms of health-related PF as the first category, its key components are body composition, cardiorespiratory endurance, flexibility, muscular endurance, power, and strength. These components are key determinants of health as they can reduce the risk of chronic disease and promote well-being [1]. On the other side, the second category of PF comprehends skill-related PF and it consists of components such as speed, balance, agility, and coordination and reaction time [1]. As the name suggests, skill-related PF components are crucial in sports as the fundamental basis of performance. It should be noted that although PF is in part genetically determined, it can also be greatly affected by environmental factors, primarily in the form of physical exercise [2].

Current evidence states that sedentary behavior (SB) among children is highly common on a global scale. For instance, a recent study from Canada suggested that only 7% of children and youth aged 6–19 years participate in at least one hour of moderate to vigorous intensity physical activity (PA) per day, thus meeting the current PA recommendations from Canada, USA, UK, Australia, and the World Health Organization (WHO) [3]. Similar trends are seen in Europe as well. In a study performed in 2002, researchers concluded that only about a third of children aged 11, 13 and 15 years reported enough PA to meet the current WHO guidelines [4]. The ramifications of SB are detrimental and can affect the children's health and development to a great extent. SB has a powerful potential to alter the body composition with a tendency of reduced muscle mass and excess fat mass accumulation within a body [5]. Independently of time engaging in PA, SB increases the risk of developing type 2 diabetes [6], cardiovascular disease [6], metabolic syndrome [6], weight gain [7–9], and obesity [10,11], and of cardio-metabolic, all-cause mortality and a variety of physiological and psychological matters [12].

Furthermore, lifestyle and healthy/unhealthy behaviors established during childhood and adolescence can become lifelong habits since dramatic physiological and psychological adaptations take place at these ages [2]. It is argued that children not practicing physical exercise will never fully develop their genetic potential in terms of motor skills [11]. It is also known that the present PA is the best predictor of future PA [13–15].

Being physically active improves physical health but also affects cognitive function in a great manner. In 1989, Pate claimed that the most important reason for conducting fitness testing in youth is that this process can facilitate learning in the cognitive and affective domains [16]. Short-term exercise results in temporary changes in children's physical arousal that affect thinking processes; chronic exercise training produces structural changes in the brain and enhancements in PF [17,18]. Multiple studies point out that PA is a mechanism for beneficial structural and functional alterations to the brain (e.g., increased neurotrophins, cerebral blood flow, or grey matter volume), which, in turn, enhances cognitive outcomes [18]. In addition, regular PA leads to better circulation and oxygen supply to the brain, an increase in bone and muscle density, and a higher tolerance of stress [19]. The behavioral and psychological changes induced by a single bout of exercise are visible immediately after the beginning of exercise and vanish relatively quickly after its cessation. Neurophysiological changes, which underlie the transitory behavioral and psychological changes induced by exercise

[20], can be viewed as a transient modulation of the activity of the neural networks involved in the cognitive task or the mental state of interest. In contrast, chronic effects of exercise reflect structural and durable changes in the organism, like angiogenesis [21], synaptogenesis [22], muscle hypertrophy [23,24], or neurogenesis [25].

Thus, it is important to tailor PA programs adjusted for children and adolescents that are formulated on evidence-based practice. Moreover, in order to access the current fitness level in children and adolescents, a proper series of tests has to be applied in the interest of adequate exercise prescription and motivation. Also, a suitable fitness regime will allow the measurement of progress during and after physical activity interventions. Most importantly, the most important use of fitness testing as a part of the comprehensive health-related curriculum is to teach our youth about the health benefits associated with a regular exercise regimen [16]. Accordingly, to objectively measure the PF, investigators often use various field-based tests that are easy to administer and cheaper than laboratory tests [26], and are an alternative way of measuring fitness components in population-based studies. Tests such as the EUROFIT, the ALPHA, or the ASSO fitness battery are often included in batteries aimed at evaluating components of PF in children and adolescents [27–29]. However, thorough literature research revealed many gaps and heterogeneity in the tools and batteries used for the assessment of PF in youth [30].

Because of the wide variety of tests assessing PF, this systematic review aims to identify and analyze the field-based tests used in the literature to assess PF in European children and adolescents practicing sport, in order to find an appropriate choice for the new fitness battery to be developed within the Enriched Sport Activities (ESA) project. Based on the aforementioned discussion, the significance of developing adequate fitness testing, such as ESA is clearly delineated. In the following sections, a systematic method and the outcome of it will be concisely displayed.

## 2. Materials and Methods

This work was conducted within the ESA Program, an Evidence-based Practice Exercise Program cofounded by the Erasmus+ Programme of the European Union (Key action: Sport-579661-EPP-1-2016-2-IT-SPO-SCP) involving collaborators in Croatia, Germany, Italy, Lithuania, Portugal, Spain, and Turkey [31]. It was designed as a multidisciplinary approach involving health and skill-related physical fitness components, developmental psychology and neuroscience research, with the general aim to enhance social inclusion, provide equal opportunities and promote psycho-physical wellbeing in school-age children with typical development and special needs [31].

The systematic literature review was aimed at collecting the most frequently used field-based tests for the assessment of PF in children and adolescents practicing sport. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [32] were followed (File S1).

### 2.1. Eligibility Criteria

The PICOS (Population, Intervention, Comparison, Outcomes, Study design) criteria described in PRISMA [32] were used to determine the eligibility criteria.

The included population was composed of healthy children and adolescents aged 6–17 and practicing any kind of sport. Applied exclusion criteria included pre-schoolers or subjects older than 17 years, as well as non-healthy populations and populations that do not participate in sporting activities.

Only original articles reporting on the use of PF field-based tests were included; papers reporting only on the perception of PF or with other purposes were excluded. The search was limited to articles with observational study design, while trials, validation studies, reviews, meta-analyses, abstracts, books, position statements, reference values, and editorials were not included.

Any component of PF represented the outcomes assessed through field-based tests: muscular strength, muscular and cardiovascular endurance, flexibility, speed, power, agility, balance, coordination, and reaction time. Articles were included only if they were available in languages that the authors are fluent in reading, i.e., English, Italian, French, or Spanish.

## 2.2. Information Sources and Search Strategy

PubMed (NLM) and Scopus databases were used as sources for articles published from January 2007 to October 2018 and conducted in European countries.

Single terms or a combination of the following keywords were used in order to find eligible articles combined with the AND:

Keywords1: fitness, physical fitness, sport\*

Keywords2: child\*, adolescen\*, young, youth

Keywords3: field test\*, field-based test\*, fitness battery

Keywords4: strength, strength endurance, endurance, muscle endurance, muscular endurance, cardiovascular endurance, flexibility, speed, power, agility, balance, coordination, reaction time.

## 2.3. Study Screening

The manuscript selection has been performed in two steps: in the first moment, the retrieved records were sent to Endnote® (version X8.1); in the second step, duplicates were removed and papers were screened against the inclusion and exclusion criteria.

Three independent researchers performed the revision of the literature and all doubts were solved through further analysis and discussed during the manual screening. The researchers were not blinded to the articles, authors, or associated institutions during the screening. The first selection was performed with the titles of the selected articles; during the second stage, the abstracts were examined to identify eligible papers. In the last stage, inclusion and exclusion criteria were applied to the full texts of the articles.

## 2.4. Data Collection

Papers identified as relevant were entered into a Microsoft Excel® (Microsoft Corp., Redmond, Washington, DC, USA) spreadsheet. The database, first author, year, country, target size, gender, number of males, number of females, age (years), age mean and standard deviation (SD), sport practiced, battery adopted, health-related physical fitness variables (body composition, muscular strength, muscular endurance, cardiorespiratory fitness, flexibility), and skill-related physical fitness variables (speed, agility, reaction time, coordination, power, balance) were the information collected in the Microsoft Excel® (Microsoft Corp., Redmond, Washington, DC, USA) spreadsheet.

## 2.5. Quality Assessment

A study quality assessment was performed for all retrieved papers by using the Newcastle-Ottawa Scale for observational studies [33,34]. Scales properly created for cohort and case-control studies were used, and for cross-sectional design papers, the scale adapted for cross-sectional studies as recommended by the Cochrane Collaboration was used [35].

The checklists for the three kinds of observational studies can be retrieved on the Internet ([http://www.ohri.ca/programs/clinical\\_epidemiology/oxford.asp](http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp), accessed on 6 December 2019).

In particular, the checklist used for cross-sectional studies, which were the major part, consists of three major study aspects, i.e., “selection”, including four items (sample representativeness, sample size, non-respondents, ascertainment of the exposure, for a maximum of 5 points); “comparability”, including 1 item (controlling for confounders, for a maximum of 2 points); and “outcome”, including 2 items (outcome assessment and statistical test, for a maximum of 3 points) (<https://journals.plos.org/plosone/article/file?type=supplementary&id=info:doi/10.1371/journal.pone.0147601.s001>, accessed on 6 December 2019). The maximum score that can be obtained by a study is 10, with higher scores indicating higher quality. The authors have categorized studies with “low quality” those scoring from 0 to 4, “fair quality” from 5 to 7, and “high quality” from 8 to 10.

### 2.6. Choice of Fitness Tests for the ESA Battery

The selection of the test is the final result of the activity and consultation of the Technical Expert Group (TEG 1) of the ESA Consortium (<http://www.esaprogram.eu/>). The proposed battery represents the final outcome of an agreement process among the seven participating countries.

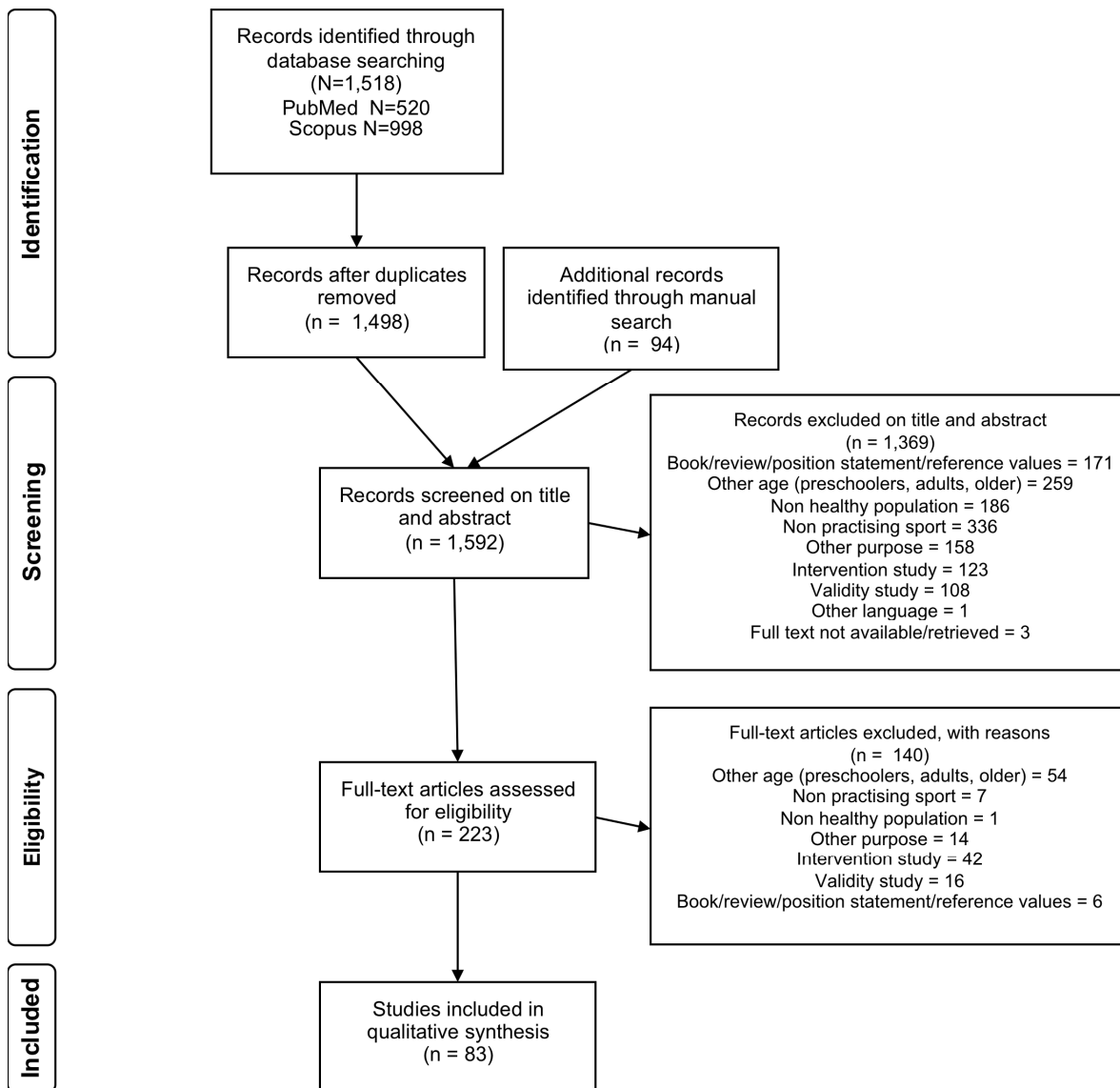
At the end of the systematic approach, an internal quality assessment was made. Each partner received a list of the field tests retrieved in the literature for the specific biomotor abilities. Afterward every test was scored, providing a judgment according to the validity, inter-operator reliability, implementation cost, administration capacity, the socio-cultural context, and the adherence to the European Commission priorities and policies within the Erasmus+ Program.

### 2.7. Data Synthesis

Data were elaborated through the STATA/MP 12.1 software (StataCorp. LP, College Station, TX, USA). A description of the sample has been provided through frequencies in numbers and percentages. A narrative synthesis has been performed to describe the PF tests used in children and adolescents in a sport context.

## 3. Results

A total of 1518 items were retrieved (520 from the PubMed and 998 from the Scopus databases); after duplicates removal and additional manual search that allowed it to obtain other 94 papers, the first screening of titles and abstract yielded a total of 223 papers that were considered potentially eligible (1369 were excluded as they did not meet the inclusion criteria) (Figure 1). After the screening of full texts, 140 papers were excluded according to the exclusion criteria and a total of 83 articles [36–118] were included in the final review.



**Figure 1.** Flow diagram of the systematic review.

### 3.1. Overview of the Retrieved Papers

The quality assessment revealed a total of 42 studies of fair quality, 40 of high quality, and 1 of very high quality, with a range between 5 and 9, and a mean score of 6.5 (Table S1). All studies were considered in the descriptive analysis and were discussed afterward.

As shown in Figure 2a, most studies assessing PF components in young people practicing sport were conducted in Belgium (14.5%), Spain (14.5%), Italy (13.3%), United Kingdom (10.8%), and Greece (9.6%). Soccer and basketball were the most frequent sports mentioned in the literature (22.9% and 15.7% of the studies, respectively), followed by tennis, rugby, gymnastics, volleyball, and others (Figure 2b).

Figure 2a. Study frequency by country

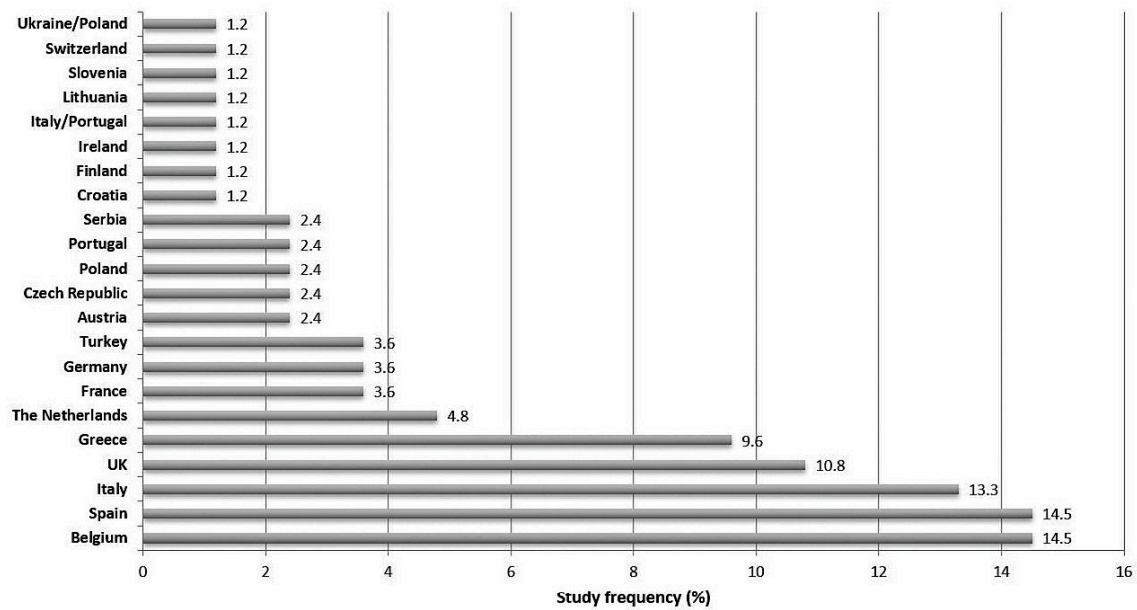


Figure 2b. Study frequency by type of sport

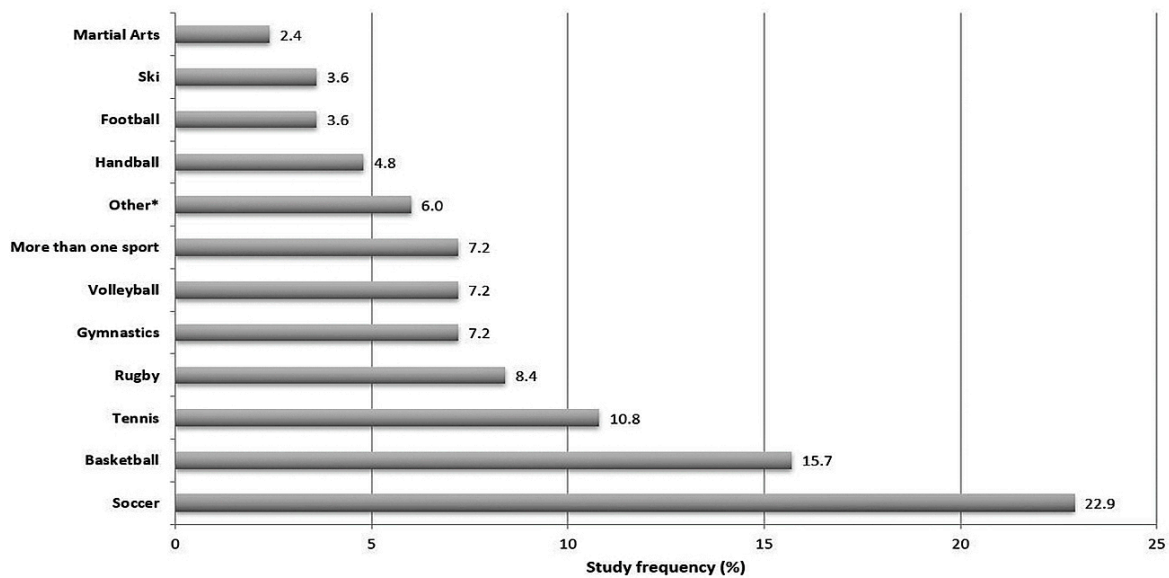


Figure 2. Study frequencies by country (a) and by type of sport (b).

The sample ranged from 7 to 22,843 young athletes with a total of 57.8% of the studies targeted to males and only 16.9% to females; in 24.1% of the studies, both males and females were included (Figure 3a). In 10.8% of the studies, the population was composed of children with a mean age of 10 years or less (primary school), while 28.9% of the studies had participants ranging between 11 and 13 years (lower secondary school). The majority of the findings (60.2%) involved an examination of a population aged 14 years or older (high school) (Figure 3b).

Figure 2a. Study frequency by country

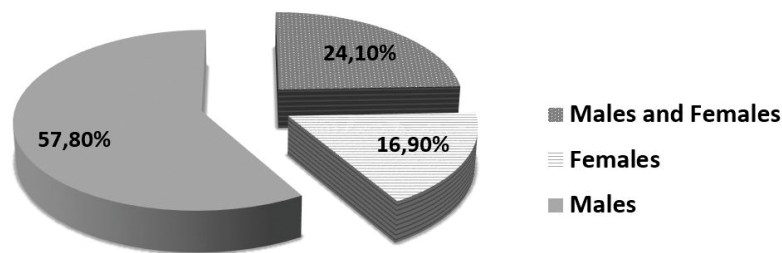


Figure 2b. Study frequency by type of sport

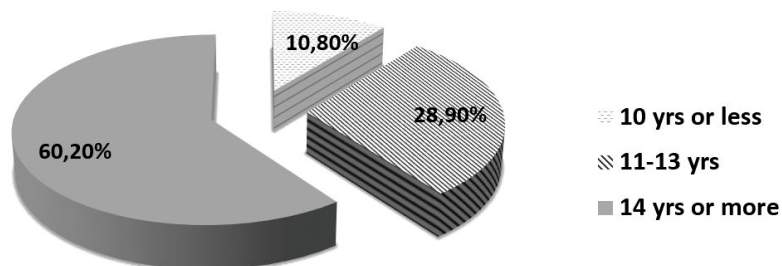


Figure 3. Study frequencies by gender (a) and by age (b).

A total of 20.5% of studies used previously established fitness batteries. Among these, 6.0% adopted the EUROFIT battery, using all tests or only a part of them; similarly, 9.6% of the studies used the Körperkoordinationstest für Kinder (KTK) in total or partially; 7.2% of the studies adopted batteries according to national sport associations/federations (such as Portuguese, Dutch, German, Swiss); 1 study used the Bruininks-Oseretsky Test Second Edition (BOT-2) battery, 1 the Hirtz's battery, and 1 the ALPHA battery.

With regard to the body composition assessment, 69.9% of the studies collected different body measures: in particular, 57.8% assessed weight and 62.7% height (sometimes including sitting height); 18.1% body fat, 4.8% body circumferences, 26.5% skinfolds, and 6.0% body lengths.

### 3.2. Fitness Tests Used to Assess the Health-Related Fitness Components

#### 3.2.1. Muscular Strength/Power

Muscular strength/power was assessed through a variety of tests in 57 studies (68.7%). Lower body strength was assessed through vertical jumps (VJs) by 70.2% of these 57 studies or by preferring the countermovement jump (CMJ) (90.0%) (Table 1). Horizontal jumps (HJs) such as the standing broad jump (SBJ) were also frequently used by 40.4% of the 57 studies. Other jumps, such as 5-jump test, Abalakov jump, and drop jump (DJ), were used in around 17% of those studies. Hops (two-leg 5-hop; one-leg, 5-hop) and other tests for the lower body assessment (Abdominal Strength Test—



AST, drop jump test—DJ, 30 sec Bosco test, Romanian Deadlift, Wingate anaerobic test, and maximal voluntary repetitions of the knee) were less frequently used (Table 1).

**Table 1.** Frequencies of the studies assessing health-related fitness components.

		N.	%
<b>MUSCULAR STRENGTH/POWER</b>		<b>57</b>	<b>68.7</b>
<b>Lower body</b>	<b>Horizontal jumps (HJ)</b>	<b>23</b>	<b>40.4</b>
	Standing Broad Jump (SBJ)	19	82.6
	HJ not specified	4	17.4
	<b>Vertical jumps (VJ)</b>	<b>40</b>	<b>70.2</b>
	VJ not specified	4	10.0
	Countermovement jump (CMJ) *	36	90.0
	Squat jump (SJ)	8	20.0
	<b>Other jumps **</b>	<b>10</b>	<b>17.5</b>
	<b>Hops ***</b>	<b>2</b>	<b>3.5</b>
	<b>Other lower ****</b>	<b>5</b>	<b>8.8</b>
<b>Upper body</b>	<b>Dinamometry</b>	<b>7</b>	<b>12.3</b>
	<b>Medicine ball §</b>	<b>10</b>	<b>17.5</b>
<b>MUSCULAR STRENGTH/ENDURANCE</b>		<b>20</b>	<b>24.1</b>
<b>Upper body</b>	Bent arm hanging	2	10.0
	Bench press	2	10.0
	Pull-ups	1	5.0
	Push-ups	5	25.0
<b>Lower body</b>	Line-drill (LD)	1	5.0
	Rope jumping	2	10.0
	1000, 500 and 200 m at maximum effort	2	10.0
<b>Abdominal</b>	Sit-up/abdominals §§	14	70.0
<b>CARDIOVASCULAR ENDURANCE</b>		<b>44</b>	<b>53.0</b>
<b>Multistage tests non intermittent</b>		<b>21</b>	<b>47.7</b>
Multistage tests: 20 m shuttle run (SR)		4	19.0
Multistage tests: other		11	52.4
<b>Multistage tests intermittent</b>		<b>15</b>	<b>34.1</b>
Yo-yo Intermittent Recovery Test (IRT) ^		12	80.0
Interval Shuttle Run Test (ISRT) ^^		2	13.3
<b>Other running tests ^^^</b>		<b>6</b>	<b>13.6</b>
<b>FLEXIBILITY</b>		<b>17</b>	<b>20.5</b>
Sit and reach		17	100.0
Stand and reach		2	11.8
Shoulder test (flexibility, mobility or rotation test)		5	29.4
Other °		1	5.9

\* including 1 study specifying CMJ with and without arms, and 1 with arms. \*\* 5-jump test, Abalakov jump, drop jump (DJ). \*\*\* including two-leg 5-hop; one-leg 5-hop. \*\*\*\* Abdominal Strength Test (AST), DJ, 30 sec Bosco test, Romanian Deadlift, Wingate anaerobic test, maximal voluntary repetitions of the knee. § 2 kg, 3 kg, 4 kg, over-head, forehand and backhand, seated. §§ only in three studies specified as 60-sec, 30-sec, and number of sit-ups. ^ including 5 Yo-yo level 1; 1 Yo-yo level 2; 2 Yo-yo level 3; 3 Yo-yo not specified. ^^ including submaximal ISRT and NAVTEN. ^^^ including 12-min run, 300 m and 2 km run, 45-15 test (= 45'' running bouts performed at progressive speed, interspersed with 15'' passive recovery), 20-m continuous progressive track run test, Cooper 12 min run test. ° including splits, lifts of side and leg (= side splits with right or left leg forward, right-leg lift test forward, left-leg lift test forward, right-leg lift test sideward, and left-leg lift test sideward).

Upper body strength was assessed through dynamometry (such as the handgrip test) in 12.3% of the studies and via medicine ball throw in 17.5% of the papers; the weight of the used ball ranged from 2 to 4 kg, and in few cases, it was specified based on the way it was thrown (over-head, forehand, and backhand, seated or standing) (Table 1).

### 3.2.2. Muscular Strength/Endurance

The muscular strength/endurance was evaluated in 24.1% of the studies, through different tests focusing on different muscle groups: bent arm hanging, bench press, pull-ups and push-ups (upper body, half of the studies); line-drill (LD) rope jumping, 1000, 500 and 200 m at maximum effort (lower body, five studies); sit-ups (abdominals, 14 studies) (Table 1).

### 3.2.3. Cardiovascular Endurance

Aerobic endurance was tested in 53.0% of the studies, through multistage non-intermittent (47.7%) and multistage intermittent (34.1%) tests. Among the non-intermittent tests, the most used was the 20 m SR (almost 50%). The Yo-yo Intermittent Recovery Test (IRT) was the most used test (80.0%) among the intermittent multistage ones and included the Yo-yo level 1, 2, and 3.

### 3.2.4. Flexibility

Flexibility was assessed in 20.5% of the studies, and all of these studies used the sit and reach test. In addition, 29.4% used flexibility, mobility or rotation tests of the shoulder, while 11.8% used the stand and reach test.

## 3.3. Fitness Tests Used to Assess the Skill-Related Fitness Components

### 3.3.1. Speed

A total of 55.4% of the studies assessed speed, through the following tests: sprints (76.1) of 5, 10, 15, 20, 25, 30, 40, or 60 m; Repeated Sprints Ability (RSA) tests (17.4%) with sprint 30 m, 40 m. or 60 m, and split at 5, 10, 20, 30, 40 m (Table 2). In the 8.7% of the studies, Bangsbo sprint test, sprinting and jumping, throwing velocity, and shuttle sprint have been adopted (Table 2).

**Table 2.** Frequencies of the studies assessing skill-related fitness components.

	N	%
<b>SPEED</b>	<b>46</b>	<b>55.4</b>
Sprint #	35	76.1
Repeated sprint with split time ##	8	17.4
Other ###	4	8.7
<b>AGILITY</b>	<b>21</b>	<b>25.3</b>
Agility test not specified	4	19.0
505-agility test	4	19.0
Illinois	3	14.3
Agility T-test	5	23.8
Other §	11	52.4
<b>SPEED/AGILITY</b>	<b>9</b>	<b>10.8</b>
10 × 5 m shuttle run (SR)	5	55.6
4 × 10 m SR	2	22.2
Sprint with change of direction	2	22.2
<b>COORDINATION</b>	<b>20</b>	<b>24.1</b>
Körperkoordinationstest für Kinder (KTK)	10	50.0
Other *	10	50.0
<b>REACTION TIME ^</b>	<b>3</b>	<b>3.6</b>
<b>POWER ^^</b>	<b>3</b>	<b>3.6</b>
<b>BALANCE ^^</b>	<b>3</b>	<b>3.6</b>

# including 5, 10, 15, 20, 25, 30, 40, and 60 m. ## sprint 30 m, 40 m or 60 m, split at 5, 10, 20, 30, and 40 m. ### Bangsbo sprint test; sprinting and jumping; throwing velocity; shuttle sprint. § Barrow zig-zag run test modified; Cross-hopping test; hurdles agility test; 15 m agility run; agility run 4 × 15 m; L-Run agility test; Pro-agility test; Side test; Spider run test; time in a slalom course without and with a ball; 2 × 15 m; zig-zag agility drill; Illinois ball dribbling. \* Obstacle run; walk backwards (WB); plate tapping; eye-hand-foot coordination; hurdle boomerang run test; low jump test; orientation SR test. ^ speed while dribbling test; simple reaction time test; react to one given signal from the five proposed. ^^ Ball throw test; double-Leg to Single-Leg Landing; single Leg Squat. ^^ Two studies used the Flamingo test; one study involved standing on one leg lengthwise on a bench as part of the test.



### 3.3.2. Agility

Agility was assessed by 25.3% of the retrieved studies. The most used test was the agility T-test (23.8%), followed by the 505-agility test (19.0%), and the Illinois test (14.3%). In 19% of the studies, the agility test used was not specified. Other types of analysis were used in 52.4% of the studies: hexagon, such as the modified Barrow zig-zag run test, Cross-hopping test, hurdles agility test, 15 m agility run, agility run 4 × 15 m, L-Run agility test, Pro-agility test, Side test, Spider run test, time in a slalom course without and with a ball, 2 × 15 m, zig-zag agility drill, and Illinois ball dribbling (Table 2).

### 3.3.3. Speed and Agility

A total of 12.2% of the studies used tests evaluating both speed and agility. The most commonly used test was the sprint with changes of direction (40%), followed by the 10 × 5 m SR (33.3%) and 4 × 10 m SR (26.7%) (Table 2).

### 3.3.4. Coordination

The studies assessing coordination (10.8%) used the KTK (50%), and the other half used Obstacle run, walk backwards (WB), plate tapping, eye–hand–foot coordination, hurdle boomerang run test, low jump test, and orientation SR test (Table 2).

### 3.3.5. Reaction Time, Power and Balance

A few studies assessed reaction time, power, and balance (3.6%); for the last component, the Flamingo balance test was mainly used (Table 2).

## 3.4. Sport-Specific Fitness Tests Used to Assess the Health- and Skill-Related Fitness Components

In soccer, the most specific used tests were the Hoff test, the ability of ball control, ball control with the head, pass accuracy, shooting accuracy, dribbling and dribbling with the pass, speed spot shooting, defensive movement, and a throw-in for distance. For basketball, investigators used speed spot shooting, passing, control dribble, defensive movement, shot, lay-up, and the two-handed chest pass to examine the health- and skill-related fitness components. For tennis, the serve velocity, the tennis-specific endurance field test (SET-Test), and the tennis-specific sprint were used. In water-sports, investigators used the Hiking endurance with incremental resistance (Bucket test, sailing specific); sprint swimming, endurance swimming, and hydrodynamic tests. In gymnastics, the rope-climbing tests was used. For skiing, the Swiss-Ski Power Test was used.

## 4. Discussion

The present study provides a framework of the field-based tests adopted to assess PF in children and adolescents practicing sport across European countries. High heterogeneity was evidenced among the used tests for health- and skill-related fitness assessment. As expected, muscular strength and power were frequently assessed, especially in sports such as soccer, basketball, tennis, and rugby. Vertical and horizontal jumps (i.e., the SBJ) were commonly used to determine lower body strength. Even though the VJs were widely used in the literature, the SBJ was finally considered for the ESA fitness battery, since, it doesn't require expensive equipment like force platforms, infrared system, accelerometer or mechanical instruments, and is widely recognized as a valid test to measure lower body muscular strength and upper body muscular strength in youth [119,120]. Moreover, the ESA Consortium agreed on implementing the SBJ rather than the VJ, since it is less demanding for instructors and participants and shows a high level of inter-operator reliability.

For the upper body strength, most of the studies used the medicine ball throw, followed by the handgrip. The use of handgrip dynamometry for the measurement of maximum isometric strength in athletes has been reported in many papers and discussed only in two reviews [121]. Although different articles in the literature addressed its validity, reliability, and standardization [121–123], it

requires rigid adherence to clinical, practical, and sports specific testing protocols to provide adequate monitoring of athletes [124]. In regards to the medicine ball throw, some studies reported on its validity and use for assessment of the upper extremity physical performance in all age groups, including athletic populations, and it appears to be a promising tool for the ESA program purposes [125–129].

Literature shows that seated medicine ball throw (SMBT) is a highly reliable and reasonably valid test for assessing upper body muscular power in the adults [130]. In nearly 400 medicine ball throws, with a variety of subjects, no injuries or complaints of discomfort occurred [130]. Moreover, some authors stated that participants enjoyed the test [130]. Notably, SMBT is cheap and easy to perform [130]. This represents a real advantage since many power tests use equipment that is costly and requires rigorous training of the practitioner [130]. For this reason, it has been considered by the authors as a suitable test to assess the upper body (arm) strength and explosive power for the battery to be developed within the ESA project.

With regard to cardiovascular endurance, most studies used non-intermittent tests such as the 20 m shuttle run test. This test is widely recognized in the literature as an effective tool to assess aerobic performance in athletes of all levels, from children to elite athletes, in all sports [131–135], and consequently in cardiorespiratory fitness [136]. The test it can highly predict both  $VO_2\text{max}$  and the velocity of  $VO_2\text{max}$  ( $vVO_2\text{max}$ ) [137–139]. Furthermore, it requires low costs, it is easy to administer and presents a very good test-retest reliability and validity while being able to test large groups of children simultaneously [140]. Therefore, it was suitable to be included in the ESA fitness battery to evaluate aerobic performance.

More than half of the studies used tests to assess “speed” as a skill-related component of fitness, such as sprint tests with and without split times. Among the sprints, because running speed and Illinois test, which is an agility test, can be used interchangeably [141], the 30 m sprint was included by the ESA team in the battery since it also requires acceleration, allowing us to obtain more information. Furthermore, this test was the most frequently used across all the considered tests and it is valid and reliable [142,143], beyond being highly relevant to team-sports performance [144–147].

Speed/Agility was measured through a variety of tests, and among them, the Illinois test, which involves straight-line sprints and rapid change of directions in varying sides and magnitudes, was used quite frequently. It was considered within the ESA project, as it can represent a valid measure of agility in different sports and in school-age children [68,141,148–151].

Additionally, in comparison with the T test and the Hexagon test, this test has components that replicate movement patterns of field team sports such as soccer, rugby, and handball [141]. Finally, but not less important, the Illinois test is a reliable and valid test to measure the change of directions [141]. Apart from high overall validity [141], the test could have an advantage in terms of ecological validity as it includes generic cues that closely replicate the majority of movement patterns performed in specific sports such as soccer [148].

Most of the studies assessing the coordination of young athletes used the KTK, a valid test aimed at determining the gross motor coordination in school-aged children [152–154]. The ESA team has considered a new test, the “Crunning Test”, to assess coordination and various other skill-related components of physical fitness. This test is a combination of crawling and running, and envisages a quadruped position to exercise the shoulders and arms, providing a complete body workout. The “crawling” exists in 21 different variations and to the authors’ knowledge, it has been very poorly used in the past [155,156]. It is a full-body cardio exercise that improves balance and mobility, boosts coordination, stabilizes and strengthens the core, and engages the shoulders, abdominals, gluteus, hips, quads, and calves [155,156]. Based on the variation used, abdominal muscles, back muscles and other core muscles are contracted to maintain that position and propel. Moreover, during the crawling the vestibular system, a sensory system associated with balance and spatial orientation, is involved, with a kind of reset stimulus that takes back to revisiting the mobility patterns one has learned as a baby [155,156].

Therefore, beyond motor skills, the central nervous system is also involved in this type of exercise [157]. Different websites report the theory of “central nervous system resetting” during

crawling gaits that explains how the human brain in adults tries to synchronize coordination, movement, and reflexive stability, helping the body regain strength, mobility, and stability one had in their youth. Unfortunately, as far as we know, scientific evidence does not support this construct.

One limitation of this literature review is that it is restricted to European countries. This choice was driven by the fact that the ESA Program is a European project, and the authors tried to focus on gaps in the assessment of fitness components only on children from European countries. The base concept was to focus on more limited aspects in order to restrict the search and create more targeted and exclusive tools characteristic of similar contexts and cultures. Thus, the European literature was explored with regard to the PF tests used in youth, in order to find an appropriate battery for the European ESA project. Moreover, a lack of studies conducted in some European countries was evidenced, with this contributing to possible publication bias. It is not clear whether those studies are not published or were published in other local languages and thus could not be retrieved. Nonetheless, all studies retrieved were judged by the authors to have a fair or high quality of sample size, methodology and statistics used, thus reducing the risk of bias.

Another source of bias could have been that some studies were unclear about the precise method used. In line with this issue, Petrigna et al., recently highlighted how important it is to report and consequently adopt proper Standard Operating Procedures (SOPs) related to every single test adopted [158].

In summary, this study reports on the field-based fitness tests used in the context of different sports in young populations. Previous studies examined the use of such tests in the school context, but the present findings add information specifically in the sports context with the intent to fill the gaps in the literature regarding fitness components' assessment.

Different fitness test batteries have been developed for school-age children. The EUROFIT Physical Fitness Test Battery was developed by the Council of Europe for the use within the school environment since 1988 and included tests for the health-related fitness components assessment [28]. Nonetheless, those tests do not assess all aspects of PF and do not reflect the specific features of different kinds of sports. The ALPHA battery examined as well the health-related PF in young populations [27]. Subsequently, the ASSO-Fitness Test Battery was addressed to school adolescents with the aim of collecting information on their fitness level, as well with particular attention to the health-related fitness components [29,30,159]. These traditional methods of assessing the PF components in young populations only partially reflect the needs for athletic skills assessment in the pediatric age and needs of the ESA Consortium. Further development of the fitness assessment battery is now envisaged within the ESA project, where fitness is analyzed in the sports context for young people, and cognitive skills are also considered together with motor components and technical skills. In fact, cognitive processing skills such as decision-making and perception are also important in athletic performances, and priority should be given to the assessment of such aspects in the public health context. Moreover, feasibility, sustainability and effectiveness in measuring all the health-related and skill-related fitness components should be basic aspects of a fitness test battery aimed at monitoring children and adolescents practicing sport. This search was useful to authors for the choice of the most suitable tests in the context of the youth sport environment within the EU priorities and the EACEA Erasmus+ Program. Starting from the results of the literature, the test selection was made according to the scoring of the Consortium of every single test adopting the following key factors: (a) implementation cost; (b) validity and inter-operator reliability; (c) socio-cultural context; (d) European Commission Policies and Priorities. Some of the most frequently used tests were confirmed, such as the standing broad jump, the seated ball throw, the 20 m SR test, the 30 m sprint, and the Illinois agility test, while a new one was chosen (i.e., the Crunning Test), as they all received the highest scores, and they were in line with the need for encompassing the assessment of different skills together, and of assessing and developing at the same time cognitive skills and PA (Table 3).

**Table 3.** Summary of the new ESA Fitness Test Battery (ESA-FTB).

FITNESS TEST	Main Fitness Component/s Measured	Detailed Item/s Measured
SEATED BALL THROW	Muscular strength/power	Explosive strength of upper limbs, Power
STANDING LONG JUMP	Muscular strength/power	Explosive strength of lower limbs, Power
20 M SR	Cardiovascular endurance	Maximum volume of oxygen consumption (VO <sub>2</sub> )
30 M SPRINT	Speed	Reaction speed, joint flexibility, Speed, Reaction time
ILLINOIS TEST	Agility, speed, coordination	Speed endurance and coordination of lower limbs, reaction time
CRUNNING TEST (ESA TEST)	Agility, speed, coordination, balance, power, reaction time	Skill related components of physical fitness

The Illinois agility test was considered suitable for ESA, since it requires at the same time memory and planning. The 20 m SR test was included in the test battery because it is standardized, requires little equipment and it is relatively easy to conduct and administer. Finally, a new fitness test that has not been used yet called the Crunning test (also called ESA test) was considered in order to assess all different skills at the same time; it could have a certain efficacy in the assessment of coordination, agility, speed, and power simultaneously, while also requiring the involvement of the central nervous system. Considering the nature of the project, this represents a priority for the ESA Consortium. All these tests included in the ESA battery were field-based tests that are easy to administer, allow the assessment of all components of PF in short periods, and also include cognitive aspects. Motor and cognitive performances are combined in the ESA tool to accurately assess young athlete abilities and skill performance in sports clubs or fitness centers with the aim of planning effective training programs and raising new sport talents. Readers can find more info by visiting the projects' official website: <http://www.esaprogram.eu/>.

**Supplementary Materials:** The following are available online at [www.mdpi.com/2071-1050/11/24/7187/s1](http://www.mdpi.com/2071-1050/11/24/7187/s1). File S1: PRISMA checklist; Table S1: Quality scores of the individual studies.

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