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European fitness landscape for children and adolescents: updated reference values, fitness maps and country rankings based on nearly 8 million test results from 34 countries gathered by the FitBack network

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ABSTRACT

Objectives (1) To develop reference values for health-related fitness in European children and adolescents aged 6–18 years that are the foundation for the web-based, open-access and multilanguage fitness platform (FitBack); (2) to provide comparisons across European countries.

Methods This study builds on a previous large fitness reference study in European youth by (1) widening the age demographic, (2) identifying the most recent and representative country-level data and (3) including national data from existing fitness surveillance and monitoring systems. We used the Assessing Levels of PHysical Activity and fitness at population level (ALPHA) test battery as it comprises tests with the highest test–retest reliability, criterion/construct validity and health-related predictive validity: the 20 m shuttle run (cardiorespiratory fitness); handgrip strength and standing long jump (muscular strength); and body height, body mass, body mass index and waist circumference (anthropometry). Percentile values were obtained using the generalised additive models for location, scale and shape method.

Results A total of 7 966 693 test results from 34 countries (106 datasets) were used to develop sex-specific and age-specific percentile values. In addition, country-level rankings based on mean percentiles are provided for each fitness test, as well as an overall fitness ranking. Finally, an interactive fitness platform, including individual and group reporting and European fitness maps, is provided and freely available online (www.fitbackeurope.eu).

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Fitness testing in youth is important from health, educational and sport points of view.
⇒ The European Union-funded ALPHA project reviewed the existing evidence and proposed a selection of field-based fitness tests that showed the highest test–retest reliability, criterion/construct validity and health-related predictive validity among available tests.

WHAT THIS STUDY ADDS

⇒ The FitBack project provides the most up-to-date and geographically diverse reference fitness values for Europeans 6–18 years of age.
⇒ This study introduces the first web-based, open-access and multilingual fitness reporting platform (FitBack) providing interactive information and visual mapping of the European fitness landscape.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ From a health perspective, very low fitness levels are a non-invasive indicator of poor health at both individual and group levels (eg, school and region), which have utility for health screening and may guide public health policy. There are already examples of regional and national fitness testing systems that are integrated into healthcare systems.
- ⇒ From an educational perspective, fitness testing is part of the school curriculum in many countries, and the FitBack platform offers physical education teachers an easy-to-use tool for interpreting fitness test results by sex and age.
- ⇒ From a sport perspective, these reference values can help identify young individuals who are talented in specific fitness components.

Conclusion This study discusses the major implications of fitness assessment in youth from health, educational and sport perspectives, and how the FitBack reference values and interactive web-based platform contribute to it. Fitness testing can be conducted in school and/or sport settings, and the interpreted results be integrated in the healthcare systems across Europe.

INTRODUCTION

Robust and consistent evidence supports that physical fitness is a powerful marker of health in children and adolescents.[1 2] Among the different fitness components, cardiorespiratory fitness (CRF, used in the literature and this article interchangeably with aerobic fitness) and muscular strength (used in the literature and this article interchangeably with muscular fitness) have shown the strongest and most consistent health-related associations and are therefore considered to be the main health-related fitness components.[3 4] Other fitness components include flexibility, motor fitness and body composition/anthropometry (height, body mass, body mass index (BMI) and waist circumference). Recently, data from large registries have added compelling evidence linking both CRF and muscular strength in late adolescence with all-cause mortality and cardiovascular-specific and cancer-specific mortality in later life.[5–8] In addition, these two fitness components predict severe, chronic and irreversible all-cause disease 30 years later as indicated by granted disability pensions,[9–12] and also specifically cardiovascular, musculoskeletal, neurological and psychiatric diseases granted by a disability pension.[9–12] Particularly, CRF is the most well-studied and strongest predictor of future health.[2] Indeed, a position stand from the American Heart Association has highlighted the clinical value of CRF in youth and recommended that it be regularly assessed.[13] In addition to the well-documented associations between fitness and physical/mental health among youth,[1–4 14] emerging evidence supports that better fitness is related to better cognition, academic performance, and healthier structural and functional brain outcomes.[15–29] For example, recent observations from the ActiveBrains project have shown that total brain size, as well as total grey and white matter volumes, is larger in fit compared with unfit children with overweight/obesity.[30] This is important because total brain size is positively associated with intelligence.[31] These findings are in line with those from Chaddock and colleagues, who included children also with normal weight, and found that fitter kids had larger grey matter volumes in subcortical brain regions such as hippocampus[17] and dorsal stratium.[19]

The evidence hereby presented about fitness as a powerful marker of health in youth supports the relevance of fitness assessment at the individual and population levels. However, the availability of different fitness batteries/tests leads to a lack of consistency and comparability across studies. To address this problem, the European Commission funded the ALPHA project. By conducting a set of systematic reviews[2 32 33] and methodological papers, the ALPHA consortium aimed to identify the field-based fitness tests that demonstrated the highest test–retest reliability, criterion/construct validity and health-related predictive validity (see ALPHA summary article[34]). Anthropometry and body composition are known to be tightly linked to fitness performance and health and were therefore considered as fitness components in the ALPHA project. The final output of the project was the ALPHA-fitness test battery for children and adolescents, which in its high-priority version (a shorter, more suitable version for school-based use) recommended using: the 20 m shuttle run test for assessing CRF; the handgrip and standing long jump tests for assessing muscular strength and power; and BMI and waist circumference as indicators of total and central obesity, respectively. A year later and after following a similar systematic review process, the US Institute of Medicine (now the National Academy of Medicine) recommended these same tests for the assessment of youth physical fitness,[35 36] strengthening the recommendation of using the ALPHA fitness test battery.

As the next step to the ALPHA project, the European Commission funded the FitBack consortium (www.fitbackeurope.eu), representing the European Network for the Support of Development of Systems for Monitoring Physical Fitness of Children and Adolescents. The major goal of the network is to take an important step toward the implementation of fitness surveillance and monitoring across Europe as an educational tool for physical literacy.[37] The final output of the FitBack project has been the development of a web-based, open-access and multilanguage fitness platform which allows the results of fitness testing to be automatically and interactively interpreted based on sex-specific and age-specific reference values and is supported by user-friendly visual feedback and tips for improvement. For this purpose, we gathered available fitness data on European children and adolescents. Previous fitness reference values published were mostly from individual countries (see references in online supplemental table 1) or multicentre EU projects (eg, IDEFICS - Identification and prevention of Dietary- and lifestyle-induced health EFfects in Children and infantS - and HELENA - Healthy Lifestyle in Europe by Nutrition in Adolescence - projects[38 39]) collecting data in one to two cities per country. The study by Tomkinson and colleagues provided the first European reference values that included numerous countries and covered a wide age demographic (subjects 9–17 years old).[40] However, until now, European reference values have not covered all school-age children (primary, secondary and high school) from age 6 years to 18 years. Also, the writing group was aware of nationally representative fitness monitoring systems and large datasets not included in Tomkinson's study, indicating the need to update existing reference values. There was also a pressing need to develop an automated, freely accessible web platform containing these normative values to facilitate the interpretation of sex-specific and age-specific fitness test results.

The aim of this article is to develop health-related fitness reference values for European children and adolescents aged 6–18 years. Additionally, we provide European fitness maps and country ranking for the main health-related fitness components, all together as part the new, free-access, FitBack web platform (www.fitbackeurope.eu). Since paediatric obesity is being comprehensively monitored by other organisations (eg, World Obesity Federation, www.worldobesity.org/; WHO-Europe www.euro.who.int/en/health-topics/disease-prevention/nutrition/activities/who-european-childhood-obesity-surveillance-initiative-cosi), the focus of this article is mainly on CRF and muscular strength. Nonetheless, we also provide reference values and European maps for anthropometric measures (body height, body mass, BMI and waist circumference) as online supplemental material.

METHODS

Data search and pooling

A systematic review of existing datasets including fitness tests in children and adolescents was previously performed by Tomkinson *et al* and details of the search have been published.[40] These data were included in the FitBack dataset, with Monte Carlo simulation used to produce pseudo data (from reported means and SDs) when raw data were unavailable. In addition to this, the authors of the FitBack network conducted a centralised narrative search based on fitness terms to identify new datasets not included in the Tomkinson *et al* review.[40] For inclusion, valid data on sex, age and at least one of the ALPHA fitness tests (high-priority version) was required. In the previous study by Tomkinson *et al*, the age range was 9–17 year old, whereas in this study, we widened the age demographic to include subjects aged 6–18 years old. It is important to note that our search strategy was focused on fitness, and specific searches on adiposity, BMI or waist circumference were not conducted for pragmatic reasons (eg, the very large number of studies including these key words). Therefore, it is possible that we missed relevant anthropometry-specific datasets. This, together with the fact that other organisations are comprehensively monitoring paediatric obesity, is the reason why we primarily focused on CRF and muscular strength, and reported results for anthropometric measures (body height, body mass, BMI and waist circumference) as online supplemental material.

The FitBack network involved numerous experienced researchers working in paediatric fitness across Europe, which helped to identify unpublished fitness datasets that were pooled with gathered data. Moreover, large datasets from existing surveillance systems in Europe such as SLOfit,[41] NETFIT[42] and Fitescola[43] were also included. Further, we excluded older datasets if a more recent and more representative dataset was available for certain countries. The ambition was to use the most recent available data for each country, which in some cases was a single large dataset, while in others was the accumulation of several studies or datasets covering different geographical regions within a country. Sources used for generating the reference values are available on the FitBack website (www.fitbackeurope.eu/en-us/fitness-map/sources) as well as in online supplemental table 1.

Physical fitness measures

The FitBack dataset was compiled for studies that used the ALPHA fitness test battery[2 32–34] since these tests have shown to be feasible, reliable, valid, and scalable for children and adolescents. Moreover, some of them are used in well-established European national fitness surveillance and monitoring systems like SLOfit,[41] NETFIT[42] and Fitescola.[43] Specifically, CRF was assessed using the 20 m shuttle run test.[44] The number of completed stages was used as an indicator of CRF. However, different studies had expressed the result of the 20 m shuttle run test in other units, such as completed laps (shuttles) or speed at the last completed stage, and there are at least three known protocols/versions of this test.[45] All data were converted and harmonised into completed stages according to the original Léger protocol,[44] as described elsewhere.[45] Muscular strength was assessed by the handgrip strength (ie, upper-limb muscular strength) and standing long jump tests (ie, lower-limb muscular strength). Total and abdominal adiposities were assessed by BMI and waist circumference, respectively, following standardised procedures. For handgrip, most studies collected data from both hands, with the average of the best performance from both hands used in our analyses. Two studies had handgrip strength data only for the dominant hand, which is known to be systematically higher compared with the non-dominant hand. Exploratory analyses on Spanish data in children[46] showed a 0.6 kg mean difference between hands, and thus, we applied a –0.3 kg correction factor to these two studies to estimate the average score.

Statistical analysis

We applied different cleansing procedures to the data. First, data were trimmed to remove values outside the probable lower and upper limits. The limits were defined based on authors' experiences working with previous large datasets. The limits used were 20 m shuttle run (0–21 stages), handgrip strength (0–80 kg), standing long jump (15–330 cm), body height (80–220 cm), body mass (0–200 kg), BMI (7–60 kg/m^2) and waist circumference (40–130 cm). Second, outliers were identified and removed as follows. For each fitness measure, herein referred to as the *test*, a multivariate regression model including the test as the dependent variable and age (modelled as a cubic spline with 5 degrees of freedom (df)), sex and their interaction as independent variables was fitted. Studentised residuals were obtained, and then 0.01% of the subjects with the smallest and largest studentised residuals were removed from further analysis. Weights were computed via iterative poststratification (aka iterative proportional fitting)[47] to match the sample joint distributions by age, sex and country to population data. Country-specific population values were obtained from EUROSTAT. The sample weights were trimmed to avoid excessively large sampling variances.[47]

Percentile curves and reference values were developed using generalised additive models for location, scale and shape (GAMLSS).[48] Several continuous (Box-Cox Cole and Green (BCCG), Box-Cox power exponential (BCPE), Box-Cox-*t* (BCT), generalised inverse Gaussian) distributions were fitted to the data, optimising the df for P-splines fit for all parameters of the respective distributions using Schwarz Bayesian criterion (SBC); appropriate link functions were used for the parameters. BCCG is routinely used in the lambda mu sigma (LMS) method.[49] BCPE and BCT are extensions of LMS adding an extra parameter, ν, to allow modelling (positive or negative) kurtosis (with $\nu = 2$ BCPE and BCCG (LMS) coincide). In all the models, $\lambda = 1/3$ and $\lambda = 1/2$ were used for the power transformation of age. Separate analyses were performed for boys and girls. The final model for each test and sex was determined by using SBC. The analysis was performed using R language for statistical computing (R V.3.6.3)[50]; GAMLSS were fitted using R package GAMLSS[51]; poststratification weights were obtained using R package survey.[51] The best fitting model for each test is presented in online supplemental table 2.

Table 1 Reference values (percentiles) for cardiorespiratory fitness as assessed by the 20 m shuttle run test (expressed in completed stages as a decimal) in European children and adolescents (N=1 026 077)

	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
Girls' ages (years)													
6.0–6.9	0.6	0.8	0.9	1.1	1.4	1.6	1.8	2.1	2.4	2.8	3.4	4.1	5.5
7.0–7.9	0.6	0.8	1.0	1.3	1.5	1.8	2.1	2.4	2.7	3.2	3.9	4.6	6.1
8.0–8.9	0.5	0.9	1.1	1.5	1.8	2.1	2.4	2.8	3.2	3.7	4.5	5.3	6.9
9.0–9.9	0.5	1.0	1.3	1.7	2.1	2.5	2.9	3.3	3.7	4.4	5.3	6.1	7.9
10.0–10.9	0.5	1.1	1.4	2.0	2.4	2.8	3.3	3.7	4.3	4.9	5.9	6.9	8.7
11.0–11.9	0.6	1.2	1.6	2.2	2.7	3.1	3.6	4.1	4.6	5.3	6.4	7.3	9.2
12.0–12.9	0.7	1.4	1.8	2.4	2.9	3.4	3.8	4.3	4.9	5.6	6.6	7.5	9.3
13.0–13.9	0.8	1.4	1.9	2.5	3.0	3.4	3.9	4.4	4.9	5.6	6.6	7.5	9.3
14.0–14.9	0.8	1.5	1.9	2.5	3.0	3.5	3.9	4.4	5.0	5.6	6.6	7.5	9.3
15.0–15.9	0.8	1.5	1.9	2.5	3.0	3.5	3.9	4.4	5.0	5.6	6.6	7.5	9.3
16.0–16.9	0.7	1.4	1.9	2.5	3.0	3.5	3.9	4.4	4.9	5.6	6.6	7.4	9.2
17.0–17.9	0.7	1.4	1.9	2.5	3.0	3.4	3.8	4.3	4.8	5.5	6.4	7.3	9.0
18.0–18.9	0.7	1.4	1.8	2.4	2.9	3.3	3.8	4.2	4.7	5.4	6.3	7.1	8.8
Boys' ages (years)													
6.0–6.9	0.6	0.8	0.9	1.2	1.4	1.7	2.0	2.4	2.9	3.4	4.2	5.0	6.4
7.0–7.9	0.6	0.9	1.1	1.4	1.7	2.1	2.5	2.9	3.4	4.0	4.9	5.7	7.2
8.0–8.9	0.6	1.0	1.2	1.7	2.1	2.5	3.0	3.5	4.1	4.8	5.8	6.7	8.2
9.0–9.9	0.6	1.1	1.5	2.0	2.6	3.1	3.6	4.2	4.9	5.7	6.8	7.7	9.4
10.0–10.9	0.6	1.3	1.7	2.4	3.0	3.6	4.2	4.8	5.5	6.4	7.5	8.5	10.2
11.0–11.9	0.7	1.4	2.0	2.7	3.4	4.0	4.6	5.3	6.0	6.8	8.0	9.0	10.7
12.0–12.9	0.8	1.6	2.2	3.1	3.8	4.4	5.0	5.7	6.4	7.3	8.5	9.4	11.1
13.0–13.9	0.9	1.9	2.6	3.5	4.2	4.9	5.5	6.2	7.0	7.8	9.0	9.9	11.7
14.0–14.9	1.0	2.2	2.9	3.9	4.7	5.4	6.1	6.8	7.5	8.4	9.6	10.5	12.3
15.0–15.9	1.1	2.4	3.2	4.3	5.1	5.8	6.5	7.2	7.9	8.8	10.0	11.0	12.8
16.0–16.9	1.1	2.5	3.4	4.4	5.2	6.0	6.7	7.3	8.1	8.9	10.1	11.1	12.8
17.0–17.9	1.1	2.5	3.4	4.5	5.3	6.0	6.6	7.3	8.0	8.8	10.0	10.9	12.6
18.0–18.9	1.0	2.5	3.3	4.4	5.2	5.9	6.5	7.2	7.8	8.6	9.7	10.6	12.2

Smoothed percentiles were calculated using the generalised additive model for location, scale and shape method, and weights were applied according to country population. Age at the midpoint of each interval was selected to provide percentiles. For instance, for the interval 6.0–6.9, data presented were those corresponding to an exact age of a 6.5-year-old child. P10 indicates 10th percentile; other percentiles are abbreviated accordingly. Data sources are available online (www.fitbackeurope.eu/en-us/fitness-map/source) and in online supplemental table 1.

RESULTS

After cleaning and removing outliers, 7 966 693 test results were available, including 1 026 077 for the 20 m shuttle run; 787 966 for handgrip strength, 1 345 159 for standing long jump, 1 466 821 for body height, 1 466 295 for body mass, 1 464 795 for BMI, and 409 580 for waist circumference. These data came from 106 datasets belonging to 34 European countries, on children and adolescents aged 6 to 18 years. We originally aimed to collect data as recent as possible to obtain up-to-date reference values, preferably since 2000. Most (69%) datasets (representing 95% of all test results) were collected post-2000; however, pre-2000 data were included when post-2000 were unavailable at the country level. Using these data, we developed CRF and muscular strength reference values (tables 1–3) and corresponding percentile curves (figure 1). Reference values for body height, body mass, BMI and waist circumference are presented in online supplemental tables 3-6 and online supplemental figures 1 and 2. Percentile curves for CRF and muscular strength are higher for boys compared with girls across all ages, with differences increasing with age. The age-related increase in fitness performance tends to stabilise from age 14 years to 15 years onwards. Variation between the fittest (eg, percentiles 90–99) and least fit (eg, percentiles 1–10) is larger for boys compared with girls, particularly for the 20 m shuttle run and handgrip strength tests.

Mean country-level percentiles and rankings are shown in table 4. Country-level rankings based on mean percentiles are provided for each fitness test, as well as an average estimate for each fitness component (CRF, muscular strength) and the overall European fitness ranking. The top 5 most aerobically fit countries were Iceland, Norway, Slovenia, Denmark and Finland, and the top 5 physically strong countries were Denmark, Czech Republic, The Netherlands (only one muscular strength test available), Slovenia and Finland. Online supplemental tables 7 and 8 show the corresponding country-level mean percentile and ranking positions for body height, body mass, BMI and waist circumference.

Country comparisons according to mean percentiles are also graphically represented in figure 2, with European fitness maps for each test shown separately. The traffic light colour code was used to represent country-specific percentile ranks, with red indicating lower fitness levels, yellow indicating intermediate fitness levels and green indicating higher fitness levels. The corresponding European maps for BMI and waist circumference are presented as online supplemental figure 3. These maps are available in an interactive mode at the FitBack web platform (www.fitbackeurope.eu/en-us/fitness-map) for boys and girls, together and separately. Visual inspection of the fitness maps shows that Southern European countries and the UK generally performed the worst. The correlation between country-level CRF and muscular strength

Table 2 Reference values (percentiles) for muscular strength as assessed by the handgrip strength test (expressed in kg, average of the maxima for both hands) in European children and adolescents (N=787 966)

	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
Girls' ages (years)													
6.0–6.9	4.2	5.6	6.3	7.2	7.8	8.3	8.8	9.3	9.9	10.7	11.8	12.9	15.5
7.0–7.9	4.7	6.4	7.3	8.4	9.1	9.7	10.4	11.0	11.7	12.6	13.9	15.3	18.4
8.0–8.9	5.2	7.4	8.5	9.8	10.7	11.4	12.2	13.0	13.8	14.9	16.6	18.1	21.9
9.0–9.9	5.8	8.4	9.7	11.3	12.3	13.3	14.1	15.1	16.1	17.3	19.3	21.1	25.6
10.0–10.9	6.7	9.7	11.3	13.0	14.3	15.3	16.3	17.4	18.5	20.0	22.2	24.3	29.3
11.0–11.9	8.0	11.6	13.3	15.3	16.8	18.0	19.1	20.3	21.6	23.2	25.7	28.1	33.7
12.0–12.9	9.5	13.6	15.5	17.8	19.3	20.7	21.9	23.2	24.6	26.4	29.1	31.6	37.8
13.0–13.9	11.1	15.5	17.7	20.0	21.7	23.1	24.5	25.8	27.3	29.2	32.0	34.7	41.1
14.0–14.9	12.4	17.1	19.3	21.8	23.5	25.0	26.4	27.8	29.3	31.2	34.1	36.9	43.4
15.0–15.9	13.1	18.0	20.2	22.8	24.6	26.0	27.4	28.8	30.4	32.3	35.2	38.0	44.6
16.0–16.9	13.4	18.4	20.8	23.4	25.1	26.6	28.0	29.4	31.0	32.9	35.8	38.6	45.2
17.0–17.9	13.7	18.9	21.3	23.9	25.7	27.2	28.6	30.0	31.5	33.4	36.3	39.1	45.7
18.0–18.9	14.3	19.6	22.0	24.6	26.4	27.9	29.2	30.6	32.2	34.1	37.0	39.7	46.3
Boys' Ages (years)													
6.0–6.9	4.8	6.4	7.1	8.0	8.7	9.2	9.8	10.3	11.0	11.7	13.0	14.1	17.1
7.0–7.9	5.5	7.3	8.3	9.4	10.2	10.9	11.5	12.2	13.0	13.9	15.4	16.8	20.3
8.0–8.9	6.2	8.5	9.6	10.9	11.9	12.7	13.5	14.3	15.3	16.4	18.2	19.9	24.0
9.0–9.9	7.0	9.5	10.8	12.4	13.5	14.5	15.4	16.4	17.5	18.8	20.9	22.8	27.4
10.0–10.9	7.8	10.7	12.1	13.9	15.2	16.3	17.4	18.5	19.7	21.3	23.6	25.8	30.9
11.0–11.9	8.9	12.2	13.9	15.9	17.4	18.7	20.0	21.2	22.7	24.4	27.1	29.6	35.3
12.0–12.9	10.2	14.1	16.1	18.5	20.3	21.8	23.3	24.8	26.5	28.5	31.7	34.6	41.1
13.0–13.9	12.2	16.9	19.3	22.2	24.4	26.2	28.0	29.8	31.8	34.3	38.0	41.4	49.0
14.0–14.9	14.9	20.3	23.2	26.7	29.2	31.4	33.5	35.6	37.9	40.8	45.1	49.0	57.4
15.0–15.9	17.7	23.8	27.0	30.9	33.6	36.0	38.3	40.6	43.2	46.3	50.9	55.0	63.7
16.0–16.9	20.2	26.7	30.1	34.1	37.0	39.5	41.9	44.3	46.9	50.1	54.8	58.9	67.6
17.0–17.9	22.4	29.1	32.6	36.7	39.7	42.2	44.6	47.0	49.7	52.9	57.5	61.6	70.0
18.0–18.9	24.4	31.2	34.8	39.0	42.0	44.5	46.9	49.4	52.0	55.2	59.7	63.7	71.9

Smoothed percentiles were calculated using the generalised additive model for location, scale and shape method, and weights were applied according to country population. Age at the midpoint of each interval was selected to provide percentiles. For instance, for the interval 6.0–6.9, data presented were those corresponding to an exact age of a 6.5-year-old child. P10 indicates 10th percentile; other percentiles are abbreviated accordingly. Data sources are available online (www.fitbackeurope.eu/en-us/fitness-map/sources) and in online supplemental table 1.

rankings was moderate (r=0.59) and is graphically represented in figure 3. Shaded areas represent those countries ranked in the top 10 for CRF, muscular strength or both.

DISCUSSION

Main findings in the context of previous literature

This article provides the most up-to-date and comprehensive reference values for the health-related fitness of European children and adolescents aged 6–18 years. We also provided country-level mean percentiles for each fitness component. Our overall country-level fitness rankings suggest that Northern (Denmark, Finland, Iceland and Norway) and Central Eastern European countries (Slovenia, Czech Republic and Slovakia) have the fittest children and adolescents, while Southern European countries (Spain, Italy and Greece) and the UK are comparatively less fit. Interestingly, we observed a moderate positive correlation between country-level CRF and muscular strength, indicating that despite being different fitness components, countries having higher CRF levels generally also had higher muscular strength levels. A major contribution of the present study is that it comes together with the FitBack interactive web platform (www.fitbackeurope.eu), which is free, multilingual (English, Spanish, French, German and Italian) and ready to be used by researchers and practitioners in physical education, sport and health, as well as by policy makers across Europe. FitBack can be useful and informative even for other continents temporally until they develop their own normative values and similar web platforms. The FitBack platform provides individual and group-based fitness reports supported by educational materials for implementation of fitness monitoring to support fitness education (ie, to help understand why fitness and fitness testing are important, how to interpret fitness test results, how to set exercise goals, how to improve fitness levels, etc) and improve physical literacy, as well as interactive European fitness maps based on our reference values.

To date, the largest and best available fitness reference values for European children and adolescents were those published by Tomkinson *et al* in 2018.[40] Our study updates such work by adding new data and expanding the age range from 9 years to 17 years to 6–18 years.[40] It is challenging to directly compare the previous and current reference values, given between-study differences in included studies, countries, ages and sexes. Nevertheless, as an example, the 50th percentile values for the 20 m shuttle run ranged from 3.4 to 4.1 stages in girls aged 9–17 years and from 4.4 to 7.7 stages in boys aged 9–17 years in Tomkinson's study, with the corresponding FitBack values ranging from 2.9 to 3.8 in girls and from 3.6 to 6.6 in boys. For handgrip, the corresponding values were 13.6–28.4 kg in girls and 15.3–45.0 kg in boys in Tomkinson's study and 14.1–28.6 kg in girls

Table 3 Reference values (percentiles) for muscular strength as assessed by the standing long jump test (expressed in cm) in European children and adolescents (N=1 345 159)

	P1	P5	P10	P20	P30	P40	P50	P60	P70	P80	P90	P95	P99
Girls' ages (years)													
6.0–6.9	47.4	63.3	71.1	80.2	86.5	91.9	96.8	101.6	106.9	113.0	121.5	128.8	143.0
7.0–7.9	55.1	71.1	79.0	88.3	94.8	100.3	105.5	110.6	116.0	122.5	131.6	139.3	154.6
8.0–8.9	63.1	79.1	87.2	96.7	103.4	109.0	114.3	119.5	125.2	131.9	141.4	149.6	165.8
9.0–9.9	70.8	87.0	95.1	104.8	111.6	117.3	122.7	128.1	134.0	140.9	150.8	159.2	176.3
10.0–10.9	77.2	93.8	102.3	112.2	119.2	125.2	130.8	136.4	142.5	149.7	160.0	168.9	186.8
11.0–11.9	82.9	100.6	109.6	120.1	127.6	133.9	139.9	145.8	152.3	159.9	170.9	180.4	199.6
12.0–12.9	87.3	106.2	115.7	126.9	134.8	141.6	147.8	154.1	161.0	169.1	180.7	190.7	211.1
13.0–13.9	90.2	110.1	120.1	131.9	140.2	147.2	153.7	160.3	167.4	175.8	187.9	198.3	219.4
14.0–14.9	91.1	112.0	122.3	134.4	142.9	150.1	156.8	163.5	170.8	179.4	191.6	202.2	223.5
15.0–15.9	90.7	112.0	122.5	134.8	143.3	150.5	157.2	163.9	171.2	179.7	191.8	202.3	223.4
16.0–16.9	89.7	111.4	121.9	134.2	142.7	149.8	156.5	163.1	170.2	178.6	190.5	200.7	221.3
17.0–17.9	89.9	111.8	122.4	134.7	143.1	150.3	156.8	163.3	170.3	178.6	190.3	200.3	220.3
18.0–18.9	91.1	113.3	124.0	136.2	144.6	151.6	158.1	164.6	171.5	179.6	191.0	200.8	220.3
Boys' ages (years)													
6.0–6.9	51.6	69.3	77.8	87.4	94.1	99.6	104.6	109.6	114.9	121.1	129.7	137.0	151.2
7.0–7.9	60.0	78.2	87.0	96.9	103.8	109.5	114.7	119.9	125.5	131.9	141.1	148.8	164.0
8.0–8.9	68.2	86.9	95.9	106.1	113.2	119.1	124.6	130.0	135.7	142.5	152.1	160.2	176.5
9.0–9.9	75.5	94.7	103.9	114.4	121.7	127.8	133.4	139.0	145.0	152.0	162.0	170.5	187.6
10.0–10.9	81.2	101.1	110.7	121.5	129.1	135.3	141.1	146.9	153.1	160.4	170.7	179.6	197.5
11.0–11.9	86.4	107.5	117.6	129.0	136.9	143.5	149.5	155.6	162.0	169.7	180.5	189.8	208.8
12.0–12.9	92.2	115.1	125.9	138.1	146.4	153.4	159.8	166.2	173.0	181.1	192.5	202.4	222.5
13.0–13.9	99.8	125.0	136.8	150.0	159.0	166.5	173.3	180.1	187.4	196.0	208.2	218.7	240.1
14.0–14.9	107.8	135.4	148.0	162.1	171.7	179.6	186.9	194.0	201.7	210.7	223.4	234.4	256.8
15.0–15.9	114.3	143.6	156.9	171.5	181.4	189.6	197.0	204.4	212.2	221.4	234.4	245.5	268.3
16.0–16.9	118.6	149.1	162.8	177.7	187.7	195.9	203.4	210.8	218.6	227.8	240.7	251.8	274.4
17.0–17.9	122.1	153.4	167.2	182.2	192.2	200.4	207.8	215.1	222.8	231.8	244.5	255.4	277.6
18.0–18.9	125.4	157.1	170.9	185.8	195.6	203.7	210.9	218.0	225.6	234.4	246.8	257.4	279.0

Smoothed percentiles were calculated using the generalised additive model for location, scale and shape method and weights were applied according to country population. Age at the midpoint of each interval was selected to provide percentiles. For instance, for the interval 6.0–6.9, data presented were those corresponding to an exact age of a 6.5-year-old child. P10 indicates 10th percentile; other percentiles are abbreviated accordingly. Data sources are available online (www.fitbackeurope.eu/en-us/fitness-map/sources) and in online supplemental table 1.

and 15.4–44.6 kg in boys in FitBack. Further, the corresponding values for the standing long jump test were 123.9–156.4 cm in girls and 133.8–205.8 cm in boys Tomkinson's study, and 122.7–156.8 cm in girls and 133.4–207.8 cm in boys in FitBack. Thus, the median fitness levels in the FitBack study are slightly lower than those in Tomkinson's study for the 20 m shuttle run, and nearly identical for handgrip strength and the standing long jump. These between-study differences are likely because the included datasets differ in sample size, collection time frames, country representation and sample representativeness. Tomkinson's reference values for the 20 m shuttle run were based on 445 092 data points from 24 countries (see table 9 of Tomkinson *et al* study[40]), whereas the FitBack reference values were based on 1 026 077 data points from 30 European countries. The corresponding sample sizes for handgrip strength and standing long jump are n=203 295 vs 787 966 and n=464 900 vs 1 345 159 for Tomkinson *et al*'s study versus FitBack, respectively.

Usefulness and practical implications of fitness testing and monitoring

Our reference values, when integrated into the interactive FitBack web platform, have practical utility and implications. First, fitness testing and monitoring is extremely important from a public health and clinical point of view, as recently acknowledged by the American Heart Association[13] and others.[52] Measuring cardiometabolic risk factors from blood samples is invasive and ethically questionable for youth at the population level. Likewise, mental and cognitive health assessments are often complex, sensitive and time consuming. Since physical fitness has repeatedly and consistently been shown to be a powerful marker of physical, mental and cognitive health in youth, fitness testing and monitoring will provide valuable insights into the health status of youth at individual and group levels. However, clinicians may not have the time, resources, facilities or expertise to conduct fitness testing (eg, the 20 m shuttle run test) in clinical settings. Therefore, we believe that the most feasible alternative and future goal is that population-level fitness testing be conducted in schools, with test results and interpretation incorporated into the healthcare system databases and forming part of an individual's medical records that can be viewed by paediatricians and school doctors/nurses. This might be even more relevant in low-to- middle-income countries. Such practice has been implemented at the regional level in Galicia, Spain,[53] and at the national level in Slovenia[40] and Finland.[54] In addition, our article and the interactive FitBack website provide a valuable and cost-effective solution for establishing fitness monitoring at the school, community, regional and national levels. For instance, policy makers at education, sport and health institutions can obtain valuable information about regional differences or temporal trends by monitoring

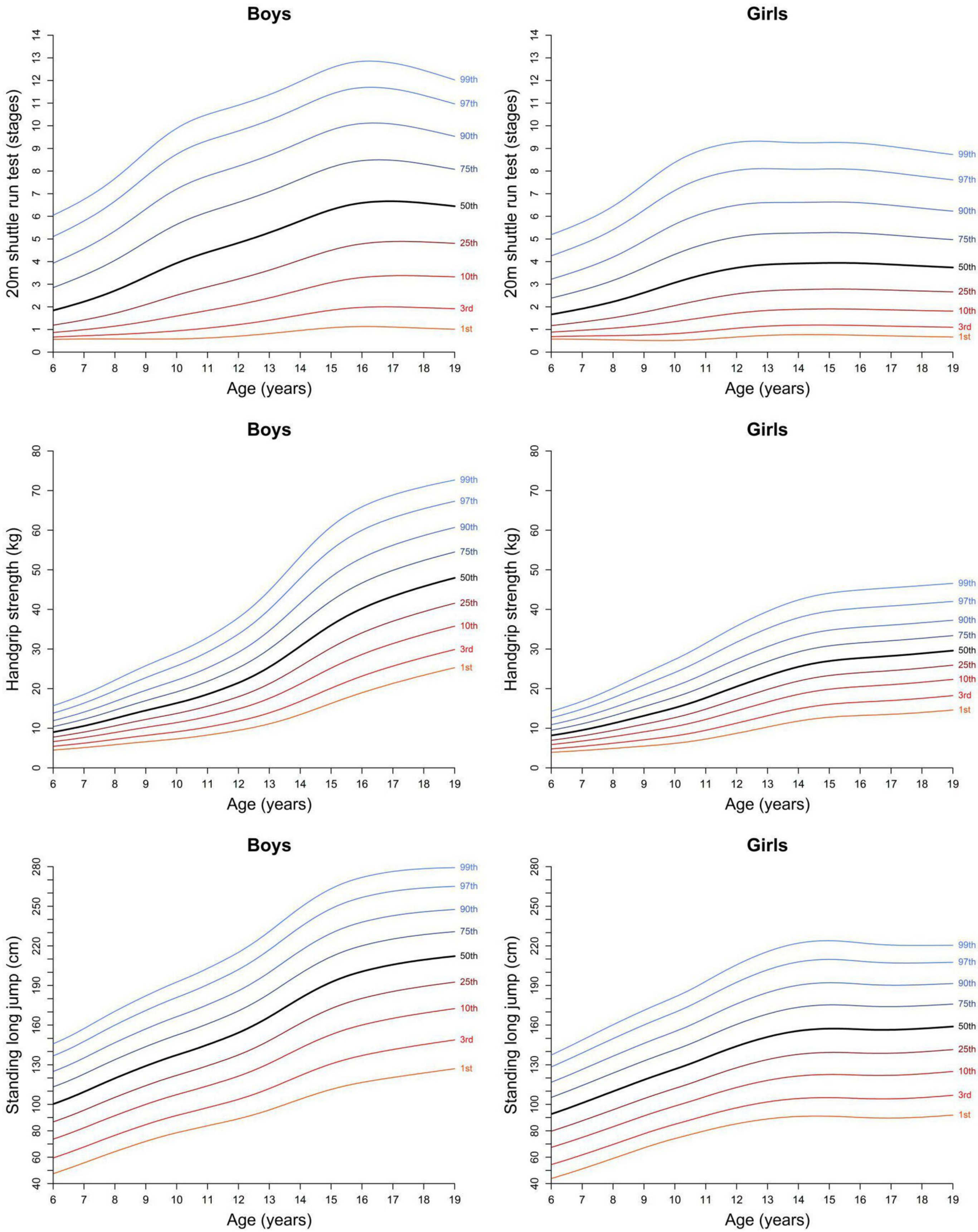

Figure 1 Percentile curves for cardiorespiratory and muscular strength tests among European children and adolescents. Smoothed percentiles were calculated using the generalised additive model for location, scale and shape method, and weights were applied according to country population. Data sources are available online (https://www.fitbackeurope.eu/en-us/fitness-map/sources) and in online supplemental table 1.

Table 4 Mean percentile and ranking position of each country according to the pooled EU reference values

		20 m shuttle run test							Handgrip strength								Standing long jump											
		Both		Girls		Boys				Both		Girls		Boys				Both		Girls		Boys						
	N	Centile	Rank	Centile	Rank	Centile	Rank		N	Centile	Rank	Centile	Rank	Centile	Rank		N	Centile	Rank	Centile	Rank	Centile	Rank		Average rank MS	Avg.rank CRF	Avg.rank MS&CRF	Overall fitness ranking
ISL	6127	81.3	1	85.2	1	77.7	1	SLO	4648	75.4	1	74.8	1	75.8	1	ISL	6589	72.4	1	74.7	1	70.2	1	DEN	2	4	3	1
NOR	2302	75.3	2	76.5	2	74.2	2	DEN	5938	64.7	2	64.2	3	65.2	2	CZE	439	69.1	2	72	2	66.2	3	NET	3	–	3	1
SVN	4752	73	3	75.9	3	70.2	4	NET	1713	64.6	3	68.3	2	60.8	6	BUL	497	68	3	67.1	5	68.9	2	FIN	5	5	5	2
DEN	9178	68.9	4	67.7	5	70.8	3	BEL	18 012	61.2	4	60.6	4	61.9	4	SVN	211 629	66.5	4	68.4	4	64.7	5	SVN	7	3	5	2
FIN	2077	66.5	5	68.8	4	63.8	5	LIT	3188	60.1	5	56.4	6	64.4	3	FIN	1393	66	5	67.1	6	64.9	4	CZE	2	9	5.5	3
FRA	11 627	61.4	6	61	8	61.9	7	KOS	742	57.6	6	52.9	10	61.7	5	CRO	22 135	65.9	6	70.1	3	60.7	8	ISL	10	1	5.5	3
CYP	1058	61	7	63.7	6	58.6	10	GER	1399	55.9	7	59.9	5	52	11	SLO	5163	65.2	7	66.3	7	64.4	6	SLO	4	8	6	4
SLO	4709	60.8	8	59.1	11	62.1	6	POL	47 061	55.8	8	53.2	9	58.2	7	SWI	2982	64.4	8	64.6	8	64.2	7	NOR	11	2	6.5	5
CZE	1561	60.7	9	63.2	7	58.4	11	HUN	614 569	54.4	9	55.2	7	53.7	9	EST	4997	61.5	9	62.8	9	60.2	9	BUL	7	–	7	6
GER	1968	59.3	10	60.5	9	58.2	13	SVN	4828	54.1	10	54.3	8	54	8	LIT	12 158	58.6	10	58.5	11	58.7	10	BEL	8.5	12	10.3	7
IRE	1055	59	11	59.8	10	58.2	12	BUL	497	51.5	11	49.3	13	53.6	10	NOR	2490	58.5	11	61.2	10	55.9	11	SWI	8	13	10.5	8
BEL	19 623	57.8	12	54.8	14	60.5	8	EST	1681	51.4	12	52.5	11	50.3	14	AUS	595	56.2	12	57.5	12	54.8	12	GER	11.5	10	10.8	9
SWI	3699	56.7	13	54.7	15	58.7	9	AUS	389	50.6	13	49.6	12	51.6	12	BEL	19 161	55.5	13	56.7	13	54.3	14	LIT	7.5	14	10.8	9
LIT	8397	56.3	14	57.6	12	55	16	MCD	7177	48.8	14	46	18	51.4	13	LAT	7743	54.6	14	54.5	15	54.7	13	CRO	6	16	11	10
UK	40 841	55.7	15	53.5	17	57.7	15	CYP	1204	47.8	15	47.6	15	48	15	SWE	1076	53.4	15	53.4	16	53.4	15	CYP	18.5	7	12.8	11
CRO	595	55.5	16	52.5	18	58.1	14	SWE	2719	46.1	16	45	19	47.2	16	GER	5999	53.4	16	54.6	14	52.2	18	FRA	22	6	14	12
SWE	950	52.3	17	54.8	13	49.4	19	POR	7199	45.8	17	47.8	14	43.7	18	POL	47 326	52.3	17	51.2	20	53.3	16	EST	10.5	18	14.3	13
EST	4647	51.1	18	53.7	16	48.6	20	GRE	688	45.4	18	46.7	16	43.9	17	LUX	1128	51.5	18	52.9	18	50.4	21	SWE	15.5	17	16.3	14
SPA	25 877	48.3	19	46.4	22	50.2	17	ISL	387	44.1	19	46.4	17	42.2	19	HUN	604 114	51.4	19	53.1	17	49.8	22	POL	12.5	21	16.8	15
POR	30 265	47.1	20	44.3	23	50	18	LAT	7743	42.3	20	42.5	21	42.1	20	ITA	21 448	51.4	20	51.8	19	50.9	19	AUS	12.5	22	17.3	16
POL	45 925	46.9	21	48.1	20	45.8	22	UK	23 373	42.3	21	42.9	20	41.6	21	FRA	32 943	51.3	21	50.3	21	52.3	17	IRE	25	11	18	17
AUS	270	46.4	22	49.1	19	43.7	24	IRE	1149	40.3	22	40.6	22	40	24	CYP	1193	49.5	22	48.1	23	50.8	20	LUX	18	–	18	17
ITA	4084	44.6	23	43.1	24	45.9	21	FRA	813	40.1	23	38.8	25	41.5	22	ALB	2114	47.4	23	49.4	22	45.7	25	HUN	14	24	19	18
HUN	5,93,803	44.6	24	47.6	21	41.7	25	ITA	5768	39.9	24	39.3	24	40.4	23	GRE	256 826	44.7	24	42.9	26	46.5	23	UK	25	15	20	19
GRE	1,76,056	44.1	25	42.7	25	45.4	23	SPA	23 097	39.3	25	39.6	23	39	25	SRB	20 341	44.4	25	43	25	45.9	24	POR	22	20	21	20
KOS	741	39.1	26	41.3	26	37.2	27	ALB	1984	17.7	26	16.4	26	18.8	26	SPA	27 218	42.9	26	42.3	28	43.4	27	KOS	18	26	22	21
MCD	1011	38	27	36.2	28	39.7	26	BIH	–	–	–	–	–	–	–	POR	7715	42.5	27	40.2	30	44.9	26	SPA	25.5	19	22.3	22
SRB	18 772	36.4	28	36.5	27	36.4	28	CRO	–	–	–	–	–	–	–	IRE	1158	41.8	28	43.5	24	40.1	30	ITA	22	23	22.5	23
LAT	3264	30.1	29	28.6	29	31.4	29	CZE	–	–	–	–	–	–	–	UK	13 981	41.3	29	40.8	29	41.9	28	GRE	21	25	23	24
BIH	843	26.3	30	24.2	30	28.3	30	FIN	–	–	–	–	–	–	–	KOS	742	40.8	30	42.9	27	39	31	LAT	17	29	23	24
ALB	–	–	–	–	–	–	–	LUX	–	–	–	–	–	–	–	BIH	843	39.2	31	36.5	31	41.6	29	ALB	24.5	–	24.5	25
BUL	–	–	–	–	–	–	–	NOR	–	–	–	–	–	–	–	MCD	1023	34.6	32	32.8	32	36.3	32	MCD	23	27	25	26
LUX	–	–	–	–	–	–	–	SRB	–	–	–	–	–	–	–	DEN	–	–	–	–	–	–	–	SRB	25	28	26.5	27
NET	–	–	–	–	–	–	–	SWI	–	–	–	–	–	–	–	NET	–	–	–	–	–	–	–	BIH	31	30	30.5	28
N	1 026 077							N	787 966							N	1 345 159											

The three-digit country codes were used to abbreviate the full country names (https://en.wikipedia.org/wiki/List_of_UNDP_country_codes).
For each fitness test, the countries were sorted according to their rank position in the Both (girls and boys) column. The ranking for muscular strength was computed as the average of the country ranking position in handgrip and standing long jump tests, while ranking for cardiorespiratory fitness directly reflects the country ranking position in the 20 m shuttle run test. Sex-specific and age-specific percentile values were calculated using available country-level data and were averaged across sexes and ages to obtain the mean percentile for each country compared to the European Union reference values. Smoothed percentiles were calculated using the generalised additive model for location, scale and shape method and weights were applied according to country population. Not all countries have representative data, and therefore caution should be paid when interpreting country comparisons presented this study and in the platform. Data sources are available online (www.fitbackeurope.eu/en-us/fitness-map/sources) and in online supplemental table 1.
ALB, Albania; AUS, Austria; BEL, Belgium; BIH, Bosnia and Herzegovina; BUL, Bulgaria; CRF, cardiorespiratory fitness; CRO, Croatia; CYP, Cyprus; CZE, Czech Republic; DEN, Denmark; EST, Estonia; FIN, Finland; FRA, France; GER, Germany; GRE, Greece; HUN, Hungary; IRE, Ireland; ISL, Iceland; ITA, Italy; KOS, Kosovo; LAT, Latvia; LIT, Lithuania; LUX, Luxembourg; MCD, North Macedonia; MS, muscular strength; N, sample size and total sample size at the bottom of the table; NET, Netherlands; NOR, Norway; POL, Poland; POR, Portugal; SLO, Slovakia; SPA, Spain; SRB, Serbia; SVN, Slovenia; SWE, Sweden; SWI, Switzerland.

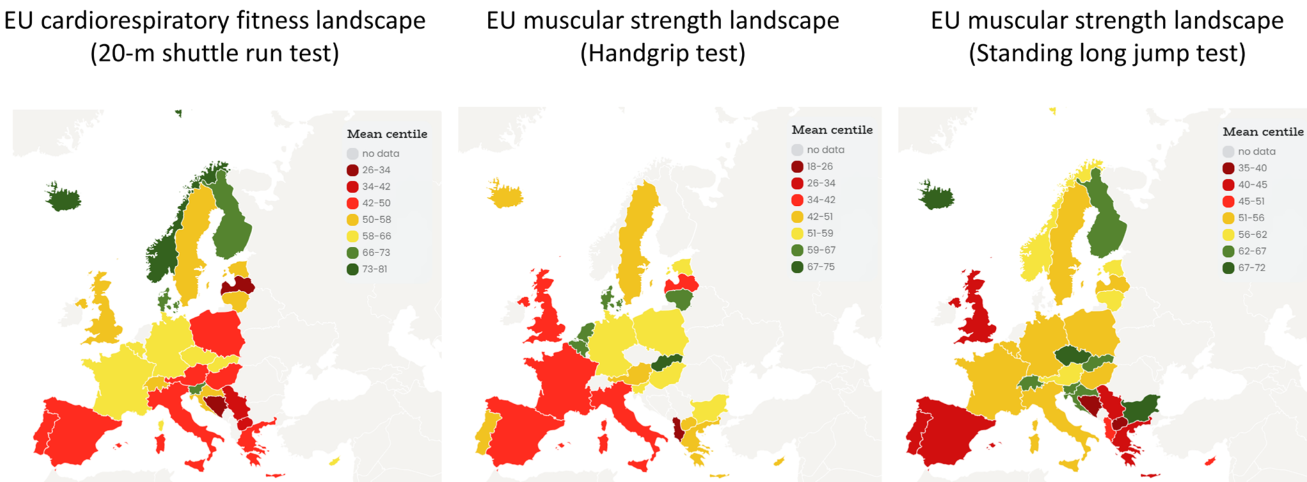

Figure 2 European fitness maps for cardiorespiratory and muscular strength in children and adolescents. Sex-specific and age-specific percentile values were calculated using available country-level data and were averaged across sexes and ages to obtain the mean percentile for each country compared with the EU reference values. Smoothed percentiles were calculated using the generalised additive model for location, scale and shape method, and weights were applied according to country population. Separate European fitness maps for girls and boys for these tests (as well as those for the obesity markers of body mass index and waist circumference) are available online (www.fitbackeurope.eu/en-us/fitness-map). The website map is interactive so that detailed information for each country is shown with the mouseover function. Not all countries have representative data, and therefore, caution should be paid when interpreting country comparisons presented in this study and in the platform. Data sources are available online (www.fitbackeurope.eu/en-us/fitness-map/sources) and in online supplemental table 1. EU, European Union.

fitness levels over time and use these reference values and the FitBack tool for proper sex-specific and age-specific interpretation. Indeed, the use of fitness surveillance to inform decision making is one of the top-ranked priorities in paediatric fitness according to international experts.[55] As a timely example, fitness monitoring can flag a sudden decline in fitness, and therefore health, due to unique/unexpected situations, such as COVID-19 pandemic-related lockdowns and the substantial, rapid declines in youth fitness levels reported in countries with fitness surveillance systems.[56 57] Thus, interventions for specific target groups can be implemented to prevent worse deterioration of fitness levels.

Second, fitness monitoring is part of physical education curricula in many European countries, but most European teachers do not currently have access to an easy-to-use and automatic tool for interpreting sex-specific and age-specific fitness test results. With our article and the FitBack platform, we aimed to contribute to an extensive implementation of fitness monitoring across European schools. In this context, the FitBack platform also provides information to avoid undesirable practices, such as grading students based on their fitness levels and fitness competitions among students, by using fitness testing as an educational tool to facilitate learning and understanding about fitness and its importance to health and sport and setting individual goals for improvement. Such an approach to fitness testing should help improve physical literacy among European youth. Physical literacy can be defined as 'the motivation, confidence, physical competence, knowledge and understanding to value, and take responsibility for, maintaining purposeful physical pursuits/activities throughout the life course".[58] Despite some debate how fitness and its monitoring correspond to the physical literacy paradigm,[59] the FitBack consortium supports the interpretation that fitness and motor skills collectively represent physical competence, which is a key component of physical literacy. In line with this, some physical literacy assessment tools (eg, Canadian Assessment for Physical Literacy and Passport For Life) assess motor skills and physical fitness for physical competence.[59] In this context, fitness testing should be much more than just 'one more school assessment'. Schools are in a unique position to positively affect the lifelong physical activity and physical fitness levels of their students by instilling values and developing skills that will help children throughout their lives. Moreover, the FitBack network has recently been granted by Erasmus+Sport programme with a new project called 'FitBack4Literacy', which aims to design and test a physical literacy toolkit including the FitBack reporting system. In the next 3 years (2023–2025), this toolkit will be developed and provided in 15 European languages and made freely available on the FitBack platform. Thus, the FitBack platform will have greater potential to be transformed in pedagogical practice by physical education teachers as well as generalist teachers who also conduct physical education classes in the early schooling years. Thus, enhancing physical fitness through goal setting and an appropriate physical activity programme and tracking individual changes through fitness monitoring may improve students' physical literacy journey. Those with better fitness education may be more attuned to their body and what is required for good function, and may be able to foster lifelong physical activity habits.

Third, our reference values can be used for sport/athletic profiling and monitoring, as well as talent identification and development.[43 60] Youth who have fitness levels above the 90th percentiles may be considered talented in certain fitness components, and sports participation could be promoted to them and their family. Likewise, changes in fitness levels in response to a lifestyle intervention could be tracked against our sex-specific and age-specific percentile bands to identify expected, better than expected or worse than expected developmental changes.

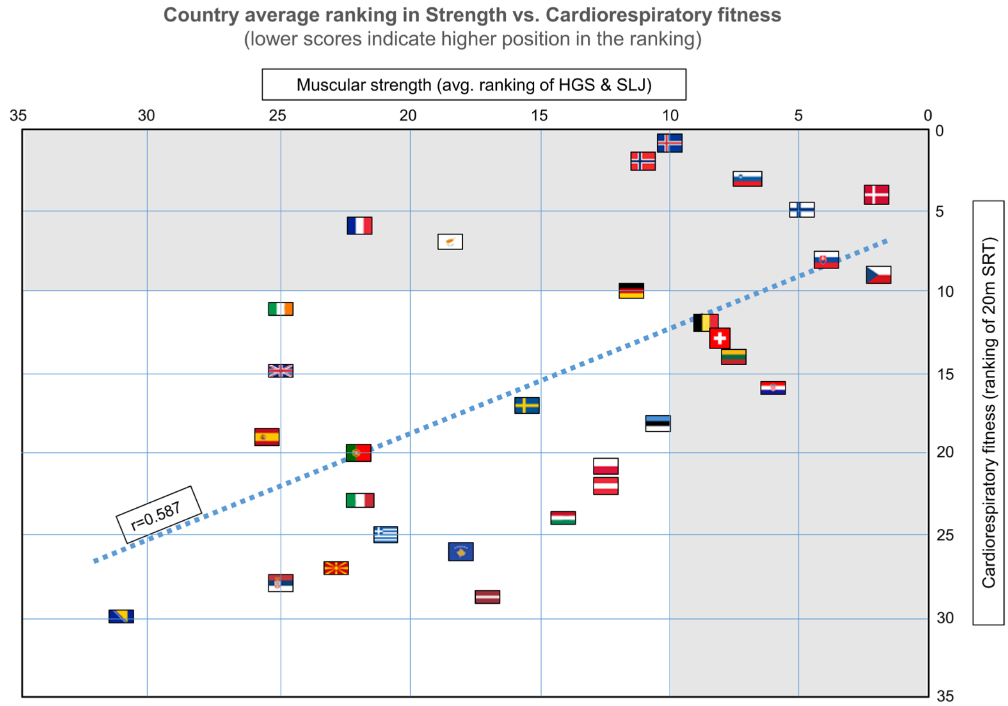

Figure 3 Country average ranking in muscular strength and CRF in European children and adolescents. CRF in European children and adolescents. The ranking for muscular strength was computed as the average of the country ranking position in HGS and SLJ tests, while ranking for CRF directly reflects the country ranking position in the 20mSRT. Grey shaded areas indicate countries ranked in the top 10 for either muscular strength, CRF or both. This figure was created based on the data presented in table 4. Four countries (Albania, Bulgaria, Luxembourg and The Netherlands) were not included since they had either missing muscular strength or CRF data. Not all countries have representative data and therefore caution should be paid when interpreting country comparisons presented in this study and in the platform. Data sources are available online (www.fitbackeurope.eu/en-us/fitness-map/sources) and in online supplemental table 1. 20mSRT, 20 m shuttle run test; CRF, cardiorespiratory fitness; HGS, handgrip strength; SLJ, standing long jump.

Limitation and strengths

While the FitBack network gathered roughly 8 million test results for the development of new health-related reference values, the included data are not representative of all European youth. Some countries such as Slovenia, Hungary and Portugal (www.fitbackeurope.eu/en-us/monitoring-fitness/best-practice) have established fitness monitoring systems that cover all school ages and all country regions. Other countries such as Greece[61] and Poland[62] have conducted nationally representative fitness testing at particular points in time, while most European countries do not have nationally representative fitness data available. This implies that our country-level comparisons should be taken cautiously, given that not all data are representative of their source populations. Our ambition was to identify the best available and most recent data (using the ALPHA fitness tests) for each country to update existing CRF and muscular strength reference values, and to strengthen the evidence supporting the FitBack platform. Unfortunately, included fitness data were collected at different times, and temporal trends in fitness may have biased our results. To minimise the potential for bias, old data collected in the 1980s were excluded from our analyses (see online supplemental table 1). Only harmonised cross-country testing at the same time will provide the most accurate comparisons. While not nationally representative, the HELENA study collected harmonised fitness data in 2005–2008 across 10 European cities, and the results suggested that adolescents living in Southern Europe (Spain, Italy and Greece) had lower levels of CRF and muscular strength, as well as more total and central adiposities, than their peers living in Central Northern Europe.[63] These findings are consistent with the FitBack results hereby presented and are in line with previous reports.[64 65] Another limitation of our study is the protocol variation across studies. In order to improve this moving forward, we recommend researchers use the ALPHA fitness test battery manuals of operations and explanatory videos that are freely available (http://profith.ugr.es/alpha-children available in English and Spanish), and which have been incorporated into the FitBack platform (www.fitbackeurope.eu/en-us/make-report/about-testing). Finally, while we obtained data from 77% (34/44) of European countries (https://www.schengenvisainfo.com/countries-in-europe/), additional data are required from the remaining countries to paint a complete European fitness picture. On the other hand, there are some important strengths/contributions from our study and the FitBack network, including (1) the development of the largest and most up-to-date fitness reference values for school-age Europeans; (2) increased awareness of the importance of fitness surveillance and monitoring; (3) the identification of countries that have access to large fitness databases and those which do not, and (4) to facilitate fitness testing and interpretation through the FitBack platform, which we hope will improve the amount, quality and availability of future fitness data. All these points can add to ongoing international initiatives such as country report cards to support the Active Healthy Kids Global Matrix (https://www.activehealthykids.

org/global-matrix/), which now includes physical fitness as a core indicator.

CONCLUSION

There is overwhelming evidence supporting the importance of fitness testing from a health, educational and sport point of view. Further, the EU-funded ALPHA project identified the most reliable and valid fitness tests, providing the methods (manuals of operations and videos) needed to evaluate youth health-related fitness levels in a standardised manner across Europe. Now, the FitBack project provides the scientific and practitioner communities with the steps needed for the implementation of youth-based fitness assessment and interpretation in school or sporting settings across Europe. Our sex-specific and age-specific reference values have practical implications and are the foundation of the FitBack platform for interactive individual and group-based interpretation of fitness levels. These reference values should be revisited in the future as more countries introduce national surveillance systems to reflect the updated fitness levels of European youth. The FitBack network, therefore, welcomes new members and is searching for missing and new fitness data.

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