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Consensus

The Youth Fitness International Test (YFIT) battery for monitoring and surveillance among children and adolescents: A modified Delphi consensus project with 169 experts from 50 countries and territories

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Abstract

Background: Physical fitness in childhood and adolescence is associated with a variety of health outcomes and is a powerful marker of current and future health. However, inconsistencies in tests and protocols limit international monitoring and surveillance. The objective of the study was to seek international consensus on a proposed, evidence-informed, Youth Fitness International Test (YFIT) battery and protocols for health monitoring and surveillance in children and adolescents aged 6−18 years.

Methods: We conducted an international modified Delphi study to evaluate the level of agreement with a proposed, evidence-based, YFIT of core health-related fitness tests and protocols to be used worldwide in 6- to 18-year-olds. This proposal was based on previous European and North American projects that systematically reviewed the existing evidence to identify the most valid, reliable, health-related, safe, and feasible fitness tests to be used in children and adolescents aged 6−18 years. We designed a single-panel modified Delphi study and invited 216 experts from all around the world to answer this Delphi survey, of whom one-third are from low-to-middle income countries and one-third are women. Four experts were involved in the piloting of the survey and did not participate in the main Delphi study to avoid bias. We pre-defined an agreement of ≥80% among the expert participants to achieve consensus.

Results: We obtained a high response rate (78%) with a total of 169 fitness experts from 50 countries and territories, including 63 women and 61 experts from low- or middle-income countries/territories. Consensus (>85% agreement) was achieved for all proposed tests and protocols, supporting the YFIT battery, which includes weight and height (to compute body mass index as a proxy of body size/composition), the 20-m shuttle run (cardiorespiratory fitness), handgrip strength, and standing long jump (muscular fitness).

Conclusion: This study contributes to standardizing fitness tests and protocols used for research, monitoring, and surveillance across the world, which will allow for future data pooling and the development of international and regional sex- and age-specific reference values, health-related cut-points, and a global picture of fitness among children and adolescents.

Keywords: Fitness; Experts; Delphi; Protocols; Youth Fitness International Test

1. Introduction

Since the early 2000s, a wealth of studies have provided clear and consistent evidence supporting physical fitness (a set of attributes that people have or achieve that relates to their ability to perform physical activity) in childhood and adolescence as a powerful marker of current and future health.[1−4] The physical fitness components that have demonstrated the strongest health-related benefits are generally cardiorespiratory and muscular fitness. For instance, poor cardiorespiratory and/or muscular fitness in young people predicts future psychiatric diseases and suicide,[5,6] cardiovascular disease risk factors,[1−3] cardiovascular disease morbidity and mortality,[5,7−13] and all-cause disability and mortality.[5,7,9,10,13] Although mostly based on cross-sectional evidence, it has also been shown that better cardiorespiratory and muscular fitness in childhood and adolescence is associated with better mental health, cognitive and academic performance, higher neuroelectric activity, and larger gray matter and total brain volumes.[6,14−24]

It is therefore clear that assessing fitness in childhood and adolescence can provide valuable information about the current and future health status of the population. The added benefit of including fitness in health surveillance and monitoring is that it is non-invasive, cost-effective, and relatively simple (requires modest tester training and expertise). In fact, there are examples of national fitness monitoring and surveillance systems for children and adolescents in Europe proving its feasibility, as recently described by the European Union (EU) funded FitBack project,[25] and in other regions of the world.[26] Examples of these countries and territories include Finland; France; Hungary; Portugal; Serbia; Slovenia; Scotland, UK; Japan; China; Republic of Korea; and Brazil. Some of them include optional or compulsory fitness assessment as part of school curriculum, and others conduct representative sampling in the form of national surveys (e.g., Canadian Health Measures Survey (CHMS)). An example of the usefulness of these fitness surveillance systems is the fact that they have been able to evaluate the impact of the coronavirus disease 2019 (COVID-19) pandemic on health-related fitness.[27−29] These systems also have the capacity to identify regions, municipalities or neighborhoods, as well as sub-populations (e.g., by income status, immigrant status, cultural/racial background) at increased risk of poor health as indicated by their low relative fitness levels, which is information of clear importance for targeted public health policy. Moreover, some fitness monitoring systems, such as those in Finland and Slovenia, have linked fitness data to national health information systems. These systems have found that the most feasible way of conducting fitness testing among children and adolescents is through schools, during physical education sessions.[25]

Despite the great potential of fitness assessment for monitoring and surveillance, the major limitation has been the inconsistency in fitness tests and protocols used across studies and national testing systems, which limits comparability.

These inconsistencies hamper the interpretation of the fitness test results when comparing to representative normative values or sex- and age-specific health-related cut-points. Furthermore, for each fitness test there are a number of measurement protocols available, which also negatively impacts comparability, data pooling, and interpretation. Consequently, there is an important need to identify a core set of fitness tests for health monitoring and surveillance internationally, and to standardize the protocols for each test.

Therefore, the objective of the current study was to seek international consensus on a proposed, evidence-informed,[30,31] Youth Fitness International Test (YFIT) battery and protocols for health monitoring and surveillance in children and adolescents aged 6−18 years. To achieve this objective, we conducted an international Delphi study with a large and diverse expert group to investigate the level of agreement with the proposed tests and protocols. The Delphi approach is a systematic expert consensus procedure for gathering the most reliable opinions from a group (ideally large and diverse) of independent experts who cannot meet in real-time for logistic or economic reasons and with the ultimate goal of attaining consensus.[32] This Delphi study is directly related to 3 of the 10 international priorities (i.e., international surveys using common measures; develop universal health-related fitness cut-points; develop international field-based fitness test) for physical fitness research and surveillance among children and adolescents, as recently identified by international fitness experts.[33]

2. Methods

2.1. The evidence supporting the proposed fitness tests

This Delphi study builds on 2 major evidence-based sources, the EU-funded Assessing Levels of PHysical Activity and fitness (ALPHA) project[31] and the Institute of Medicine (IOM, currently named the National Academy of Medicine) report from the USA.[30] Briefly, the ALPHA project aimed to identify a set of valid, reliable, feasible, and safe field-based fitness tests to assess health-related fitness in school-aged children and adolescents (6−18 years old) to support standardized public health monitoring within the EU. The focus was to select tests that would be easy and feasible for use in school settings. The evidence used to support decisions was based on 4 separate reviews[3,4,34,35] (3 of which employed systematic review methodology): (a) cross-sectional associations between physical fitness and health outcomes;[4] (b) validity of fitness tests to predict future health;[3] (c) criterion validity of fitness tests;[34] and (d) test−retest reliability of fitness tests.[35] Moreover, a number of methodological studies were conducted to address the knowledge gaps identified,[31] with the feasibility and safety of the selected tests subsequently studied.[36] As an example, skinfold thicknesses were part of the evidence-based test battery but were not included in the high-priority test battery because they showed limited feasibility (due to equipment, expertise, sensitivity issues, and time needed). Therefore, the high-priority ALPHA fitness test battery proposed the following measures: (a) weight and height (to compute body mass index (BMI)) and (b) waist circumference to assess anthropometry and body composition; (c) the 20-m shuttle run to assess cardiorespiratory fitness; and (d) handgrip strength and (e) standing long jump to assess musculoskeletal fitness.[31] The ALPHA project provided an operations manual with specific protocols to conduct the tests and supporting videos that are available online at the FitBack website (https://www.fitbackeurope.eu/en-us/fitness-report/about-testing).

The IOM report on *Fitness Measures and Health Outcomes in Youth* aimed to recommend the best health-related fitness measures to include in a national fitness survey of children and adolescents, and also to recommend fitness test items that would be feasible to administer in a school environment (Section *Fitness Measures for Schools and Other Education Settings*).[30] The evidence used to inform decisions was based on a systematic review of the literature that focused on longitudinal and experimental studies measuring both fitness and health outcomes in children and adolescents aged 5−18 years. The review included evidence on field-based measures of fitness published between the years 2000 and 2010. The full IOM report can be freely accessed at https://www.ncbi.nlm.nih.gov/books/NBK241315/. The IOM report proposed the following measures: (a) weight and height (to compute BMI) to assess anthropometry and body composition; (b) the 20-m shuttle run to assess cardiorespiratory fitness; and (c) handgrip strength; and (d) standing long jump to assess musculoskeletal fitness.[30] The report also recommended measures of skinfold thicknesses and waist circumference for the U.S. National Survey, but not for school-based testing due to challenges with the time and expertise required as well as potential privacy issues when conducting the tests. The IOM report did not recommend specific testing protocols.

2.2. The proposed YFIT battery: Core tests and protocols

We propose the YFIT battery that is aligned with those recommended by the ALPHA project and the IOM report, and as such, the proposed YFIT battery is considered evidence-based, valid, reliable, health-related, feasible, and safe. The proposed core fitness tests for monitoring and surveillance in children and adolescents include (a) weight and height (to compute BMI) to assess body composition; (b) the 20-m shuttle run to assess cardiorespiratory fitness; and (c) handgrip strength and (d) standing long jump to assess muscular fitness. Waist circumference was not included in this proposal, in line with the IOM report, due to potential privacy issues with exposing the abdomen for measurement and possible cultural or ethical issues that may arise in some cultures and countries.

For the YFIT battery, we proposed using the protocol instructions and accompanying videos developed for the ALPHA project. Additional details can be found in the ALPHA Test Manual (https://profith.ugr.es/). The original ALPHA protocols, after language editing and revision, were used to develop the Delphi survey materials used in this study (see the original protocols with track changes made as results of the Delphi survey, Supplementary Table 1).

2.3. Designing and piloting the Delphi survey

We conducted a single-panel modified Delphi study with a group of international fitness experts, and approval by the ethics committee was not required. This Delphi study was developed and reported in accordance with the Conducting and Reporting Delphi Studies (CREDES) guidelines (See checklist as Supplementary Table 2).[37] We developed a standardized survey using Microsoft Forms (Microsoft Corp., Redmond, WA, USA). The survey outlined the evidence for each of the proposed tests, including details on the proposed test protocols. For each test, we asked participants whether they agreed with the proposed test for international surveillance and monitoring and whether they agreed with the corresponding protocol. For each question, participants were able to respond "yes" or "no". When a participant selected "no", they were asked to explain why they disagreed, using an open-ended response. The survey was piloted with a small group of experts (GRT, JRZ, KK, and CDN, 50% women) to assess the clarity of the survey content. The 4 experts involved in the piloting of the survey did not participate in the main Delphi study to avoid bias. The Delphi procedure allowed the expert participants to provide their opinions and to systematically refine, if necessary, the content to attain consensus.[32] We aimed for agreement of ≥80% among the expert participants for consensus.[37–42]

2.4. The process of selecting fitness experts to be invited to participate

Sampling of expert participants took place in 4 phases. First, we invited participants who took part in the Global Youth Fitness Forum on September 7th, 2023 that was organized by the Public Health Agency of Canada. Most of these participants co-authored a previous Delphi study.[33] Second, we ran a SciVal (www.scival.com) search on November 14th, 2023. SciVal is a bibliometric repository that categorizes Scopus publications into different topic clusters, each representing a distinct field of research. These topics are identified through direct citation analysis and named based on key terms from the aggregated publications with a unique classification number. The topic identified as "Cardiorespiratory Fitness; Skinfold Thickness; Body Mass (T.7814)" covers comprehensive studies on physical fitness components and their tests in youth. Experts who had been a first or senior (i.e., last/corresponding) author on relevant publications in this field since January 2020 with an h-index of ≥5 were invited.[33] Notably, SciVal updated a new generation of topics on May 21st, 2024. The new topic most relevant to the "youth fitness test" was "Adolescents; Muscle Strength; Fitness (T.6179)", which covered 77.6% of the studies previously categorized under T.7814. Third, we ran an additional search of www.expertscape.com on November 9th, 2023 to identify top researchers who have published in the area of pediatric physical fitness. Last, we searched our personal networks to identify additional people with expertise in fitness testing in children and/or adolescents, while prioritizing those from low- and middle-income countries and women to ensure that we obtained insights from a gender and internationally diverse expert group. It is important to note that to reduce risk of bias only two of the experts invited to participate in this Delphi survey participated in the ALPHA project and only two participated in the IOM report.

2.5. Delphi study methods, data management, and analysis

In total, we invited 216 participants with expertise on fitness in children and adolescents to complete the Delphi survey. The survey was first circulated by email on December 15th, 2023 and data collection closed on March 8th, 2024. We provided participants with up to 3 reminder emails between January and February 2024. All analyses were conducted in Microsoft Excel 2016 (Microsoft Corp.) or SAS Enterprise Guide 7.1 (SAS, Cary, NC, USA). Analyses were carried out as frequencies or means stratified by gender and geographic region.

3. Results

3.1. Characteristics of the expert group responding to the Delphi survey

The characteristics of the Delphi expert panel members are presented in Table 1. Of the 216 fitness experts invited to participate, 169 from 50 countries and territories (including special administrative regions such as Hong Kong, China) responded to our survey, resulting in a 78% response rate (Fig. 1). The χ^2 test revealed that the response rates across both genders and various world regions did not statistically differ from those not responding, with the exception of Asia, where the response rate was lower (52.4%) probably due to their winter vacation period and the Spring Festival in China. Fig. 1 visually shows how the percentage of experts responding from different world region and gender groups is similar to those invited, indicating overall representativeness in the participation/response. A detailed gender- and country-level description of the respondents is provided as Table 2. In short, respondents were on average 46 years of age, mostly scientists/researchers (88%), and had more than 10 years of postgraduate experience (65%). A total of 63 women completed the survey, representing 37% of respondents. Sixty-one respondents were from low- or middle-income countries (self-reported by the respondents), representing 36% of respondents. Most respondents were from Europe (54%), followed by the Americas (25%), with a balanced distribution between North and South America (13% and 12%, respectively), followed by Africa (8%), Asia (7%), and Oceania (5%).

3.2. Main results of the Delphi study

The main results of the Delphi study are presented in Fig. 2 for the full sample, by gender and by world region. The percentage of agreement was above 80% (targeted consensus) for the 4 fitness measures proposed, precluding the need for a second Delphi survey round. The agreement for using BMI

Table 1
Descriptive statistics of the panel of experts (n = 169).

	Total	Man	Woman
Age (year)	46.3 ± 10.8	47.3 ± 11.4	44.7 ± 9.8
Gender			
Man	105 (62.1)	–	–
Woman	63 (37.3)	–	–
Non-binary	1 (0.6)	–	–
Occupation			
Scientist/researcher (e.g., professor, scientist, post-doctoral fellow)	149 (88.2)	92 (87.6)	56 (88.9)
Research assistant/research manager	4 (2.4)	2 (1.9)	2 (3.2)
Student (e.g., doctor of philosophy student)	8 (4.7)	5 (4.8)	3 (4.8)
Other	8 (4.7)	6 (5.7)	2 (3.2)
Career stage (years of experience post-graduation)			
Current student	12 (7.1)	6 (5.7)	6 (9.5)
0−5	19 (11.2)	10 (9.5)	9 (14.3)
6−10	29 (17.2)	19 (18.1)	9 (14.3)
11−20	53 (31.4)	31 (29.5)	22 (34.9)
21+	56 (33.1)	39 (37.1)	17 (27)
Primary region of occupation			
Africa	14 (8.3)	6 (5.7)	8 (12.7)
Asia	11 (6.5)	8 (7.6)	3 (4.8)
Oceania	9 (5.3)	5 (4.8)	4 (6.3)
Europe	92 (54.4)	61 (58.1)	31 (49.2)
North America	22 (13.0)	13 (12.4)	8 (12.7)
South America	21 (12.4)	12 (11.4)	9 (14.3)
Primary country GDP (self-reported)			
High-income	108 (63.9)	70 (66.7)	37 (58.7)
Middle-income	45 (26.6)	26 (24.8)	19 (30.2)
Low-income	16 (9.5)	9 (8.6)	7 (11.1)

Notes: Data are presented as n (%) or mean ± SD unless otherwise stated. Percentages may not add up to 100 % due to rounding.
Abbreviation: GDP = gross domestic product.

was the lowest at 87%, with higher agreements obtained for the other tests (i.e., 92% for handgrip strength, 93% for 20-m shuttle run, and 98% for standing long jump). The level of agreement for all proposed tests was above 80% for both men (85%−98%) and women (92%−97%) and across all the world regions (85%−100%). Comments and suggestions related to the tests proposed, as well as authors' overall answers are presented in Supplementary Tables 3−6.

We also attained consensus for all proposed test protocols, >80% in the full sample and by gender (Fig. 2). This level of consensus precluded the need for a second Delphi survey round. Levels of agreement for the test protocols were also >80% for most world regions (Fig. 2). There were, however, a few test protocols in certain regions (4 of 24 bars represented in Fig. 2) where the percentage was lower (i.e., 67%−68%). For example, only 68% of North American participants agreed with the protocol for BMI, and we did not attain the 80% threshold for the 20-m shuttle run (78%), handgrip strength (78%), or standing long jump (67%) protocols in Australia and Oceania. It is important to note that choosing "No" in the survey does not necessarily mean disagreement with the proposed protocol, but it was the only way in which to provide opinions/observations. In such cases, participants were able to suggest slight modifications to the protocols or considerations, which are presented in Supplementary Tables 3−6. The original protocols, with changes highlighted, are presented in Supplementary Table 1, and the final protocols (clean of track changes), which were refined based on the expert panel's comments, are presented in Table 3. As seen in the version of the protocols with changes tracked (Supplementary Table 1), the main content of the protocols was not largely modified and, therefore, a second Delphi survey round was not conducted. Importantly, some of the refinements made to the protocols based on comments from the international and diverse expert group included important cultural and religious considerations regarding the clothing recommended for the measurements, which makes YFIT a more inclusive test battery. We also provide additional guidance for the sequence of fitness tests and for handgrip strength testing (i.e., optimal hand size grip span converter table) since it has been shown that maximal handgrip strength is associated with an optimal grip span that is dependent on the hand size of the child[43] and adolescent[44] (Supplementary Tables 7−8). An illustration summarizing the project and findings is presented as Fig. 3.

4. Discussion

4.1. Summary of main findings

In the present study, we proposed the YFIT battery, an evidence-based and international consensus-based fitness test battery for monitoring and surveillance among children and

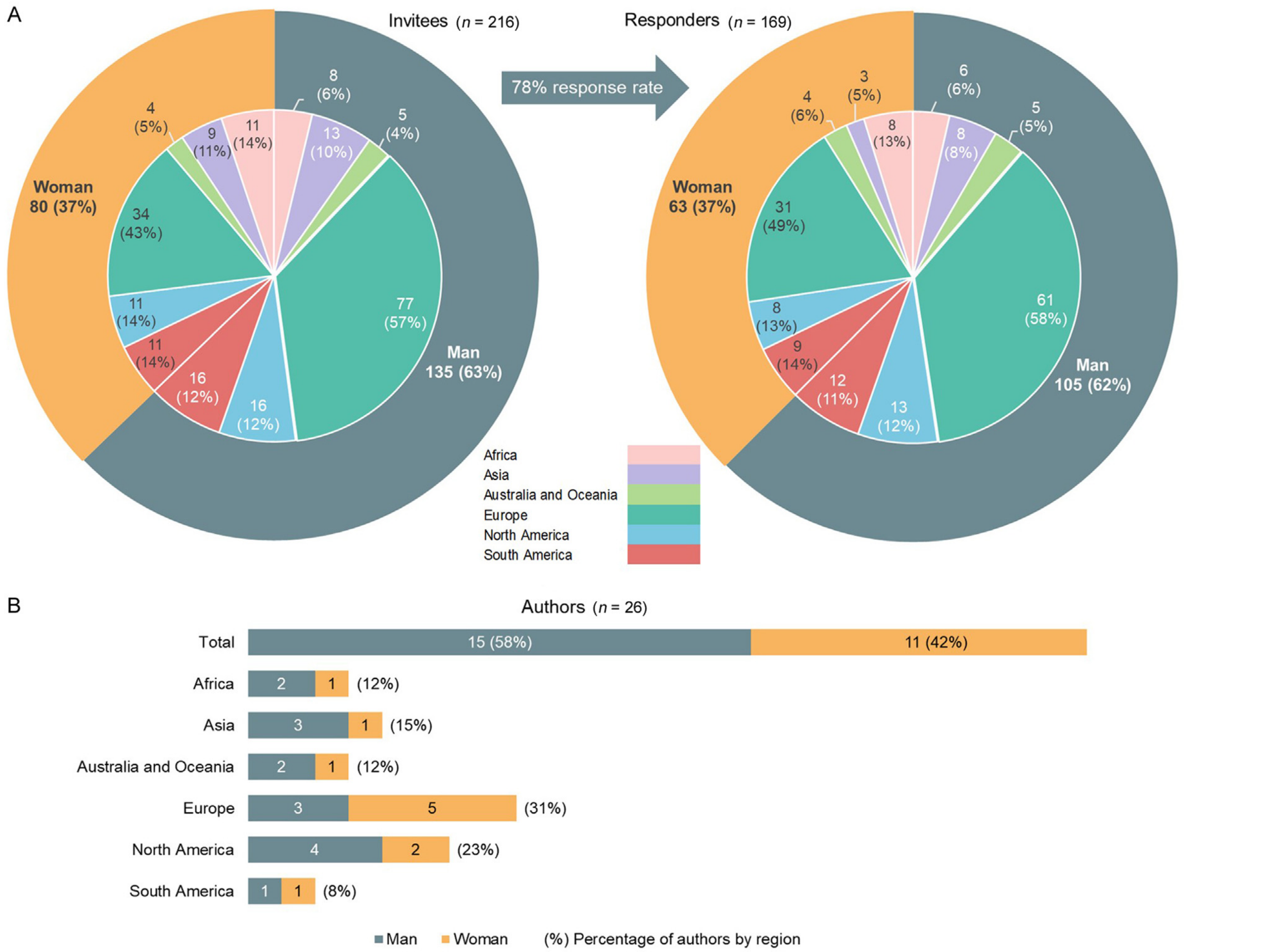

Fig. 1. The gender and geographic distribution of the (A) Delphi survey invitees (*n* = 216) and responders (*n* = 169) and (B) authors (*n* = 26). Data shown are *n* (%). Note that 80 (woman) + 135 (man) = 215, plus 1 person reporting non-binary gender totals 216 survey invitees. The same applies to the 169 Responders. Percentage may not add to 100% due to rounding.

adolescents that is valid, reliable, health-related, feasible, and safe. To attain international consensus on the YFIT battery, we completed a Delphi survey using a large, gender, and geographically diverse expert panel. We obtained a high response rate (78%) and high agreement (≥85%) for all proposed tests across genders and geographical regions, indicating overall consensus (≥80%) for the core set of fitness tests included in the YFIT battery. The core measures included body weight, body height, and BMI as markers of body size/composition; 20-m shuttle run as a marker of cardiorespiratory fitness; and handgrip strength and standing long jump as markers of upper and lower body muscular fitness, respectively. We also attained an overall consensus (≥80%) for the corresponding test protocols. A number of minor modifications were proposed by respondents, which were incorporated into the final test battery protocol provided in this study. In addition, there are guidance tools available to help avoid student's frustration or bad experiences during fitness testing at school that can be accessed on the FitBack website (See: (a) Before fitness testing and (b) Provide appropriate fitness testing environment).

4.2. Interpretation and relevant comments provided by the respondents

It is important to consider the YFIT battery as the core or minimum number of fitness tests and protocols recommended for international monitoring and surveillance. However, these measures should not dissuade countries/regions from including additional fitness components or other fitness tests depending on the purpose of the evaluations. For example, if a certain country/region has historically collected fitness data using tests other than those proposed here, it is reasonable to continue using some or all of those tests for tracking temporal trends. In this case, the inclusion of the YFIT core tests could be considered as complementary to existing tests. Likewise, if a country/region plans to start a new fitness monitoring/surveillance system, then the YFIT core fitness tests are recommended at a minimum, plus other potentially relevant tests (if any). Although this study has focused on monitoring/surveillance, the same principle could apply to research projects that include these core tests plus any other tests relevant for their analytical goals. In the future, standardized

Table 2
Detailed gender- and country-level information of the Delphi responders, representing 50 countries and territories.

Countries and territories	*n*
Africa (*N* = 8)	14 (8 women)
Botswana	1
Ghana	1
Kenya	4
Malawi	1
Nigeria	1
South Africa	2
Uganda	3
Zimbabwe	1
Asia (*N* = 4)	11 (3 women)
China	6
Hong Kong, China	3
Japan	1
Saudi Arabia	1
Australia and Oceania (*N* = 1)	9 (4 women)
Australia	9
Europe (*N* = 26)	92 (31 women)
Austria	2
Belgium	1
Croatia	3
Czech Republic	2
Denmark	1
Estonia	5
Finland	6
France	3
Germany	3
Greece	1
Hungary	2
Iceland	1
Ireland	1
Italy	6
Lithuania	3
Montenegro	1
North Macedonia	2
Poland	1
Portugal	7
Serbia	2
Slovenia	4
Spain	19
Sweden	3
Switzerland	2
The Netherlands	2
UK	9
North America (*N* = 3)	22 (8 women)
Canada	11
Mexico	2
USA	9
South America (*N* = 8)	21 (9 women)
Argentina	3
Brazil	6
Chile	7
Colombia	1
Ecuador	1
Paraguay	1
Peru	1
Uruguay	1
Total (*N* = 50)	169 (63 women)

Note: The word "territories" includes internationally recognized "special administrative regions", for example, Hong Kong, China. Total includes one non-binary individual.

international fitness measurement will result in a large amount of comparable data across countries/regions, thus opening many possibilities for research while informing policy interventions seeking improvements and equity.

Furthermore, when a test is finally selected, it is of utmost importance to follow the same protocols to increase standardization, data comparability, generation of future reference values, and health-related cut-points. In this context, our study obtained opinions on fitness test protocols from world experts, resulting in some minor protocol refinements. We are not aware of other fitness test protocols that have followed a similar expert consensus process. Therefore, strict adherence to these protocols is highly recommended for standardization. The protocols also include demonstration videos, key information about the equipment needed, as well as assessor instructions and specific instructions for the person being evaluated, which are all important for measurement standardization. Moreover, the protocols suggest a testing sequence and important safety considerations.

The overall consensus on the use of the 20-m shuttle run, handgrip strength, and standing long jump tests was very high (>90% agreement). Across all participants, the level of agreement for the standing long jump was the highest at 98%, suggesting it is the preferred fitness test for monitoring and surveillance. Although the agreement for using BMI as a measure of body composition was still high, it was the lowest among the proposed measures (87%). After reading the comments provided by the expert panel, we believe that this lower agreement was mainly due to BMI being framed as a measure of body composition, which was not considered ideal by some experts because BMI is neither able to distinguish between fat and lean mass nor central/abdominal adiposity. We fully appreciate this concern, and it may be more appropriate for the terminology to change from "body composition" to "body size/weight status", which appears to better reflect the underlying construct. Regardless of this terminology, we believe that weight, height, and BMI are the minimum anthropometric indices needed in this core fitness battery for several reasons. First, BMI is currently the only globally accepted measure to define overweight and obesity across the lifespan for surveillance purposes. Second, BMI is simple, feasible, and robust—unlike body fat percentage, which is known to be costlier and varies largely by method, even between gold standard methods (e.g., there are large differences between air-displacement plethysmography and dual-energy X-ray absorptiometry[45]). Third, regardless of its validity as a marker of adiposity, BMI is an excellent marker of future disease risk.[46,47] Fourth, as indicated above, it is important to stress that other field-based measures such as skinfolds or waist circumference raise privacy and feasibility issues for use at a large scale and especially in certain settings/cultures, and the YFIT battery was developed to be international and inclusive. Fifth, it is also important to note that the separate measures of weight, height, and BMI can be useful for scaling and

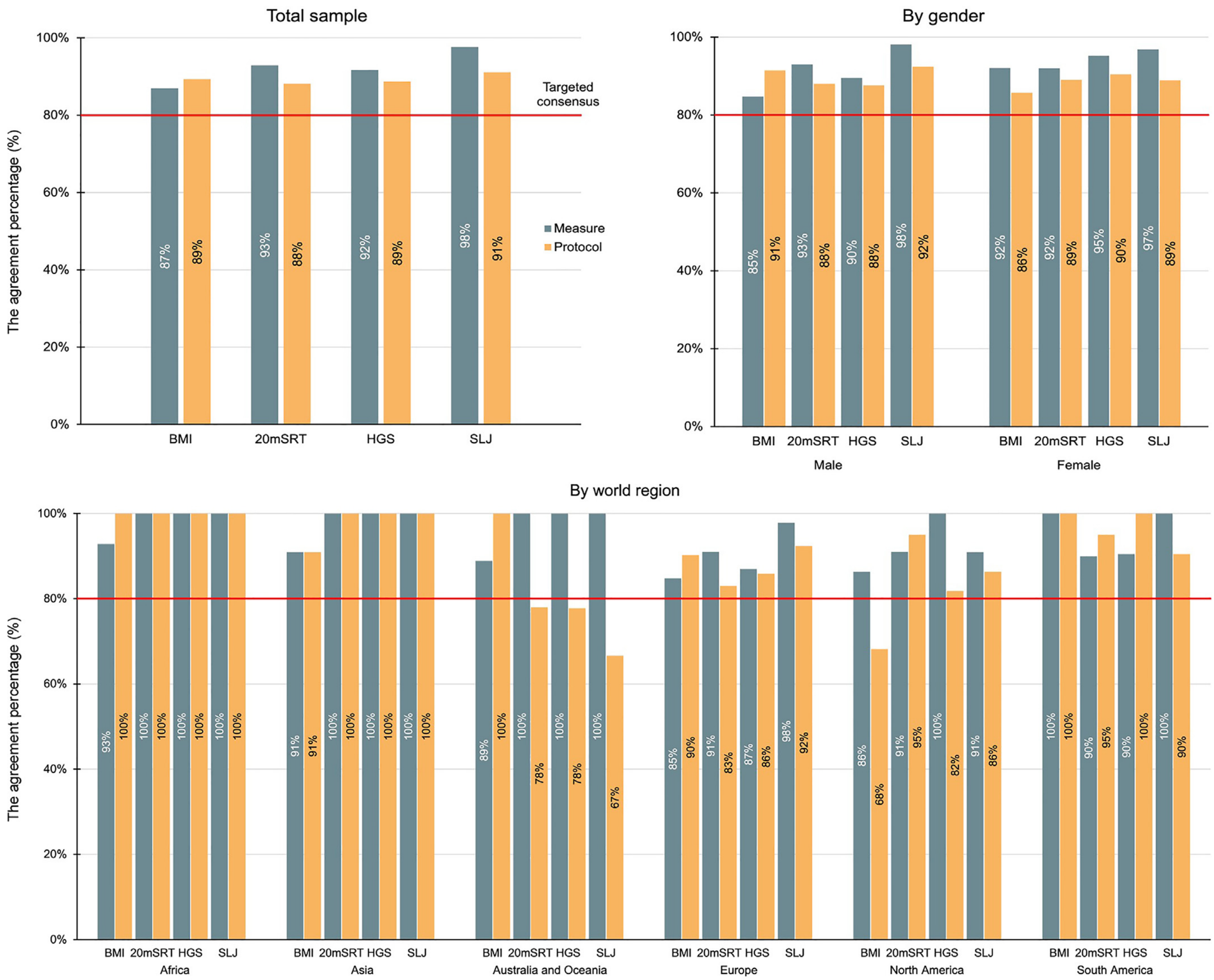

Fig. 2. The percent agreement for BMI, 20mSRT, HGS, and SLJ by total sample, gender, and region of occupation ($n = 169$). Agreement was assessed by asking participants whether they agree with recommending each measure as the best and most feasible to use in international health surveillance and monitoring. Agreement with the protocol was assessed by asking participants whether they agree with the recommended protocol identified for international health surveillance and monitoring. Consensus was considered successful if reaching 80% agreement or higher. The response options for both questions were "Yes" or "No". 20mSRT = 20-m shuttle run test; BMI = body-mass index; HGS = handgrip strength; SLJ = standing long jump.

interpreting the other fitness tests. Sixth, other indices, such as the tri-ponderal mass index (body mass divided by height cubed) or different sex- and age-specific *z*-score measures, can be computed at any time based on collected weight and height data. Nevertheless, if there are no time, resource, or privacy concerns, additional anthropometric measurements will provide valuable information about body composition and fat distribution. In those cases, our recommendation is to follow the ALPHA and IOM evidence-based proposals,[30,31] which include skinfold thicknesses (to estimate body fat percentage) and waist circumference (which also allows for abdominal adiposity and body shape (i.e., waist-to-height ratio) to be estimated).

It is important to note that the systematic reviews that informed the ALPHA project and IOM report were conducted roughly a decade ago. However, more recent systematic reviews also support the same key fitness tests proposed. For the cardiorespiratory fitness component, there is strong evidence suggesting the 20-m shuttle run is the best field-based measure given it is reliable,[48] valid,[49] health-related,[50] health-disciminant,[51] and scalable for use in large-scale surveys.[52] For the muscular fitness component, García-Hermoso and colleagues[2] concluded that the handgrip strength and standing long jump were the most studied tests in relation to health outcomes in children and adolescents, and Fraser and colleagues[53] concluded that handgrip strength and standing long jump were the 2 muscular fitness tests with the highest health-related discriminatory ability. The usefulness of BMI as an internationally agreed metric to define overweight and obesity for surveillance purposes in children and

Table 3
The final protocol descriptions for each of the identified fitness tests after incorporating modifications based on suggestions from the Delphi participants.

Fitness test	Content	Description
Body composition	Demonstration	See the video link (https://www.youtube.com/watch?v=BXhqQZcEaLk).
	Equipment	An electronic scale and a telescopic height-measuring instrument.
	Examiner instructions	(a) Body mass: The child must stand on the platform of the scale without support. The child stands still over the center of the platform, with the body weight evenly distributed between both feet. Light clothing (as culturally accepted) is recommended for this measurement, excluding shoes, heavy long pants and sweaters. (b) Body height: Hair ornaments (e.g., hats) must be removed, braids undone, and ponytails must be positioned at the back, not on top. The child stands on the stadiometer without shoes and with feet placed slightly apart and the back of the head, shoulders, buttocks, calves, and heels touching the vertical board. Legs must be kept straight and the feet flat. The tester must position the child's head so the ear canal and the lower edge of the eye socket are parallel to the base-board (i.e., the Frankfort plane positions horizontally). The headboard must be pulled down to rest firmly on top of the head while flattening hair. The measurement is registered after the child is asked to take a deep breath in. If hair/head ornaments cannot be removed due to cultural reasons, the tester should estimate the height in centimeters (cm) after subtracting the height of the hair/head ornament.
	Scoring	Two measurements of both body weight and body height are performed, and the mean of each is retained. Weight is recorded in kilograms to 0.1 kg, and height is recorded in centimetres to 0.1 cm. *Example:* 58.4 kg and 157.3 cm.
20-m shuttle run test	Demonstration	See the video link (https://www.youtube.com/watch?v=Fg7Suqa46hU).
	Equipment	Select a test site, preferably a 22- to 25-m-long gym. An outdoor court or a grass field is also suitable, provided it has enough space and is even in surface. Allow for a space of at least 1 m at either end of the track. A wide area is recommended to test more children simultaneously, allowing 1 m between each child to improve safety. The running surface should be as flat as possible and not slippery. The 2 ends of the 20-m track should be clearly marked. Additional equipment includes 4 cones to mark the 20-m distance, a tape to measure the 20-m distance, a speaker or device to play the audio cues, and the pre-recorded audio cues. The recommended audio version, ideal for recording half stages, is available here: (see attached Audio file). Note 1: We acknowledge the support of Prof. Luc Léger from the University of Montreal, Canada for donating the original audio file of the 20-m shuttle run test under the framework of the FitBack platform, where the audio file is hosted. Note 2: If the minimum space (i.e., 22 m) required to conduct this test is not available within the school facilities (either indoors or outdoors), consider the possibility of conducting the test in the close surroundings of the school (e.g., a park or sport facility) as long as the safety considerations are maintained (flat and non-slippery surfaces, no cars or objects that can be harmful, *etc*.).
	Examiner instructions	Children are required to run between 2 lines 20-m apart in pace with the audio signals. The initial running speed is 8.5 km/h with the speed increasing by 0.5 km/h at each consecutive min (1 min is equal to 1 stage in the test). The examiner terminates the test when the child fails to reach the line for 2 consecutive times. Otherwise, the test ends when the child stops due to fatigue. Since pacing for this test can be difficult for children, the examiner can allow some flexibility when arriving to the line slightly before or after the audio signal for the first couple laps of a stage.
	Participant instructions	"The shuttle run test gives an indication of your aerobic capacity, i.e., your endurance, and involves running there and back along a 20-m track. Speed will be controlled by an audio track emitting a beeping sound at regular intervals. Pace yourselves to be at one end of the 20-m track or the other when you hear a sound. Touch the line at the end of the track with your foot, then turn and run in the opposite direction. At first, the speed is slow, but it will increase slowly and steadily every minute. Your aim in the test is to follow the set rhythm for as long as you can. You should stop when you can no longer keep up with the set rhythm. Remember the number announced by the recording when you stop, that is your score. The length of the test varies according to the individual: the fitter you are, the longer the test lasts. To sum up, the test is maximal and progressive; in other words, easy at the beginning and hard towards the end. Good Luck!"
	Scoring	After the child has stopped the test, the last completed (i.e., audio announced) half stage is recorded. Only 1 test trial is needed. *Example:* a score of 6.5 stages. If higher precision is required (e.g., intervention studies aiming to detect small changes), the final time spent in the test can be expressed in seconds (s) in addition to the number of shuttles/laps.
Handgrip strength	Demonstration	See the video link (https://www.youtube.com/watch?v=r8wSXq0NWzY&t=11s).
	Equipment	A hand dynamometer with adjustable grip and a printed copy of the Ruler-Table (to adjust grip to hand size) are available in this manuscript as Supplementary Tables 7 and 8, and in the ALPHA Manual of Operations.

(*continued on next page*)

Table 3 (Continued)

Fitness test	Content	Description
	Examiner instructions	Place the top of the dynamometer so it lies across the middle of the palm. Hand size should be measured as the distance separating the distal extremes of the first and 5th fingers of the right hand. The result of the hand size should be rounded to the nearest whole cm. Alternatively, a hand size ruler can be used (see Pages 18−19: https://www.ugr.es/~cts262/ES/documents/ALPHA-FitnessTestManualforChildren-Adolescents.pdf). Using the hand size, adjust the dynamometer grip span. Ask the participant which is their dominant hand to record on the result sheet. The tester can ask the participant which hand is used for throwing if the participant isn't confident in which hand is dominant. The dominant hand should be tested first. During the test, the arm and hand holding the dynamometer should not touch the body. The dynamometer is held in line with the forearm and hangs down at the side with the hand held in a neutral position with the thumb forward. While standing (if possible) the child squeezes gradually and continuously for at least 2 s, performing the test twice (alternating hands) with the optimal grip span (previously calculated, according to the hand size, see Supplementary Tables 7−8) and allowing a short 30-s rest between testing rounds. The indicator must be returned to 0 after each attempt, depending on the dynamometer.
	Participant instructions	"Take the dynamometer with one hand, the dominant hand first. Squeeze it as forcefully as you can while holding the dynamometer away from your body. Don't let it touch you during the test. Squeeze gradually and continuously for at least 2 s. Do the test twice per hand: the best result scores."
	Scoring	Both hands are to be tested twice (dominant and non-dominant, 30-s break, dominant and non-dominant), and the best result (of each hand) is scored. The participants should indicate their dominant hand (the one used for throwing) with that information being recorded (e.g., dominant hand = right or left or ambidextrous). The result is expressed in kg to the closest 0.1 kg. *Example:* a result of 24 kg scores 24.0 kg. It is very important to report the values for the right and left hand separately (indicating the dominant), which will allow in the future any type of analyses (including asymmetry analyses). As a general recommendation and in addition to reporting the value of both hands separately, reporting the average of both hands is informative from a health point of view since it indicates the overall handgrip strength level of the person that is informative of both hands.
Standing long jump	Demonstration	See the video link (https://www.youtube.com/watch?v=jHJ5OMZE_MA).
	Equipment	A non-slippery hard surface, a stick to identify the landing location, a tape to measure the jumping distance, an adhesive tape to identify the start line, and cones to mark off the testing location.
	Examiner instructions	Jumping for distance from a standing start and with both feet at the same time. One horizontal line is drawn or marked using tape to identify the start line. Place a tape measure at a right angle to and off to the side of the start line. The jumping distance is measured from the jump line to the point where the back of the heel nearest to the start line lands on the ground. The child is asked to place their toes behind the start line. While bending their knees and swinging their arms, they are asked to jump as far as possible while balanced on both feet. If the child falls backward or touches the floor with their hands or any body part behind their feet, the attempt needs to be repeated. If the child falls forward but keeps the back foot planted after landing, the test is considered valid.
	Participant instructions	"Stand with your feet shoulder-width apart and toes just behind the line. Bend your knees with your arms in front of you, parallel to the ground. As you swing both arms, push off vigorously and jump as far as possible, taking off and landing with both feet at the same time. Try to land with your feet together and stay upright. If you fall forward after landing, try to keep your back foot planted so that the measurement can be done, otherwise the jump needs to be repeated. If you fall backward after landing, you need to repeat the jump."
	Scoring	Two trials are carried out and the best result is recorded. The result is recorded to the nearest full cm. *Example:* a jump of 1 m 56 cm scores 156 cm.
Recommended sequence for testing and safety considerations (Notes: This section with recommended sequence and safety considerations was not included in the Delphi survey and comes from the original ALPHA manual of operations. The authors consider it worth including together with the protocols information.)		1. Whenever possible, it is better to measure weight and height first before participants start sweating and losing body fluids (i.e., before warming up). 2. A short warm-up (5 min) including jogging in a line while focusing on changing directions and speed. Dynamic stretching exercises are encouraged during the warm-up. Practice some long jumps with both feet at the same time to become familiar with the later testing. 3. Conduct the handgrip strength and standing long jump in random order after the warm-up. 4. Finally, the 20-m shuttle run should be done last since it is a maximal test and children are highly fatigued afterward. 5. During all testing the examiners should use verbal encouragement to motivate participants. Safety considerations. A non-slippery surface is necessary for the standing long jump and the 20-m shuttle run tests. For the 20-m shuttle run test, a minimum of 1 extra m at each side is required (i.e., a total of 22 m is the minimum needed), but if more space is available, a 25-m-length space is better for a safe administration of the 20-m shuttle run test. Avoid fitness testing in very hot environments. Parents/legal guardians and/or children and adolescents should inform the evaluators of any condition that might be considered a contraindication for vigorous exercise. As a general rule, any child who participates without restrictions in physical education classes are able to participate in these fitness tests. If there is any doubt about whether a person can do the physical testing, the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) should be completed by the participant. If the participant answers "Yes" to 1 or more questions, the person needs to check with their doctor before participating in the fitness evaluations. In any case, it is important for the evaluator to be alert to any negative symptoms during testing, such as skin paleness, dizziness, or any other adverse symptoms. The tests should be immediately stopped if there is any sign of problems during the testing.

Abbreviation: ALPHA = Assessing Levels of PHysical Activity.

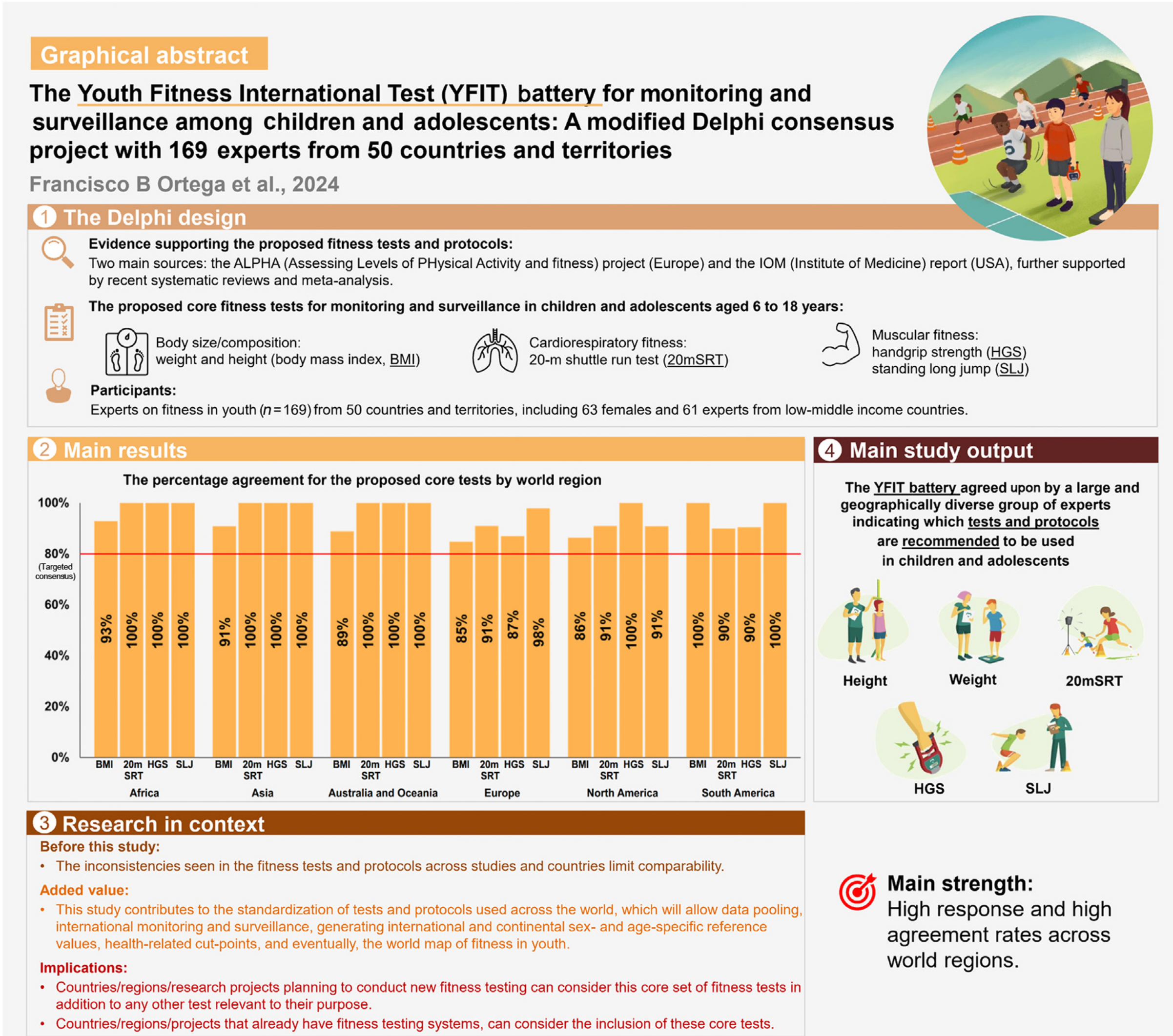

Fig. 3. Illustration summarizing the project and findings.

adolescents and its association with health outcomes is well supported by extensive evidence and has been discussed above. Finally, an additional advantage of the YFIT core fitness tests is that they are not new; historically, they have been considered acceptable for use in many countries. As an example, temporal trends in fitness using the proposed tests have been published in different parts of the world.[54–62] Likewise, data have been pooled using the proposed tests to generate norm-referenced values based on 8-million test results for European children and adolescents aged 6–18 years[63] as well as to develop the FitBack free-access, automated, multilingual web-platform that facilitates interpretation of fitness assessment. Moreover, we previously published international normative values for the 20-m shuttle run test[64] and are currently working to update these norms and develop new international normative values for handgrip strength and standing long jump for those aged 6–18 years. These will be made freely available when complete.

If the proposed fitness tests and protocols are widely adopted, initiatives like FitBack as well as the MOtor-REsearch (MO|RE) data open access database in Europe,[65] can be extended to other world regions, leading to the development of a global fitness observatory.

4.3. Limitations and strengths

A lower proportion of women and researchers from Africa and Asia (and none from Central America) participated in the Delphi survey, which further reflects the under-representation of these groups in research in general[66–68] and in sport/exercise sciences in particular.[69,70] Nevertheless, we specifically targeted these under-represented groups and managed to include >60 women and >60 researchers from low- and middle-income countries with the requisite topical expertise, which represented one-third of all participants. Although we have gathered a large and diverse sample of participants, the results of this and any other Delphi survey reflect the opinions only of those included in the study, and including different participants could potentially have resulted in different outcomes. Likewise, there is also risk of respondent bias, since the participants were not blinded to the identity of the authors leading the study.

No fitness test is perfect, and all come with certain limitations. For example, the 20-m shuttle run, despite being one of the most widely used tests in the world, has the main limitation of requiring physical space, namely a flat and non-slippery surface that is at least 22 m long. If this minimum space is not available within the school facilities (either indoors or outdoors), assessors can consider the possibility of conducting the test in the close surroundings of the school (e.g., a park or sport facility) as long as safety is maintained (flat and non-slippery surfaces, no cars or objects that can be harmful, *etc*.). Likewise, handgrip strength testing has the limitation of needing handgrip dynamometers, which may not be available or affordable in certain cases. However, a recent study has shown that low-cost handgrip dynamometers (USD∼45) are highly valid and reliable and produce similar results as other dynamometers that are 10 times more expensive, such as Jamar or TKK dynamometers.[71,72] If any of the YFIT core tests are not feasible to conduct for any reason, it is better to measure as many of the core tests as possible, as they would still provide valuable health-related fitness information. Finally, it is important to acknowledge that the YFIT battery is meant for the general population and is not adapted for children and adolescents with special needs. However, some fitness monitoring systems, such as those in Hungary and Finland, have already adapted fitness testing; guidance on this is provided on the FitBack platform (https://www.fitbackeurope.eu/Portals/0/Adapted_FitBack_final.pdf?ver=2022-08-10-124500-620) and future research directions have recently been discussed.[73,74] When more evidence is accumulated in the future, similar methods to those presented here might lead to consensus on fitness testing adapted for children and adolescents with special needs.

5. Conclusion

This study provides an evidence-based, gender and geographically diverse, international consensus on the fitness tests and protocols for monitoring and surveillance of children and adolescents worldwide. The YFIT battery resulting from this consensus study includes: weight, height, and BMI as markers of body size (weight status) and composition; 20-m shuttle run as a marker of cardiorespiratory fitness; and handgrip strength and standing long jump as markers of muscular fitness. This core set of tests can be considered evidence-based, valid, reliable, health-related, feasible, safe, and inclusive. This consensus is based on high agreement rates (87%−98%) and is consistent among diverse experts across the world. Importantly, we made specific protocol refinements based on expert feedback. When these tests and protocols are applied consistently worldwide, they will improve standardization and opportunities for international comparison, data pooling, health-related cut-point development, and informed policy changes. Given the strong evidence suggesting fitness as a powerful, non-invasive, and feasible public health marker among children and adolescents, international efforts using the proposed tests and protocols will provide highly valuable information for monitoring and surveillance purposes across the globe.

Authors' contributions

FBO conceived the study, and participated in its design and coordination and wrote the first draft of the manuscript, and designed the Delphi survey; KZ and JJL designed the Delphi survey, created the survey in Microsoft Forms, handled the data, and created the tables/figures; GRT, JRR, KK and CDN participated in the piloting of the Delphi survey. All the authors contributed intellectually to the content of the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2024.101012.

Appendix: The names and affiliations of the Fitness Expert Group that responded to the Delphi survey ($n = 169$)

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